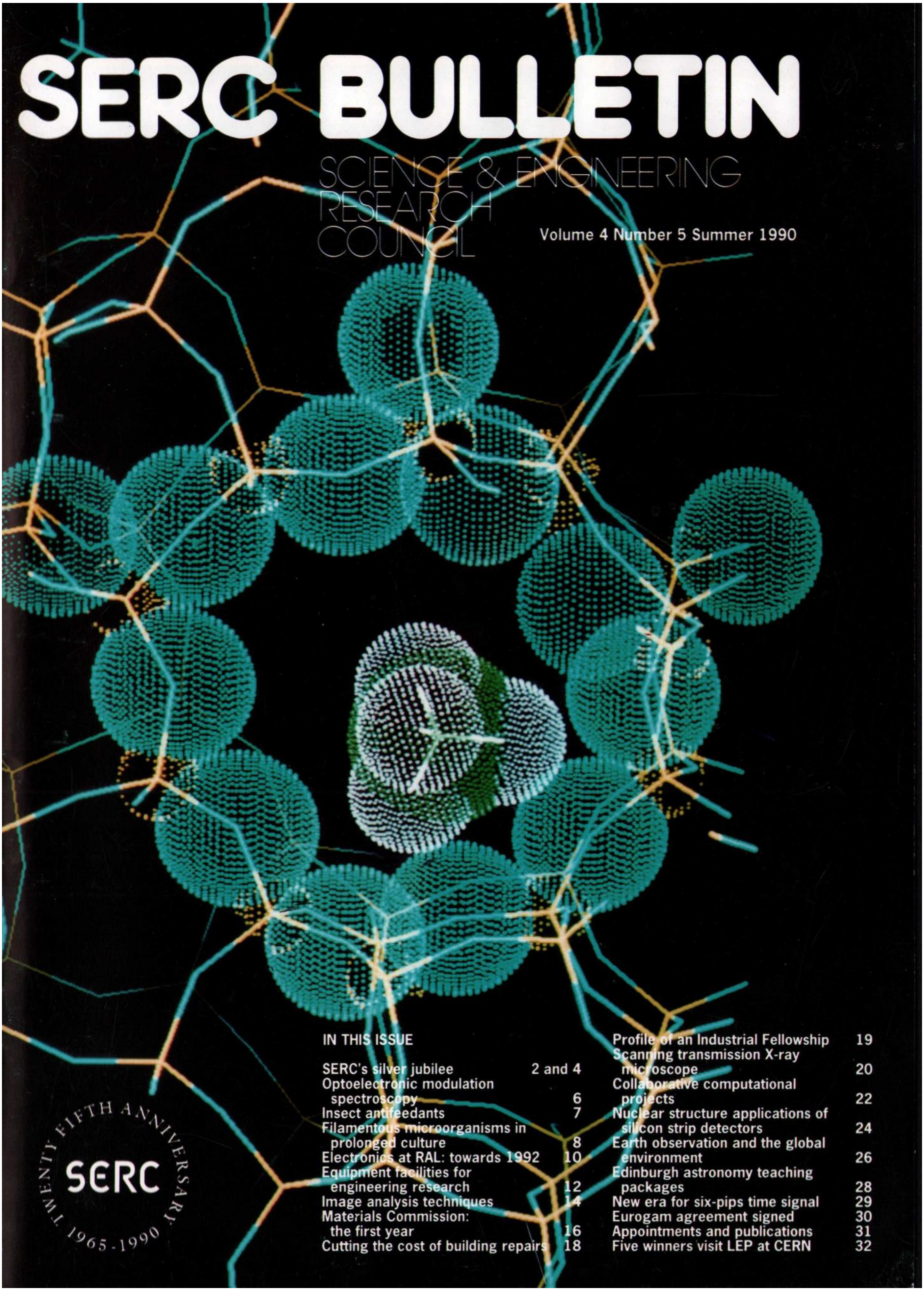

SERC BULLETIN

SCIENCE & ENGINEERING
RESEARCH
COUNCIL

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IN THIS ISSUE

TWENTY FIFTH ANNIVERSARY
SERC
1965-1990

The Science and Engineering Research Council is one of five research councils funded through the Department of Education and Science. Its primary purpose is to sustain standards of education and research in the universities and polytechnics through the provision of grants and studentships and by the facilities which its own establishments provide for academic research.

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SERC *Annual Report* (available from PRU, SERC Swindon Office) gives a full statement of current Council policies together with appendices on grants, awards, membership of committees and financial expenditure. ***SERC Bulletin***, which is normally published three times a year, summarises the Council's policies, programmes and reports.

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SERC's silver jubilee

The Science and Engineering Research Council, established as the Science Research Council by Royal Charter in April 1965, celebrates its Silver Jubilee this year.

The year also marks the 75th anniversary of SERC's precursor — the Department of Scientific and Industrial Research (DSIR) — the first separately funded government research body. DSIR, which emerged from a committee of the Privy Council for Scientific and Industrial Research set up in July 1915, was dissolved in the year SERC was created.

To celebrate this double anniversary year the following events are planned, and all our Chairmen since 1965 give glimpses of their years in office on pages 4 and 5.

TWENTY FIFTH ANNIVERSARY SERC 1965 - 1990

Diary of Jubilee Year events

June

11 Silver Jubilee Lecture by Lord Flowers, at the Queen Elizabeth II Conference Centre, London (by invitation).

14-16 Exhibition in the Brunel Plaza, Swindon, in collaboration with the other Research Councils located in Swindon — Agricultural and Food, Economic and Social, and Natural Environment

14 Official opening of the Royal Greenwich Observatory at Cambridge

15-17 Royal Greenwich Observatory open days at Cambridge

July

10-14 Rutherford Appleton Laboratory open days

August

20-24 SERC at the British Association for the Advancement of Science Annual Meeting at Swansea

September

24-25 Young scientists' and engineers' seminars at Edinburgh, convened by Professor Malcolm Longair

October

11-12 Daresbury Laboratory schools' event

13 Daresbury Laboratory family open day

November

2 SERC Swindon Office open day

19-25 Royal Observatory, Edinburgh open days for the National Astronomy Week

December

5 25th anniversary annual report press launch

Congratulations to . . .

. . . the following on their election as Fellows of the Royal Society on 15 March:

Dr Carole Jordan (Oxford University), Council member and member of the Astronomy and Planetary Board;

Professor H W Kroto (Sussex University), member of the Physical Chemistry Subcommittee, and Synchrotron Radiation Facility Committee and the Chemistry Committee;

Professor R H Williams (University of Wales College of Cardiff), member of the Compound Semiconductor Technology Subcommittee.

Front cover picture

A simulation of a methane molecule in the zeolite ZSM-5. The graphics were generated by Dr C M Freeman at the Royal Institution, and the study is part of a Collaborative Computational Project described on page 22.

Council commentary

Public expenditure survey funds

Additional funds for SERC to cover 1990-91 were announced by the Secretary of State for Education and Science John MacGregor on 10 January 1990 as part of an increase in the Government's science budget. In November 1989, the planning figures for 1991-92 and 1992-93 were announced. The extra funds are:

	Additional funding	Total SERC funding
1990-91	£26.7 million	£438.6 million
1991-92	£30.2 million	£437.4 million
1992-93	£35.9 million	£444.2 million

Part of the new funds — £6 million over three years — is for a remote sensing instrument on the proposed Earth Remote Sensing Satellite (ERS-2) due for launch by the European Space Agency in 1993. Funds rising to £4 million in 1992-93 will also be used to support several instruments for the next generation of Earth observing satellites — the ESA and NASA 'Polar Platforms'.

The Council has also allocated further funds towards research grants, studentships and fellowships, the Integrated Graduate Development Scheme, international subscriptions and enhancement of some of the facilities at its Establishments, including the CRAY computer.

The 1990-91 allocation between Boards is as follows:

	£ million
Astronomy & Planetary Science	71.2
Engineering	130.3
Nuclear Physics	78.1
Science	134.2
Central Computing	3.1
Other (including administration)	21.7
Total	438.6

Future funding for IRCs

The first nine Interdisciplinary Research Centres (IRCs) within SERC were mostly financed by substantial additional resources to SERC from the Department of Education and Science (DES). Further IRCs now being considered by the Council will be funded from within the Council's available funds. The initial capital costs of new IRCs will be met centrally from the Council while recurrent costs will be borne on a fifty-fifty basis by the sponsoring Board and the Council itself.

New international subscriptions

New UK subscriptions for five international research bodies were agreed by the Council in December. These were:

The European Incoherent Scatter Scientific Association: £496,000 (1990-91).

The European Space Agency: up to £24.28 million (1990).

The Institut Laue-Langevin: £9.84 million (1990).

The European Synchrotron Radiation Facility: £5.41 million (1990).

The European Science Foundation: £220,800 (1990) (SERC's contribution, together with those of the other UK research councils and the British Academy represents 14.46% of the total budget).

Forward Look

The major item on the agenda of the Council's meeting in February was the discussion of its Forward Look — the document that describes the allocation of resources to the work programme over the next few years and puts forward bids for additional funds to the Advisory Board for the Research Councils. Part of this document involves a description of the programmes planned for the current financial year, from April.

Clean technology programme proposed

A major new programme to help tackle the environmental problems arising from industrial processes, and the legacy of past pollution from manufacturing was discussed by the Council: Details of the five-year programme, which it is proposed will be run jointly with the Agricultural and Food Research Council, will be announced later in the year.

First beam for Charissa

A new scattering chamber facility designed to enhance the study of quasi-molecular cluster states in the atomic nucleus has taken its first beam on the Nuclear Structure Facility at Daresbury Laboratory, after more than a year of planning, design and construction. The chamber is designed to hold arrays of semiconductor detectors as part of the Charissa project — a collaboration of users from Birmingham, Oxford and York Universities and Daresbury.

Major new grants

Materials: A grant of £1 million will support work by the interdisciplinary group at Birmingham University on high temperature superconductors.

Information technology: A grant to Glasgow University of £2.7 million will support a programme aimed at developing submicron electronics for the miniaturisation of current devices and exploring new classes of devices based on quantum mechanical interference.

Space satellite developments: A grant of £3.5 million is to be awarded to the Mullard Space Science Laboratory for geophysical and astronomical research in space. The research involves provision of hardware and software for an advanced infrared radiometer designed to measure global sea surface temperature from space.

X-ray astronomy: £1.9 million is to be awarded to Leicester University for X-ray astronomy including a new project to develop an astrophysics facility and an X-ray multi-mirror.

Studies of the upper atmosphere: The improved Stratospheric, Atmospheric and Mesopheric Sounder, the satellite instrument for environment research due to be launched in 1991, will receive additional funding of £69,000 for development by Oxford University, bringing the total to £6.4 million. A further £1.3 million grant to Oxford University will be awarded for data analysis from environmental research equipment on satellites.

Review of the Teaching Company Scheme

SERC and the Department of Trade and Industry (DTI) have agreed to a review of the Teaching Company Scheme during the spring and summer of 1990.

Broadly the review will assess whether the objectives of the scheme have been met, examine the operation and management of the scheme.

The Review Panel will be chaired by Professor Fender CMG (Vice Chancellor of Keele University, and a member of Council).

The panel will have representation from SERC, academics, industry, and the DTI. There will also be observers from the Department of Economic Development (Northern Ireland) and the Economic and Social Research Council.

25 years seen from the top

Sir Harry Melville FRS
Chairman 1965-67

The pattern for SERC's forward activities was to a large extent based on the development of grant procedures in the Department of Scientific and Industrial Research (DSIR). When I came into DSIR in 1956, I found that financial support for DSIR research stations was sufficient and that this held good for the industrial research associations. In contrast the support for university research was miserable. Research studentships were growing, but there were only four postdoctoral awards! The annual expenditure on awards for apparatus and technical assistance was only £60,000 a year. These levels of grants were quickly increased to enable universities to mount overall greater efforts. Another factor was the provision of money for the development of advanced scientific instruments without which research could not be effectively done.

The biggest problem was the creation and the operation of massive support for nuclear physics (including CERN) and optical and radio astronomy. This involved not only the building of equipment but also its running costs into the indefinite future. This problem will continue, but if the UK is to maintain its high standing in science research, means must be found to solve these financial aspects of such research.

The Lord Flowers FRS
Chairman 1967-73

During my time at the SRC there were four things that especially concerned me, and they still do. Firstly, although it was not new, the policy of selectivity and concentration began to be widely expounded. It has by now been carried much too far. Second, it became generally accepted that 'big science' had to be entirely international, starting in particle physics and space research, but spreading rapidly to astronomy and to the applications of neutron beams and synchrotron radiation. We prepared the ground for the European Science Foundation too, and I hope that this modest venture will gradually become the accepted vehicle for European collaboration in both science and the humanities. Third, there was the creation of the Engineering Board. It was controversial at the time and remains so to this day; but I believe it was right, and much better than a separate research council for engineering because there are so many fertile links between science and engineering. The fourth was the great debate about the funding and organisation of civil science — the Gripes of Roth, we called it. I was in the thick of it as the first Chairman of HORC (the Heads of the Research Councils). After many years a new debate has begun on the same general theme, but now the role of the Advisory Board for the Research Councils is the particular focus. Again I am involved, this time as Chairman of the Select Committee on Science and Technology. It is amazing how little the arguments have changed!

Sir Sam Edwards FRS
Chairman 1973-77

My time at SERC, or SRC as it then was, was the time when the budget stabilised, and demand for grants overtook supply, a process continuing with increasing pressure through to present times. Why has it got so much more difficult to get support? Are there much bigger requests now because of sophistication of apparatus, or are there more people or is there less money? Back in the seventies, there was money enough for individual investigators; our problem was to fund fine new ideas which led to condensed matter physics becoming as expensive as high energy physics and astronomy and space. Fortunately the ageing high energy physics accelerators provided halls and foundations which made the synchrotron radiation at Daresbury, and the spallation neutrons at Rutherford possible. One thing I completely failed to do, was to persuade the Council that what in modern language are the Interdisciplinary Research Centres should be created. I always regretted that the kind of concentration that the Medical Research Council and the Agricultural and Food Research Council could apply did not find favour with SRC, and am delighted to see that things have completely changed. We must concentrate resources to do good research, and it must have the same scope in basic science as it has in applied science in industry. Teaching must produce specialists, but research needs specialists being brought together, and I look forward to great results in the future.

Sir Geoffrey Allen FRS
Chairman 1977-81

So many things seemed to happen! The move to Swindon, Henry Walker's retirement as Council Secretary, Appleton to Rutherford, start of the Northern Hemisphere Observatory, the Directorates, a change of government . . . etc. I inherited decisions to build ISIS, the Synchrotron Radiation Source, the Electron Beam Lithography Facility etc, but implementation remained a problem.

The Council embarked on new collaboration schemes with industry in a climate of uncertainty about our manufacturing base. The enthusiasm of the new Secretary Brian Oakley for computing and information technology was the forerunner of the Alvey programme. SRC became SERC.

We expanded international collaboration with the Netherlands in astronomy and molecular science, with Japan in molecular science. These links still flourish.

The themes of collaboration with industry and international communities will continue to evolve. SERC could lead with the West German DFG and French CNRS to help create broader European programmes. Our postgraduate studentships should include one year in another European country. Can our ageing formulae for collaboration with industry be revamped to encourage industry to invest more in R and D? Because funds are increasingly earmarked for targeted projects, can we re-establish dual support with the University Funding Council to provide adequate seed corn research? SERC is large: we might consider now an Engineering Research Council. But I would need to see a very special relation between SRC and ERC built in. And so *ad infinitum*.

Sir John Kingman FRS
Chairman 1981-85

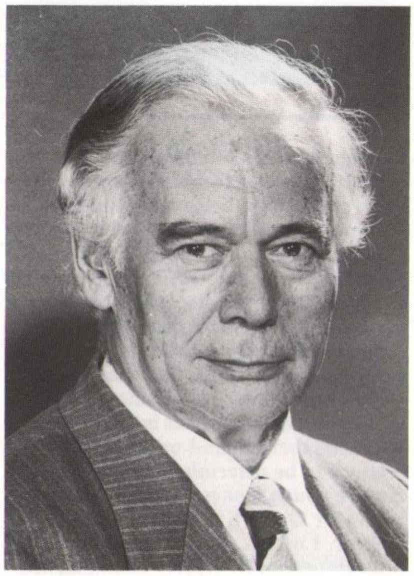
SERC differs from some other research councils in that the research it supports takes place mainly in universities and polytechnics rather than its own establishments. Even the Council's laboratories and observatories exist primarily to provide central facilities for scientists who need more than can easily be provided in their own institutions.

This aspect of the Council's strategy ties basic research in closely with teaching of undergraduates and postgraduates. It strengthens the characteristic flavour of British degree courses, that students are taught in a research environment. As higher education expands to meet the needs of an advanced industrial society, it will be increasingly difficult, but no less essential, to maintain this link.

Difficult judgements of priority will be needed, and the informed judgement of peers provides the best guarantee that timeliness and promise will be rigorously and fairly assessed. Yet the peer review system must not be so elaborate that active scientists spend all their time either writing grant applications or commenting on those of others.

It will not be easy to strike the right balance, but SERC's customers in the universities and polytechnics rely on the Council, not only to generate adequate resources to maintain the health of basic science, but also to spend them to best effect.

Professor E W J Mitchell
CBE FRS
Chairman 1985-90



Doubtless the mists of time will eventually confuse for me the Chinese-style calendar which is how I currently perceive the last five years: the year of the Royal Greenwich Observatory; the year of the Interdisciplinary Research Centre debate; the year of CERN and the European Synchrotron Radiation Facility; the year of the Morris Report; the year of the University overheads; and all of them years of increasing grant expenditure to an insatiable community.

But whatever the trials of office, one is continually revived by the scientific and technological progress made by colleagues, with Council's support, in the universities and polytechnics and SERC laboratories. Anyone even mildly interested in science and engineering could not fail to be stimulated by the range of topics, from the origin of the Universe to the smallest building blocks of matter, through the understanding at atomic and molecular levels of increasingly complex condensed matter systems in physics, chemistry and biology and their applications in the enabling technologies and engineering.

We have tried to devolve decision-making: the Interdisciplinary Research Centres decide their own projects; CASE student projects are decided by the academic and industrial partners. I believe the new Materials Science and Engineering Commission is of immense significance for the future. I hope I have been helpful in our international initiatives and am pleased to have revived research discussions with many countries.

I still have a few months to go — time to reform X, to change Y and to abolish Z; but more of those later!

Optoelectronic modulation spectroscopy

Optoelectronic modulation spectroscopy (OEMS) is a new technique which allows electron states to be spatially probed within the body of a semiconductor. It uses wavelength modulated light in an electrical impedance measurement of a device containing a depletion region to produce spectra. The peaks can be indexed to give the location of the responding states and their energy within the energy gap. Using temperature and optical intensity will allow the thermal and optical cross-sections to be determined. A particular feature which makes the method unique, writes Dr Garth Swanson of King's College, London, is that surface and bulk states can be clearly distinguished.

Extrinsic electron states which may be either at the surface or in the bulk of a semiconductor frequently have a controlling effect over the behaviour of electronic devices. This is increasingly the case as they are dimensionally scaled down. Electrical impedance measurements are often used to measure the characteristics of surface states in metal-insulator-semiconductor structures. Since it is charge entering and leaving states near to the Fermi level which is sensed, there can be a significant contribution from bulk states too. Often this is either not appreciated or simply ignored. Their responses in the frequency domain may be separable but their location in depth below the surface can not be directly determined. This situation is illustrated by the electron energy diagram in figure 1 in which the Fermi level intersects a bulk state level at B as well as surface states.

Combining the impedance measurement with illumination with wavelength modulated sub-band gap light defines two narrow ranges of energy ($\delta h\upsilon$) in the energy gap within which states are periodically depopulated at the wavelength modulation frequency f_O. Since the impedance measurement at f_E only senses states at the Fermi level, its intersection with the optically defined ranges of energy selects those states which modulate the impedance at the frequency f_O. Thus two zones are defined at definite distances from the semiconductor surface. For clarity, only one of these, at x, is shown in figure 1; the other is at an equal energy $h\upsilon_1$ from the valence band edge. The spatial and energy positions can be set by varying the mean photon energy ($h\upsilon$) and/or the semiconductor surface potential.

A spectrum taken for a GaAs-SiO_2-Al structure is shown in figure 2. This was obtained by varying the mean wavelength and plotting the modulated components of impedance, in this case f_O = 10Hz. The peaks show the responses of four separate mechanisms. Their energies are obtained directly and were indexed on to the energy diagram to show that they corresponded to four bulk energy levels. Their positions in energy with the locations of the responding states at this voltage bias are shown in the table.

Locations of the responding states at the extremes of surface potential in SiO_2/n-GaAs structures

Peak energy (eV)	Depth below surface (Å) 0 V	W_C-W_T (eV)
0.69	17	0.69
0.73	9	0.70
0.76	36	0.67
0.83	102	0.60

The measurement may be made on any device structure containing a depletion region including hetero- and homo-junctions as well as metal-semiconductor structures. An advantage of the method is that sub-band gap light is used, allowing illumination through the substrate and avoiding the need for transparent metal device contacts. Spatial information requires that the variation of potential within the device should be known. This is an important technique and will be valuable for characterising semiconductor materials and devices. The next phase of the work will be to develop a continuously scanning spectrometer which can then be used as a quantitative tool.

Background information

The research group at King's College, London has a long-standing interest in the electronic effect of surfaces on electron device behaviour. Work has concentrated on compound semiconductors including GaAs and $In_{0.53}Ga_{0.47}As$ and the use of low energy methods for forming insulator layers on them without introducing electronic damage. The need to measure these effects led to the invention of the OEMS method, which is now being patented.

Dr J G Swanson
Department of Electrical and Electronic Engineering,
King's College, London.

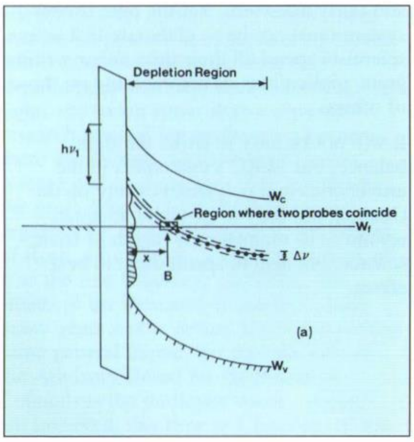


Figure 1: The electron energy diagram of a metal-insulator-semiconductor structure showing the simultaneous optical and electrical probing of the states.

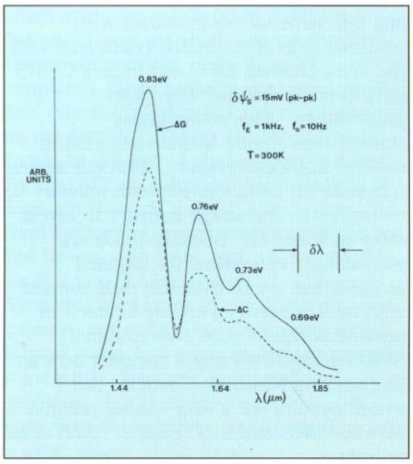


Figure 2: An OEMS spectrum showing the responses of electrons in four bulk electron energy levels.

Insect antifeedants —
'Slimming pills' that provide pest control

Rapid world population growth, increased environmental awareness and increasing insect resistance have led to demands for improved pest control chemicals for food and other crops. This places new and greater demands on organic chemists to synthesise appropriate molecules. The challenge is being met through an understanding of how some plants naturally control insects by producing antifeeding chemicals and by developing new methods to produce both these natural products and active synthetic analogues, as explained by Professor Reg Davis of Kingston Polytechnic.

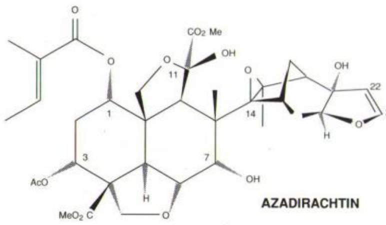
Worldwide expenditure on insecticides amounts to more than $2 billion a year and yet about 15% of crops planted are lost through damage by feeding insects and other pests. With the world human population expected to double over the next 100 years, there is an urgent need to increase the effective use of the space available for the growth of food and other crops. However, many of the currently available insecticides have a number of shortcomings — they are often non-selective; some are not easily bio-degraded; and some need to be used in large quantities, which has led to insects developing resistance.

The reaction of many people to the identified problems of insecticides and other agrochemicals is to advocate a return to organic farming, but that solution will not cope with the problems of the third world. Other answers have to be found and one lies in a recognition of the highly elaborate defence mechanisms evolved by plants. This has provided a rich source of biologically active molecules including insect repellants, attractants, growth regulators and antifeedants.

Many of these naturally occurring chemicals are more easily biodegraded than current agrochemicals and so are less likely to accumulate in the food chain or pollute the environment. They are also more specific in their action. Of these potential crop-protecting agents, antifeedants are currently attracting the most research interest due to their effect on a range of major pests. An antifeedant is defined as a chemical which inhibits feeding, by suppressing the insect's appetite and which often leads to death. They were first discovered following the observation that certain plants were avoided by swarms of ants or locusts.

Successfully establishing the structures of these complex organic molecules has required the full armoury of the organic chemist. Even then their use is further complicated by the difficulty of obtaining them in sufficient quantities and this led to a search for cheap and efficient chemical syntheses of both the naturally occurring antifeedants and a range of synthetic analogues showing comparable activity.

Professor Steven Ley FRS and his colleagues at Imperial College, London have made major contributions in both structure determination and synthesis of both natural and synthetic antifeedants. It was their X-ray crystallographic determination of the structure of azadirachtin, the only natural antifeedant currently in use, that finally laid to rest an 18-year controversy over the structure of this complex molecule.



AZADIRACHTIN

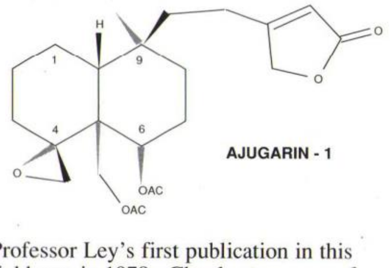
Azadirachtin is obtained from the neem tree which is widespread in Africa and South East Asia. It first came to the attention of scientists through the age-old practice of mixing neem leaves with stored grain and crops to reduce insect damage. It has exceptional biological activity against more than 40 lepidopterous species, where it is 100% lethal at a concentration of only 10 parts per million. It is also non-toxic in man and exhibits no significant phytotoxicity. Unfortunately, but not perhaps surprisingly, the exceptional activity is coupled with a low stability, making it difficult to develop a cost-effective synthesis for this complex molecule.

However, through an extensive investigation of the chemistry of azadirachtin and related molecules, Ley and his co-workers have shown that much of the antifeedant effect originates from the right-hand side of the molecule. They have been able to synthesise smaller molecules containing this structural feature which are active against some caterpillars, including Egyptian cotton leaf-worm. The exceptional potency of one of the small molecules synthesised at Imperial College (see structures) means that one gram would be sufficient to protect an area the size of two football pitches.

Professor Ley has also studied polygodial and warburganal, which are antifeedants for African army worms. The development of an elegant four-step synthesis for these molecules has shown the potential for industrial production and has led to the same methods being applied to the syntheses of related molecules showing anti-fungal and plant-growth regulator properties. An even more direct two-step synthesis of a polygodial analogue has led to a molecule with an antifeedant activity comparable to that of polygodial.

The Imperial College group has also developed a synthetic route for ajugarin-1, the major active compound from the *Ajuga remota* plant, which is a locust antifeedant. The demands of this synthesis and that of a number of related molecules have only been met by the development of new reactions and the imaginative use of established ones. Biological testing on these molecules illustrates the variety of structure-activity relationships in the antifeedant field, since unlike azadirachtin, the essential structural requirements for the activity of ajugardin-1 are not localised in any one portion of the structure.

Most recently, Professor Ley has collaborated with workers at the Jodrell Laboratory, Kew Gardens, who have isolated a molecule related to ajugardin-1 from *Scutellaria woronowii*. The structure of this molecule, named jodrellin B, was established at Imperial College using high field nmr spectroscopy and mass spectrometry and it has been shown to be a more active locust antifeedant than any related molecule.



AJUGARIN - 1

Professor Ley's first publication in this field was in 1979. Clearly, ten years of continuous work by the Imperial College chemists has led to significant advances, not only in the chemistry of antifeedants but in the development of new synthetic methods of more general use in organic chemistry.

Professor Reg Davis
Kingston Polytechnic

Filamentous microorganisms in prolonged culture

When microorganisms are grown in prolonged fed-batch or continuous culture, productivity of the process may be affected by the spontaneous generation of mutants which have a selective advantage over the parental strain. Professor Tony Trinci of Manchester University describes the appearance of morphological mutants in continuous cultures of a mould.

The simplest way of growing a fungus in liquid culture is to cultivate it in a batch culture system. However, when it is necessary to (a) avoid the fluctuating conditions inherent in batch culture, (b) cultivate the fungus at a rate below its maximum specific growth rate (μ_{max}), or (c) improve the productivity of the system (for biomass or other products), fungi can be grown as continuous cultures in chemostats.

The filamentous soil fungus, *Fusarium graminearum* A 3/5, is used by Marlow Foods for the production of Quorn myco-protein for human consumption. At Billingham, the fungus is grown in continuous culture in an airlift fermenter which consists of a 40-metre high vertically elongated loop. A 40 m^3 volume of culture is maintained in the fermenter and is fed with glucose, mineral salts and ammonia at a dilution rate of 0.19 h^{-1}. Quorn myco-protein has a relatively high ratio of polyunsaturated fats to saturated fats, has a protein content comparable to milk protein, contains dietary fibre, and is so considered a 'healthy' food. Since 1985, various products made with Quorn myco-protein have been available in most supermarkets.

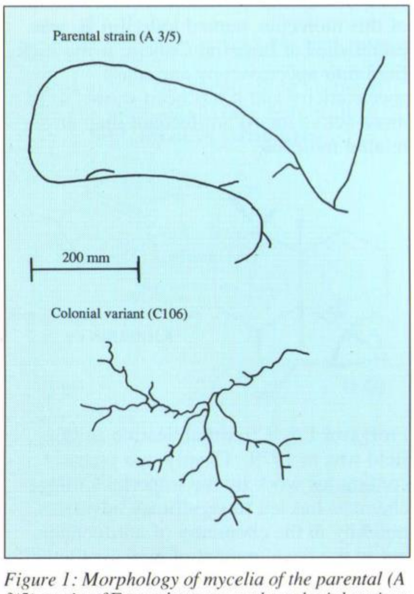


Figure 1: Morphology of mycelia of the parental (A 3/5) strain of F graminearum *and a colonial variant (C106) which appeared after prolonged continuous culture; the mycelia shown are of approximately the same total hyphal length.*

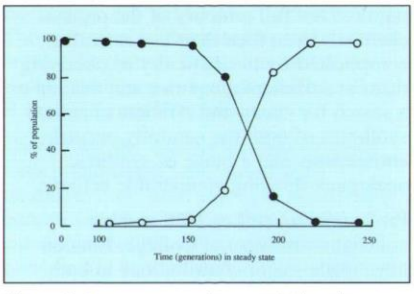


Figure 2: Appearance and accumulation of a colonial variant (CCI-1; O) of F graminearum *A 3/5 (●) in a glucose-limited continuous culture.*

When filamentous fungi or bacteria (streptomycetes) are grown in prolonged continuous culture, the relatively sparsely branched parental strain is often supplanted by a fairly highly branched (so-called 'colonial') variant which arises spontaneously in the culture (figures 1 and 2). Such colonial variants have appeared in continuous cultures of various fungi (*Paecilomyces variotii, Gliocladium virens, Trichoderma viride, Penicillium chrysogenum, Acremonium chrysogenum*, and so on) after they have been in steady-state for between 100 and 1200 hours. One reason why *F graminearum* was chosen for myco-protein production was because its sparsely-branched mycelia give the food product a fibrous texture similar to that of meat or chicken. Thus, when the parental strain of *F graminearum* is supplanted by a colonial variant, the myco-protein fermentation has to be terminated prematurely.

Similarly, the production of penicillin by *Penicillium chrysogenum* in sucrose-limited chemostat culture declines with time. This decrease in antibiotic productivity is correlated with the appearance of a colonial variant which, within about 45 generations, supplants the parental strain; this colonial variant produces about 60% less penicillin than the parental strain. Thus, when grown in prolonged continuous culture, filamentous microorganisms commonly give rise to colonial variants which have a selective advantage over the parental strain, and the presence of these variants may affect the productivity of the system.

In Manchester, Professor S G Oliver and the author are studying the stability of filamentous fungi and streptomycetes in prolonged continuous culture. The purpose of their study is to identify the selective advantage which colonial variants have when grown in mixed culture with their parental strains, and to use the information obtained to devise strategies to delay or prevent the appearance of these variants in continuous cultures. They have shown that so-called 'neutral' mutations (variants which apparently are neither at an advantage nor disadvantage compared with the parental strain) increase in continuous cultures at a linear rate (compared to the exponential rate observed for the take-over of such cultures by colonial variants). For example, figure 3 shows that three non-nitrate utilising variants of *F graminearum* accumulated at linear rates in glucose-limited cultures grown on a medium containing ammonia as the sole nitrogen source.

This observation is consistent with the predictions of H E Kubitchek and others that, in continuous culture, a neutral variant will increase in the culture vessel at a linear rate which is determined by the relative rates of forward (for example, from nitrate utiliser to nitrate non-utiliser) and back (from nitrate non-utiliser to nitrate utiliser) mutations. For *F graminearum*, the results suggest that the various genes involved in utilisation of nitrate by the fungus mutate at frequencies between 4 to 7 x 10^{-7} (calculations made assuming negligible back mutation). The

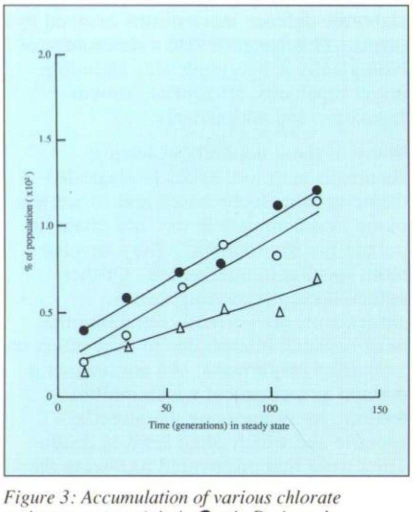


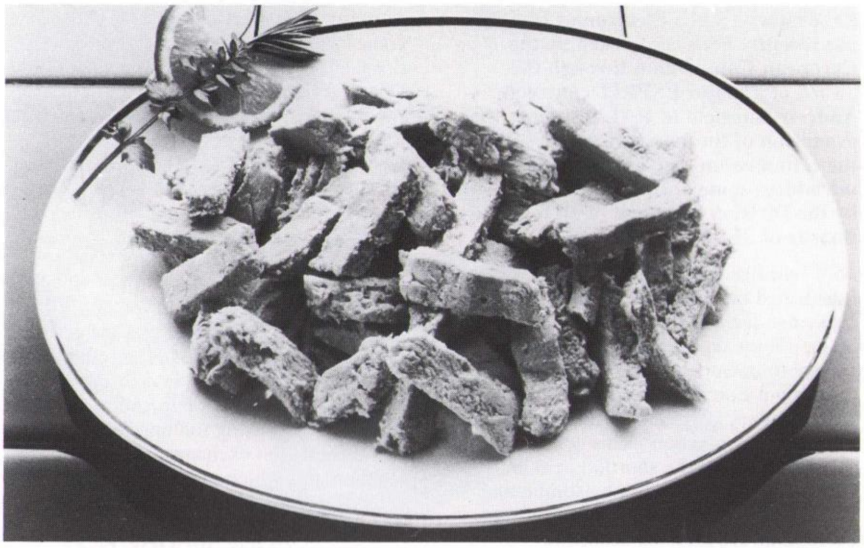
Figure 3: Accumulation of various chlorate resistant mutants (nir A, ●; nia D, Δ; and CRUN, O) in a glucose-limited culture of F graminearum *A 3/5.*

accumulation of neutral variants in prolonged continuous cultures of bacteria has been observed by others.

Colonial variants have been isolated from continuous culture of *F graminearum* grown under conditions of glucose, nitrogen and magnesium limitation. Heterokaryons formed between these and the parental strain all displayed the parental phenotype, indicating the recessive nature of the colonial mutations. Analysis of the phenotypes of heterokaryons formed between the colonial variants indicates that the 14 isolates can be assigned to nine complementation groups. However, there is some evidence that these groups may overlap. Since the colonial mutants of *F graminearum* are recessive, mutant nuclei have to be segregated from parental nuclei before the colonial phenotype is expressed. This segregation may occur when mycelia are fragmented in the stirred tank reactor or, as is more likely, when macroconidia are formed; these multinucleate spores are homokaryotic.

Mixed culture experiments have been made between various colonial variants of *F graminearum* and the parental strain. These have shown that the colonial variant in figure 3 has a selectivity coefficient of 0.145 generation^{-1} (0.04 h^{-1}). Experiments have been made to identify the basis of the selective advantage of the colonial variants and a strategy has been devised to reverse the selection process. The selective advantage may be related to morphological differences between the strains, differences in μ_{max} or differences in saturation constants (K_s) for the limiting nutrient. Although this study is being made with *F graminearum*, it is expected that the results will be of general relevance to studies involving the growth of filamentous fungi or streptomycetes in prolonged culture.

Professor A P J Trinci
Department of Cell and Structural Biology
Manchester University



Quorn myco-protein formulated with egg albumin.

Figure 4: Stereoscans of (A) myco-protein prepared from F graminearum, *and (B) beefsteak (Photo: Rank Hovis McDougall).*

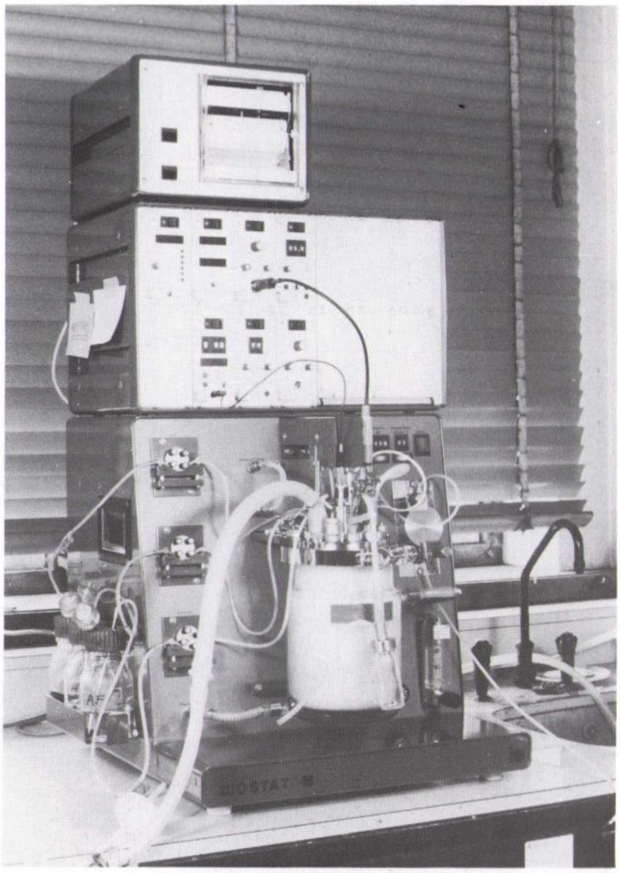


Figure 5: Marlow Foods' airlift fermenter at Billingham which contains 40 cubic metres of Quorn myco-protein, grown in continuous culture using F graminearum.

Electronics at RAL: towards 1992

The high quality of microelectronics activities of the Rutherford Appleton Laboratory (RAL) Electronics Division has recently been recognised by the European Commission through the award of a major ESPRIT contract. Andrew Kurzfeld of RAL describes the expansion of the activities as a result of the Commission's investment and introduces some of the work carried out by the Division on behalf of all four Boards of SERC.

As a significant development of its well established microelectronics design and brokerage facilities, RAL has been chosen by the European Commission to provide a service to universities and polytechnics throughout Europe in support of the ESPRIT Very Large-Scale Integration (VLSI) Design Action. This action is aimed at meeting the shortfall in skilled personnel in VLSI design by stimulating an additional 3000 training places a year by 1992 in 118 selected academic institutions in the European Community and European Free Trade Area. It is the first such training action to be set up by the Commission and may well be the forerunner of others in areas where, again, the laboratory is well placed to make a major contribution.

RAL is playing a leading role in the five-member 'Eurochip' consortium asked by the Commission to perform the service role following a highly competitive tendering exercise. The other members of the consortium are Circuit Multi Projets (France), Gesellschaft für Mathematik und Datenverarbeitung (West Germany), Interuniversitair Microelectronika Centrum (Belgium) and Danmarks Tekniske Hoejskole (Denmark). The 13.8 million ECU (£9.5 million) project will provide support for access to chip manufacture (both standard and advanced techniques), workstations, test equipment, CAD software and lecturer posts, all of which will be supported by the Eurochip consortium. This support will include the procurement of all facilities; installation of hardware and software; interfacing between the users and fabrication and test facilities; organising training for lecturers; and information exchange. The technologies which are planned to be offered include two-micron standard digital and analogue CMOS, advanced one-micron CMOS, BiCMOS, GaAs MMIC and high-speed bipolar.

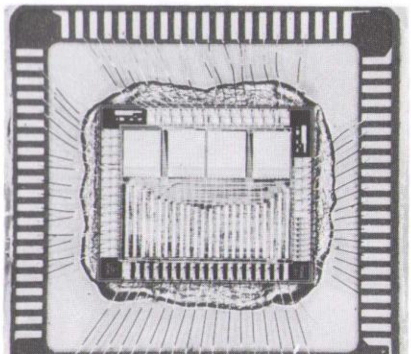
RAL is responsible for CAD software and workstations for the overall service and is the technical support centre for all services for the UK. These are major tasks, particularly as the UK is well represented on the list of chosen institutions with 38 sites. Furthermore, the services of the Eurochip consortium will be available to other Community academic institutions on a pay-as-you-use basis.

The action is now well into phase one where all technical and administrative machinery is in place, orders placed or about to be placed for hardware and software, and training programmes already under way in many of the 118 institutions. The Eurochip consortium is already negotiating contracts with potential suppliers of silicon and other processing and will, in parallel, be installing the new hardware and software required.

The second, fully operational, phase will see the service organisation providing schedules of planned processing runs and the full service to the institutions, including the necessary software and hardware support and the organisation of users' meetings where common experiences can be discussed. The UK programme manager, and a member of the Eurochip Executive Board, is **Dr John McLean** of the RAL Electronics Division, to whom all enquiries on Eurochip should be directed, telephone Abingdon (0235) 445276.

In winning this contract, RAL has taken advantage of its extensive expertise and experience gained over many years of providing microelectronics services and support to the UK academic community. The Electronics CAD (ECAD) and brokerage services were originally established with primarily Engineering Board funds to serve research grant holders, specialised training courses and other approved users. With the advent of the national ECAD initiative, which made ECAD available to all UK institutions and in which the Division played an important part in the selection and support of the infrastructural environment, the community has grown both in number and breadth. This build-up in ECAD activity was paralleled by an increasing role for the

RAL Electronics Division has a comprehensive suite of CAD tools at its disposal. Here, an electronics engineer is putting the finishing touches to a complex system design.



The coincidence array processor chip packaged for use in the OPAL trigger processor at CERN.

Division in accessing commercial microelectronic fabrication routes, again on behalf of the academic community.

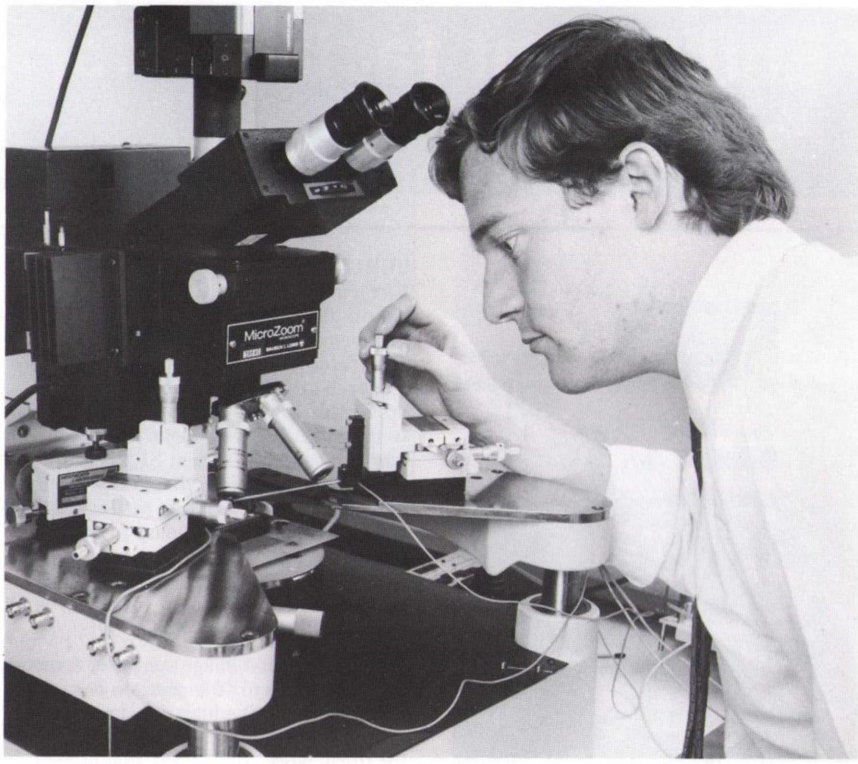
These support roles continue but are now augmented by the availability of a wider support service for the whole research community. Complex electronic systems are designed and produced for projects supported by any of the Boards of SERC using advanced integrated circuit design, microelectronics brokerage and electronic system facilities. The broad spectrum of users allows the costs of these services to be significantly reduced in each case. The synergy between the various projects allows cross-fertilisation of ideas and approaches and so achieve the optimum solution for a particular purpose quickly and efficiently.

One example of where this has proved particularly beneficial is the coincidence array chip designed for the OPAL experiment on the Large Electron Positron Collider at CERN, now incorporated in the track-trigger processor. In the experiment, the central drift chambers consist of two concentric wire chambers (JET and VERTEX) which detect charged particles. The 36 chips, one for each of the 36 sectors arranged radially around the beam pipe, were fabricated on a two-micron CMOS process and contain as their core component a custom 32 x 32 bit static random-access memory (RAM). VERTEX detector data is used to form the RAM column addresses and JET detector data is loaded into a register which gates the RAM row outputs. The memory array is split into four 16 x 16 bit blocks, each containing about 2200 transistors while the rest of the chip contains a further 6000 gates.

Further examples of the Division's work can be found in other experiments at CERN (DELPHI, ALEPH, UA1), and at DESY (ZEUS and H1), in space (the Along-Track Scanning Radiometer), on the spallation neutron source ISIS (Data Acquisition System) and in many Engineering and Science Board supported projects which use the RAL design and brokerage services. It is also interesting to note the spin-off that has occurred from the DELPHI and OPAL chips into pixel devices for Synchrotron Radiation Source experiments at Daresbury Laboratory and for medical applications. In addition the British Technology Group has recently signed an agreement with RAL to market some of the chips designed by the Division.

With the additional facilities now available, the Electronics Division is in an even better position that before to provide advanced microelectronic systems support to a wide range of projects across the whole spectrum of SERC activities. If you would like to know more, please call the author in the Electronics Division at RAL, telephone Abingdon (0235) 445286.

Dr A Kurzfeld
Rutherford Appleton Laboratory



Probe testing of a packaged device.

Visual inspection of a completed board for use in an experiment at CERN. The board utilises both commercially available and custom-designed chips and was produced in the Electronics Division Workshops at Rutherford Appleton Laboratory. The board was also designed at RAL, using the advanced board layout CAD programmes that the Electronics Division has recently acquired.

Equipment facilities for engineering research

Thermal analyser (Agema 780)

Autosizer IIc (Malvern PCS 45)

High-speed video (NAC 200)

SERC's Process Engineering and Electro Mechanical Engineering Committees have more than doubled the number of items of portable research apparatus available for use by SERC research grant holders. All the apparatus is available for short-term use in the grant holder's department for work to support current SERC grants. However, availability does vary. Some assistance can be given in setting up the equipment, but it will be up to the user to run the apparatus.

Imacon camera (Hadland Photonics 790 and 700)

These high-speed image converter cameras can produce up to 16 images on one Polaroid print. The high speed range is in steps between 1×10^4 and 1×10^7 fps or, for streak work, 10 to 1000 nS/mm.

Cinemax image intensifier (Hadland Photonics)

Manufactured for use primarily with the Hadland Photonics Hyspeed cine camera, this image intensifier can also be used with a Fastax or with the Imacon camera above. It is suitable for enhancing the brightness of dim self-luminous events, with a gain of approx 250 for white light. Resolution is 20 line pairs/mm. The Cinemax is mainly used on combustion research.

Hyspeed (Hadland Photonics)

A rotating prism camera taking up to 4×10^5 fps on up to 400 feet of 16 mm film. Complete with stand, lights, film processor and projector. The camera is compatible with the Cinemax image intensifier.

Copper vapour laser (Oxford Lasers CU 15)

A 15 W pulsed copper vapour laser with a fibre-optic delivery system. Air cooled and portable, it is intended for use as a light source.

High-speed video (Kodak Ektapro)

For even faster recording, this video provides operating speeds from 30 to 1000 fps at full aspect ratio via two synchronised cameras and a strobe flash, and speeds up to 6000 fps with narrow aspect ratio pictures. Features include a fixed playback speed of 30 fps and still frame picture. The maximum recording time is 30 seconds at 1000 fps.

An intensified camera is now available enabling pictures to be taken in very low light conditions or for an electronic shutter to be used to freeze rapid movement.

High-speed video (NAC 200)

The NAC 200 has a fixed operating speed of 200 fps using a single camera and synchronised strobe light. It records on a standard VHS tape to NTSC (American) standard, and features include slow speed forward and reverse playback and excellent still frame picture. The maximum recording time is 30 minutes.

High-speed video (NAC 400)

A more advanced version of the NAC 200 with 400 half-height frames per second, strobe lighting, PAL video output and computer-based motion analysis package. Recording time is up to one hour.

Sedigraph (Micrometrics Model 5100)

Particle sizer using sedimentation and X-ray to determine size in the range 0.1 to 300 microns in liquid samples. Complete with pycnometer for sample volume measurement and computer for control and for analysis of the results.

Disc centrifuge (Joyce Loebl DCF 4)

Particle sizer for the range 0.01 to 60 microns using centrifugal sedimentation of samples dispersed in a liquid. Rotational speed of up to 10,000 rpm with a sample of only 0.5 ml required.

Vibrating orifice aerosol generator (TSI 3450)

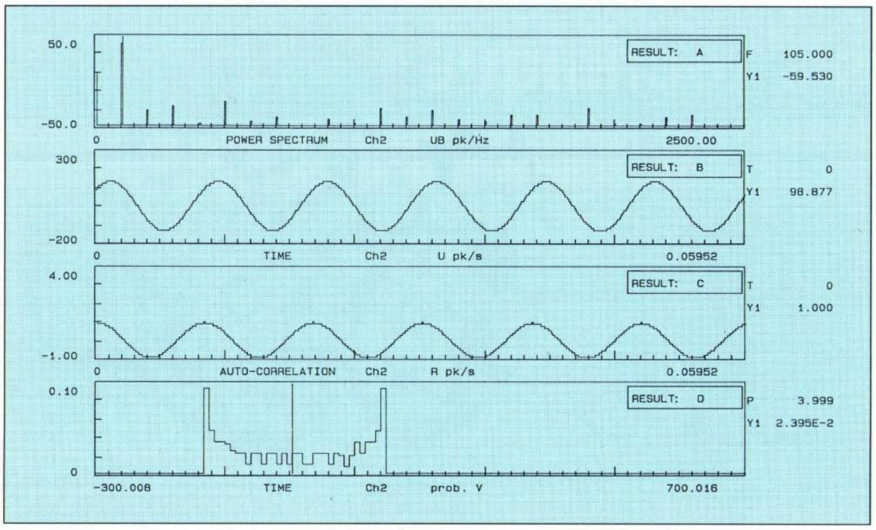
An accurate source of monosized aerosol particles, adjustable in the range 1 to 40 microns. A suitable air supply can be supplied with the generator.

Autosizer IIc (Malvern PCS 45)

Submicron particles in suspension are analysed by laser scattering. This model measures size distribution, molecular weight and diffusion coefficient of particles in the range of 0.003 to 3 microns molecular weights of 10^3 to 10^{14}. The autosizer uses a central processor and a printer output.

Droplet and particle size analyser (Malvern 2604 Lc)

The analysis of particle sizes from 0.5 to 1800 microns is determined by laser diffraction. The subject can be in the form of transient, pulsed or continuous sprays or as a powder in suspension. The analyser uses a central processor and a colour graphics plotter.



Output of spectrum analyser (Schlumberger 1220)

Phase doppler (Dantec)

Simultaneous measurement of particle size and velocity in two axes. Horizontal, vertical and reverse flows using fibre-optic probes to simplify the optical path. Size range 1 to 10,000 microns and velocity of up to 500 m/s.

Laser velocimeter (Polytech L2F)

The L2F provides twin focus time-of-flight measurement of seeded particles in fluid flow in the range of 0.5 to 3000 m/s. The apparatus includes multi-channel analysis of velocity, which can be synchronised to measure between rotating blades. The measurement volume is very small and can be within fluid boundary layers.

Rheometer (Carrimed CSL 100)

Controlled stress measurement of viscocity over the range 2.5 x 10^{-5} to 2.5 x 10^{5} pasec; shear rate 10^{-7} to 10^{4} per second and with an oscillation of 10^{-3} to 40 Hz temperature range is -100°C to 300°C. Complete with air supply and computer for results analysis.

Vibration pattern imager (Ometron VPI 9000)

This non-contacting vibration measuring system uses a laser to detect amplitude and frequency using a scanning technique and avoiding the effect on component behaviour caused by accelerometers. Spatial resolution of down to 0.1 mm with full processing and hard copy included.

Differential Scanning Calorimeter (Stanton Redcroft HT DSC1500)

Quantitative thermal analysis of small samples with respect to a reference can be obtained using controlled rate of temperature change up to 1500°C. This item is used to obtain mechanical and thermal properties, the chemical reactivity and characterisation of materials.

Cryomicrotome (Bright OFT)

Open-top cryostat with a rotary retracting microtome working in the range 0.5 to 30 microns at down to -40°C. Fitted with motor-control for automatic use it, produces microscope samples of soft tissue or foams.

Spectrum analyser (Schlumberger 1220)

Four-channel, 0 to 50 kHz with a mega-sample memory, internal generator, disc drive and plotter.

Digital oscilloscope (Le Croy 9450)

Two channel with a 350 MHz bandwidth, 50k memory and 400 mega-samples per second sample rate. Screen display can be copied on to a plotter.

Thermal imager (Agema 880 LWB)

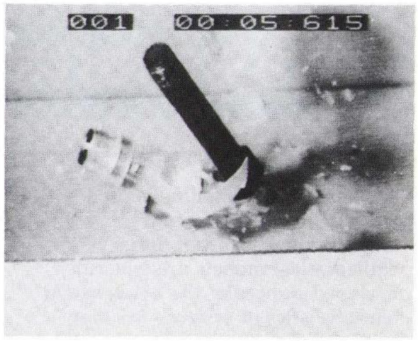
Imaging at 25 fps in the range -20 to 1500°C. The maximum sensitivity is 0.07°C and accuracy is at ± 2°C at ambient temperature. Option of single line scanning at 2500 Hz, burst capture of 25 frames in internal memory and a microscope with a field of 1.6 mm square are available.

Thermal analyser (Agema 780 LWB)

This unit, previously available through the former Polymer Engineering Directorate, is a flexible infrared measuring system to study thermally or spatially fixed or moving objects. The temperature range possible is between -20 and 1500°C with thermal sensitivity of 0.1°C at 30°C. Images are recorded on to a colour printer or Polaroid or 35 mm film.

Image analyser (Synoptics)

High-resolution (1024 x 1024) image processing system based on a personal computer intended mainly for analysis in particle sizing.



Taken with the high-speed video (NAC 200)

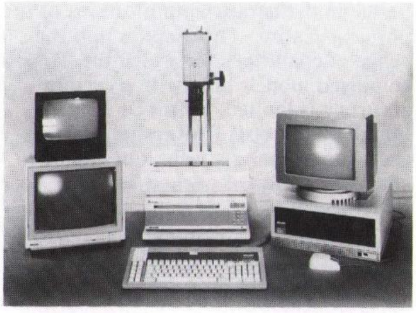
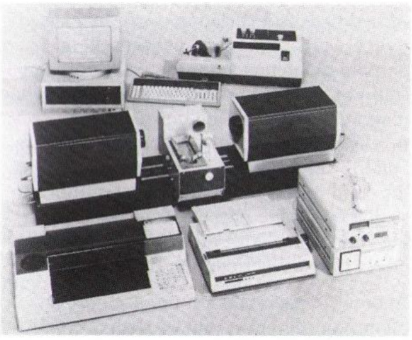


Image analyser (Oxford Framestore Applications)



Droplet and particle size analyser (Malvern 2604 Lc)

Image analyser (Oxford Framestore Applications)

This apparatus can be used with the Imacon camera, the two videos described above, and with any image input. Four video frames can be stored in 64 grey levels for further manipulation. Image processing software allows averaging, measurement, contrast enhancement and subtraction, as well as particle size and fringe pattern analysis.

For technical advice on the suitability and availability of these items, and for application forms, please contact:

Pete Goodyer
Rutherford Appleton Laboratory
Telephone Abingdon (0235) 821900
ext 6272.

Image analysis techniques

The concept of modelling is used both in experimental research and computational investigation. Mathematical models are generally developed to predict the behavioural characteristics of systems working under certain physical and operating conditions. It is common to present the description in the form of one or several mathematical equations, essentially based on deliberate simplifications of the physical reality. This implies that the range of conditions for which the employed models hold with a certain accuracy is limited, writes Dr Esmail Foumeny of Leeds University, who has used image analysis techniques for the characterisation of packed bed structure.

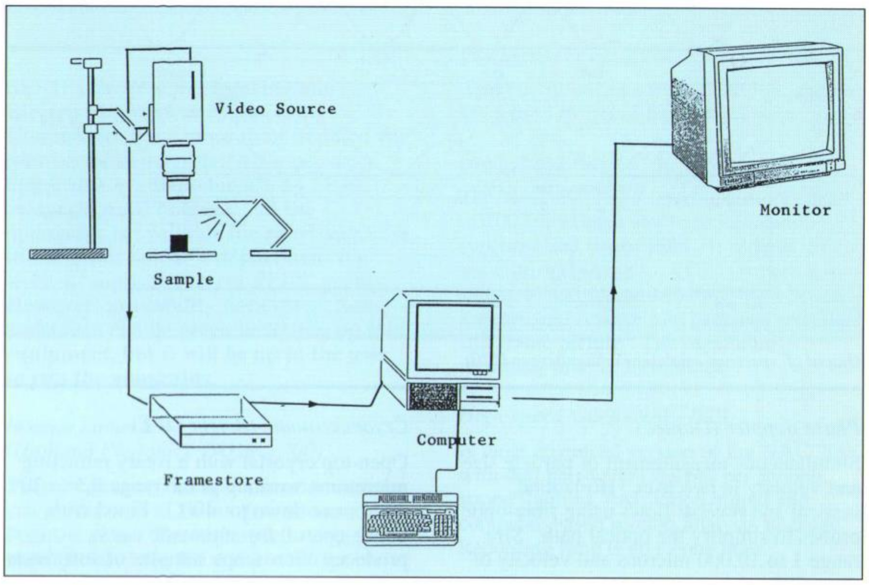


Figure 2: Simplified layout of an image analysis system

In modelling packed bed-based systems (figure 1) there is a geometrical problem. A common feature of the existing models of such systems is the assumption of plug flow which basically simplifies the bed to a regular geometry having uniform structure and flow properties. An important aspect of real beds is a certain anisotropy caused by the walls. In a zone within several particle diameters from the wall, voidage (ratio of void space to total space) is higher than in the core, which consequently results in considerable differences in flow pattern. In a heat or mass transfer process, the fluid in the core will reach equilibrium with the particle phase much sooner than the fluid in the wall region. The combined effect may exacerbate the problem.

In order to ascertain a more accurate picture of the behaviour of such systems, one needs to seek descriptive models based on realistic properties of the physical arrangement. Undoubtedly, all this greatly increases the complexity of the model. However, failing to take these into account may lead to unreliable design information. The uncertainties in the published data can be directly attributed to the inherent assumption of the existing predictive models.

To improve the reliability of the design data, it is necessary to be able to predict the non-uniformities of flow and structure so that appropriate models of the system could be tackled.

This work is an attempt to study the structural characteristics of particulate beds using an image analysis-based approach capable of providing valuable information. The overall aim here is to characterise packing assembly so that related features can be established predictively. In addition, the technique can be exploited to seek improved design configurations.

Refined technique

Rapid development in computer technology has led to a considerable evolution in image analysis techniques. This is a process for deriving numerical information from images and quantifying their parameters — size, shape and number, for example — for subsequent identification and characterisation. The technique has become an indispensable tool and has found application in such diverse fields as medicine, science and engineering.

A typical configuration of an image analysis system may consist of a video source, video digitiser and frame memory, monitor and computer. Figure 2 illustrates a simplified schematic diagram of a system. Printers may be attached to such a set-up for the hard-copy production of text, data or on-screen video images.

The principal stages of image analysis-based techniques are image acquisition, image refinement, measurement and analysis. In general, desired images are captured and subsequently digitised and stored as arrays of pixels, ready for the necessary manipulation. Captured images may be stored on either floppy or optical discs. The latter will provide a rapid access to accurately located images and can therefore lead to a better dissemination of information. Resolution of the system and capability of the software are the most important considerations in selecting a suitable image analysis device. The system used here is the one marketed by Oxford Framestore Applications Ltd. The use of image analysis calls for sample material which, in the present case, is prepared by dumping particles of desired sizes and shapes into a cylinder. The interstices of the bed are filled with resin and the solidified bed is subsequently machined at suitable intervals. The image of each cross-section is stored and later subjected to the necessary analysis treatment. Quality of each image in terms of colour contrast is an essential element. A cross-section of a typical bed is illustrated in figure 3.

Local properties of packing

Cylindrical packed beds (figure 1) have structural properties in axial, radial and angular directions: $\varepsilon(x,r,\theta)$. An effective

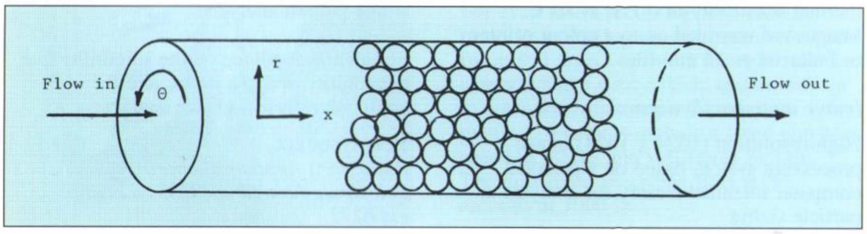


Figure 1: Schematic diagram of a packed bed

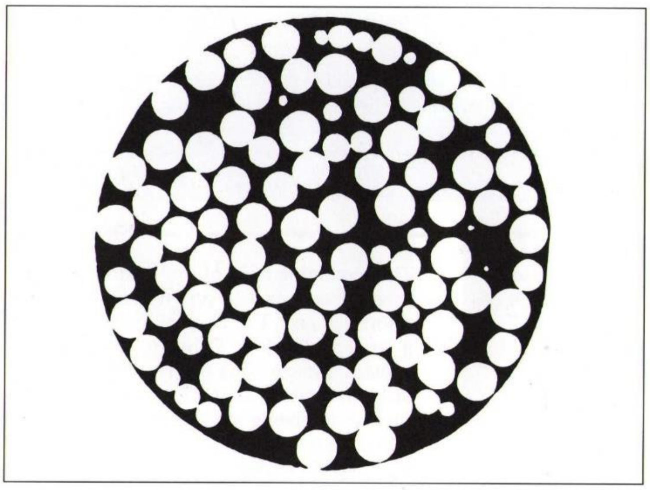


Figure 3: Typical cross-section of a cylindrical packed bed

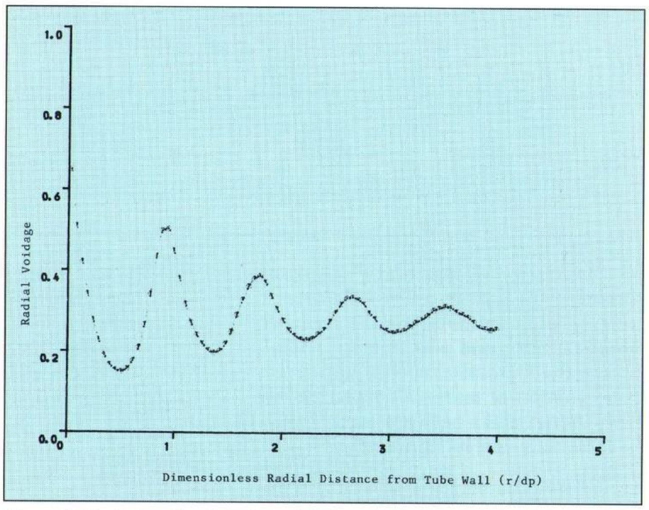


Figure 4: Variation of voidage in radial direction (tube to cylindrical particle diameter ratio = 10)

way of identifying and characterising such properties would be to examine their significance. Variation of voidage in angular direction was found to be stochastic in nature, signifying the impossibility of recognising an identifiable pattern. Moreover, in modelling heat and mass transfer processes in packed beds, it is customary to ignore the variations of temperature and concentration in the angular direction. On the basis of this, the three-dimentional voidage can be appropriately averaged to give:

$$\varepsilon(x,r) = \frac{\int_0^{2\pi} \varepsilon(x,r,\theta)\ d\theta}{2\pi}$$

where x,r,θ are the axial, radial and angular coordinates of the cylindrical bed.

Observed patterns of voidage

The technique has been used to inspect and extract the microscopic structural details of a number of packed beds. This is achieved by analysing the images of different cross-sections of each bed and obtaining the desired local information, $\varepsilon(x,r,\theta)$. Suitable averaging can provide other relevant data such as $\varepsilon(x,r)$, $\varepsilon(x)$, $\varepsilon(r)$ or ε_{mean}.

However, a typical set of data is displayed in figure 4, where radial voidage is plotted against normalised radial distance from the tube wall. Here the bed is of cylindrical nature packed with single-size spherical particles. The displayed profile exhibits a damped oscillatory pattern, with enhanced voidage in the vicinity of the wall. The distinctiveness of this poor distribution is due to the packing of the particles in relation to the boundary walls. The pronouncement of this zone is noticeable up to four particle-diameters away from the wall. This is influenced by the shape and size of the particles as well as the tube. However, the radial voidage, $\varepsilon(r)$, decreases oscillatorily from a value of 1.0, at the wall, to about 0.40 (for a sphere) or 0.3 (for a cylinder) at the bed centre. A significant feature of the observed radial profile is the location of the first minima and maxima which respectively appear some $^1/_2$ dp (particle diameter) and 1 dp away from the tube wall. Figures 5 and 6 show three-dimensional voidage representation of two beds which exhibit similar characteristics as discussed earlier. However, beds of cylindrical particles have been found to demonstrate compatible features to spherical based packings. The observed local voidage data, $\varepsilon(x,r,\theta)$, of each bed have been averaged to establish the mean voidage of the entire bed and compared with the corresponding mean voidage value obtained by water substitution. The agreement between the data of the two approaches is very good.

Having identified reproducible patterns of local voidage, the extracted data are correlated to provide suitable relationship between structural and physical properties of the particulate beds. This work is part of a multi-disciplinary project which is currently being pursued at Leeds.

To summarise, image analysis has been found to be a versatile technique and has enabled us to access information not previously possible. With the accumulation of such knowledge, it is possible to produce more sophisticated designs.

Dr E A Foumeny
Chemical Engineering Department
Leeds University

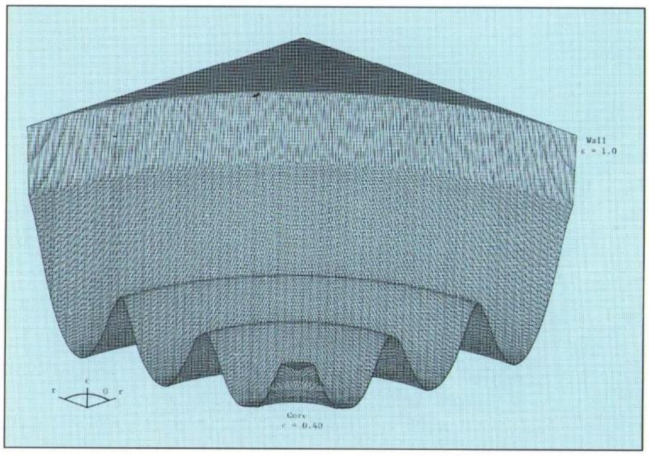


Figure 5: Three-dimensional representation of voidage pattern (tube to sphere diameter ratio = 5)

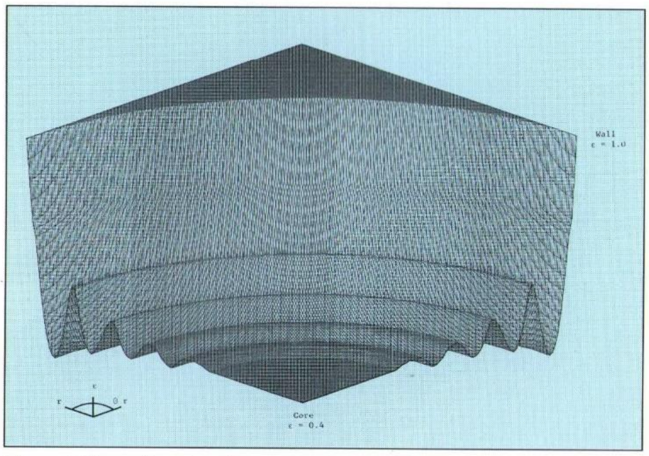


Figure 6: Three-dimensional representation of voidage pattern (tube to sphere ratio = 15)

Materials Commission — the first year

The Materials Science and Engineering Commission was set up in 1988 to oversee support for materials research in universities and polytechnics. The aim of the Commission is to improve coordination of materials research and forge better links between basic research in materials and its application.

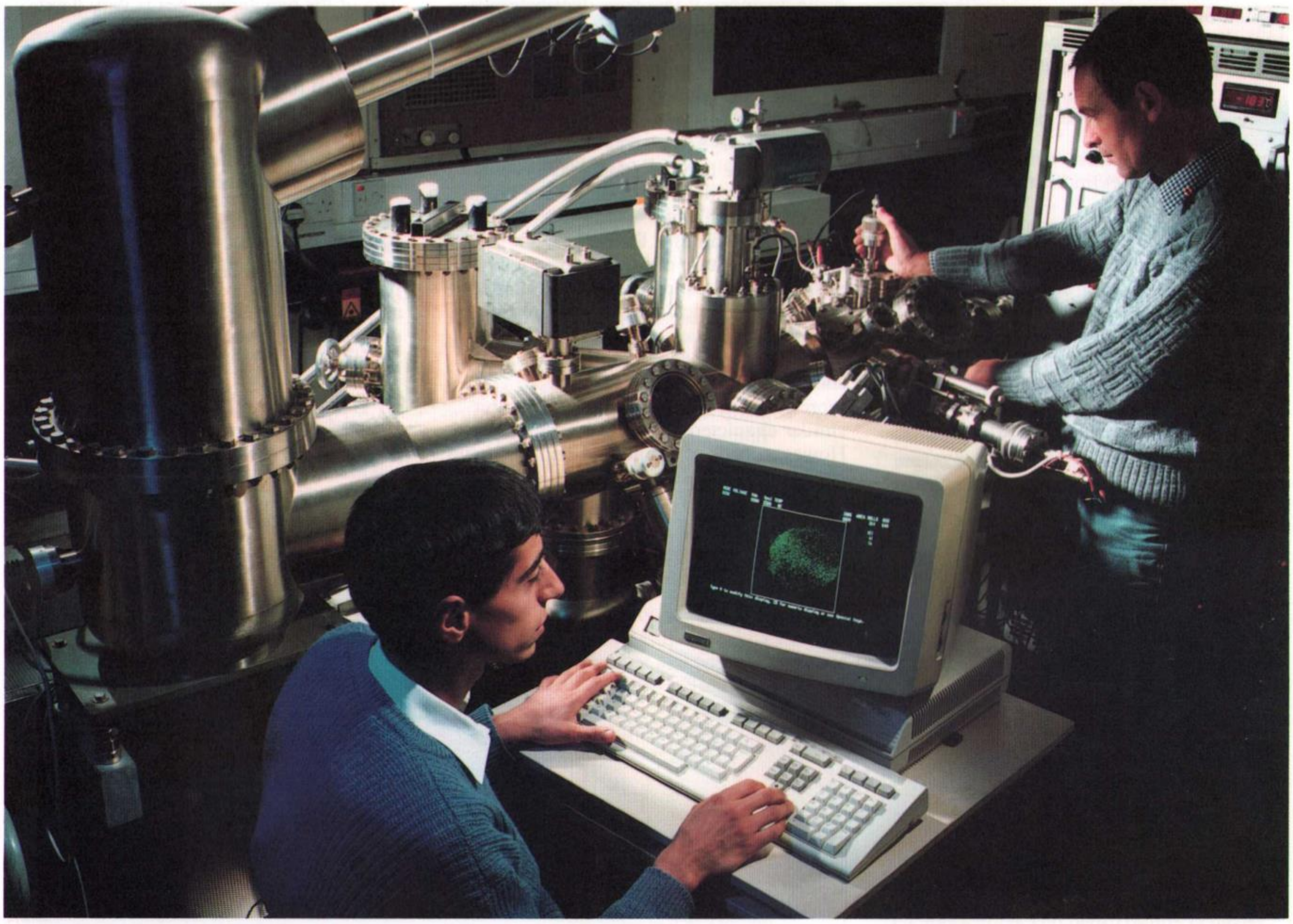
In its first year, the Commission has spent a considerable amount of time in defining its strategy to achieve the aims set out in its mission statement:

"The Materials Science and Engineering Commission will promote excellence of research and training in both the science and engineering of materials. The Commission will take an integrated view of materials research from synthesis through processing to demonstrator projects. It will seek to maintain and enhance the world-class materials research record of the UK. It will encourage the creation of new materials and facilitate the competitive exploitation of materials by British industry in international markets."

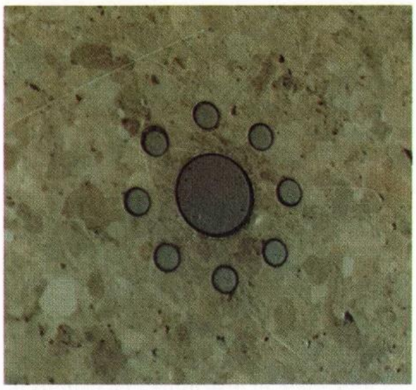
Demand for support for materials research is strong; in the 1988-89 session, 774 applications were received totalling £91 million. The Commission was able to offer 237 research grants at a total value of £22 million, of which the Commission's direct contribution was £18 million. It is essential to have priorities and be selective, in order to make best use of limited funds. However the Commission recognises that many scientific breakthroughs are unplanned, and therefore about 40% of the Commission's funding will be used to fund work of the highest scientific quality irrespective of whether or not it lies in a priority area.

The remaining 60% of the funding will be used for coordinated programmes in priority areas. The Commission has set up a Strategy Working Group to develop a strategy for selecting priority areas. In order to assist in strategic planning, three surveys are being made: industry is being asked for a 'wish list' of new and improved materials — this will form a 'market pull' approach to materials needs; UK materials scientists will be asked for their views of key materials research areas and 'hot topics' — this will form a 'science push' approach; and an international study is being made of areas our competitors are targeting.

The Commission's activities are distributed among seven committees: Ceramic and Inorganic Materials, Medical Engineering and Sensors, Metals and Magnetic Materials, Molecular Electronics,



This positron sensitive atom probe (PoSAP) is said to be the first machine on the market that is capable of taking apart materials atom by atom and reconstructing them in 3D. PoSAP was developed at Oxford University.



Miniature voltammetric carbon electrode on-line monitoring (photo: UMIST).

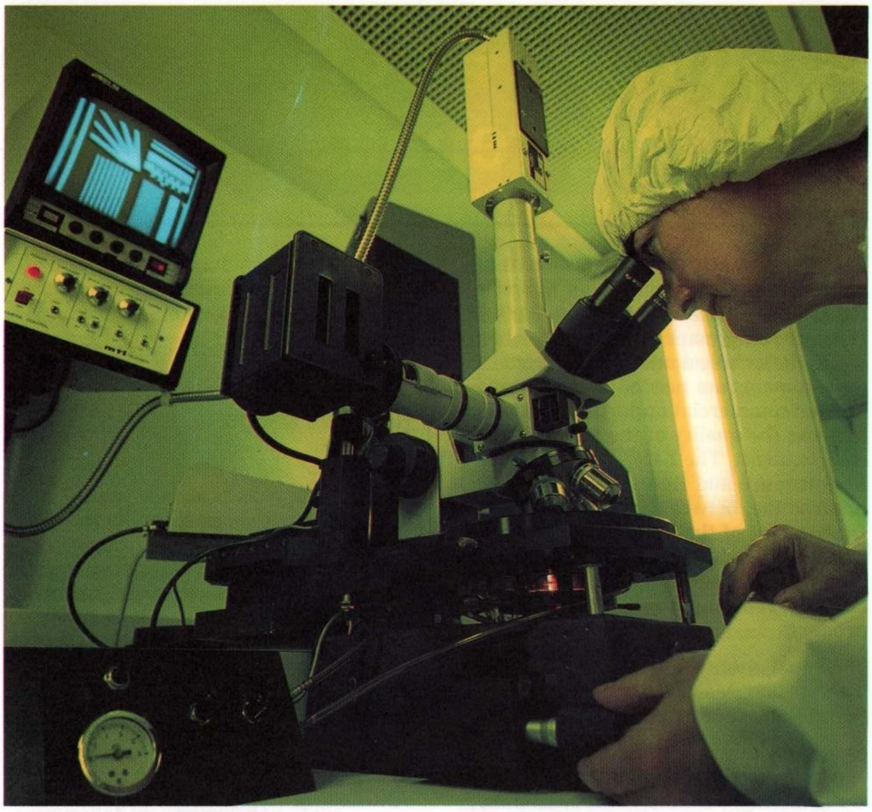
Polymers and Composites, Semiconductors, and Superconductivity.

Five Interdisciplinary Research Centres of relevance to the Commission have been established: Superconductivity (Cambridge), Semiconductor Materials (London), Surface Science (Liverpool and Manchester), Polymer Science and Technology (Leeds, Durham and Bradford), and High Performance Materials (Birmingham and Swansea).

The Commission is involved with 11 initiatives, some jointly with other SERC committees: 21st century materials; medical engineering; molecular sensors; magnetism and magnetic materials; casting; innovative polymer synthesis; nonlinear optics; molecular electronics; high temperature superconductivity; nanotechnology and low dimensional structures and devices; as well as seven LINK programmes: Molecular Electronics, Advanced Semiconductor Materials, Structural Composites, Nanotechnology, Molecular Sensors, Medical Implants and Technology for Analytical and Physical Measurement.

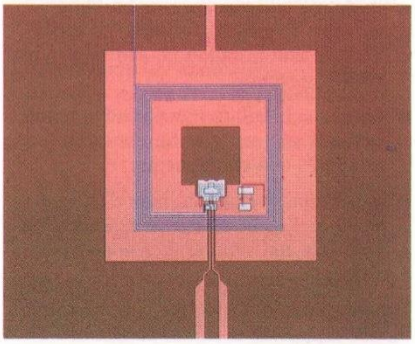
The present time is one of unprecedented opportunities for materials research. For example, in a recent survey, new materials was the R&D area considered to be making the most significant impact on market success in product development in Japan. In the UK, awareness of the importance of materials research is growing rapidly and, for example, the government's Advisory Committee on Science and Technology has identified materials science and engineering as a key enabling research area which must be strengthened in the UK.

SERC has provided substantial new funding for the Materials Science and Engineering Commission in its first year of operation and the Commission looks forward to enhancing the world-class materials research record of the UK and to seeing the fruits of this research exploited by industry in the UK.



An operator using a mask aligner for device fabrication (photo: Glasgow University).

Photomicrograph of a thin-film niobium DC Superconducting Quantum Interference Device (SQUID) made in Strathclyde University's Department of Physice and Applied Physics. It uses Nb/AL_2O_3/Nb Josephson tunnel junctions 5μm square and has an integrated spiral signal coil (shown in blue). The flux sensitivity is about $6x10^{-6}$ flux quanta per root Hz.



Polymeric materials used in the packaging and preparation of foodstuffs

Cutting the cost of building repairs

The maintenance and refurbishment of buildings now represent about half of the £35 billion UK construction market. It is a growing market and one in which research, technical and management developments are needed to promote further commercial opportunities and to improve the quality of the nation's built environment. The LINK Construction Maintenance and Refurbishment (CMR) programme, between SERC and the Department of the Environment (DOE) is aimed at reducing both the rising UK repair and maintenance bill and the rising level of imported building products.

The initial priority topics for the Construction, Maintenance and Refurbishment programme are:

- 'whole life' cost analysis: optimisation of initial and maintenance expenditure, monitoring, information, documentation and training needs for cost-effective maintenance
- up-dating and maintaining building services: improving methods of access, removal and installation, and improving control systems
- assessment, failure mechanisms, repair methods and material for concrete structures and components
- inspection, evaluation, maintenance, repair and replacement of deteriorating materials and structural or non-structural elements.

The programme, which is expected to run for six years, has an initial budget of £3 million over three years, the public sector contribution of £1.5 million being provided equally by SERC and DOE.

Three projects have already been approved and from the number of well developed outline proposals, it would seem that a high proportion of the programme budget will be committed by the end of the year.

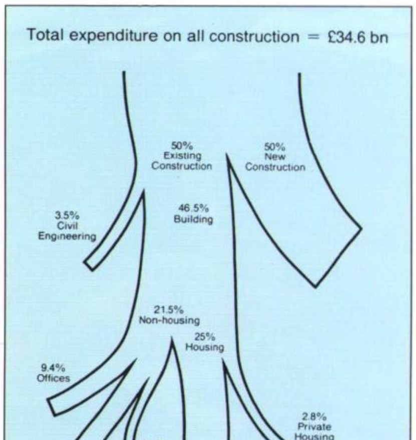
Sealant performance

The first project will study the performance of sealants in repaired structures. The project team is led by Dr Alan Hutchinson of the School of Engineering at Oxford Polytechnic and involves Taywood Engineering and a consortium of sealant manufacturers. The project is concerned with the resealing of joints in buildings and building structures, with the aim of establishing guide lines, specifications and recommendations for repair techniques and sealant systems. Experimental work at the polytechnic will be concerned with the wide range of selected sealant, primer and substrate systems.

Accelerated weathering equipment — a Zenotest 450 chamber, a climatic chamber and a QUV cabinet — has been installed to provide the basis for the research programme. A questionnaire has been devised and sent to industry in order to identify joint type, materials, surface problems, environmental conditions and sources of premature failure (if any), and a number of case studies will be undertaken in order to develop a standard replacement methodology.

Flat roofing systems

The second project deals with the assessment of life-span characteristics and as-built performance of flat roofing systems. This will be undertaken by Sam Allwinkle of Napier Polytechnic in collaboration with the British Flat Roofing Council (BFRC). Flat roofs have been used successfully from the late 19th century but acquired a poor reputation in the last 20 years. Developments in bituminous flat roofing and the introduction of a waterproof membrane have resulted in exceptionally durable new flat roofs but a lot of remedial work is necessary on older systems. The maintenance and refurbishment of roofing systems accounts for approximately 75% of all flat roofing work in the UK and accounts for an annual expenditure of some £230 million.



Distribution of UK expenditure on repair and maintenance in 1987.

The purpose of the project is to provide an objective evaluation of flat roofing systems and to obtain life-span and performance information that can be used to reduce the likelihood of future failures. The project will include a survey of a large number of existing flat roofing systems, evaluation of diagnostic tools used for non-distructive testing of flat roof systems, and provision of appropriate guidelines for feedback of the results to designers and contractors. Full-scale models will be constructed and tested at the Advanced Materials Centre at Napier Polytechnic which will enable the results of on-site surveys to be accurately assessed.

Recladding steel and concrete

The third project, by the Steel Construction Institute (SCI), Bovis Construction, and Materials and Constructed Environment Centre (MACE) of London University, will investigate the use of carbon and stainless steel for the recladding of existing steel, brick and concrete buildings. By testing, surveys, and theoretical analyses, the project will assess:

- fixings to existing structures
- design of supports to recladding systems
- implication of *revised* cladding loads and load paths
- structural interaction between the original frame and the replacement system.

Many commercial multi-storey buildings of the 1950s and 1960s now require recladding, either because of changing architectural or environmental requirements or because of inadequate durability of the cladding or its fixings. In addition, there is a continuing need to clad some much older structures. Both requirements demand particular knowledge of the behaviour of the structure before, during and after recladding. In addition, the nature of the fixings and new fixing positions will need to be taken into account at the design stage. The end point of the research will be design guidance to designers, surveyors and practitioners on the use of fixings and recladding systems on existing buildings.

Future prospects

More than 50 outline ideas have been received for possible future projects. Several of these have been approved for development into full proposals for consideration by the Programme Management Committee.

Further information on the programme can be obtained from:

V M Osgood — SERC Project Officer, SERC Swindon Office, telephone (0793) 411155

Dr R P Thorogood — DOE Project Officer, telephone 071-276 3869

P Pullar-Strecker — Programme Coordinator, telephone (0883) 712468.

Profile of an Industrial Fellowship

Professor David Bloor, who is coordinator of the SERC/Department of Trade and Industry Molecular Electronics programmes, holds the Chair of Applied Physics at Durham University. He was previously Professor of Physics at Queen Mary College, London, and while there was awarded an Industrial Fellowship to allow him to spend a year in the GEC Marconi Research Centre at Great Baddow in Essex to work on molecular materials for electronic and optoelectronic applications. His experience in industry is described here by Dr Peter Wakely, consultant to the Royal Society/SERC Industrial Fellowship scheme.

Organic materials are widely used in electronics but, with exceptions such as the use of liquid crystals in displays, they usually play a passive role in the final device. Awareness is, however, growing of their potential as active materials and, in line with this, David Bloor's objectives in his Fellowship were threefold:

- to assist in establishing expertise in the preparation and fabrication of organic crystals and films in the GEC Marconi Research Centre
- to gain an insight into the electronic industry's needs for new materials
- to identify and evaluate materials for specific applications.

The research work was focused on organic thin films for integrated optics, which provided a bridge between the synthetic chemists who were synthesising new materials and the engineers involved in developing devices utilising lithium niobate. The production of slab and channel waveguides was explored using simple coating and photo-chemical techniques. Professor Bloor was assisted in this by a CASE student (SERC's Cooperative Awards in Science and Engineering), Paul Wells, who was supported by GEC to work on this project. As a result, rapid progress was made and a range of low-loss channel guide structures produced.

Studies of novel polymers concentrated on polydiacetylenes (PDAs) developed jointly by Queen Mary College and GEC. These included comprehensive studies of the optical properties of a series of chiral soluble PDAs. The stability of several soluble PDAs was investigated and long term experiments beyond the period of the Fellowship established. Professor Bloor was also able to demonstrate how morphology and optical properties could be controlled by manipulation of the growth conditions. This work provided crucial information concerning the conformation of PDA chains in solution.

In the light of experience, how do the people directly involved — Queen Mary College, GEC Marconi and Professor Bloor himself — see this Industrial Fellowship? A few brief quotations will give some flavour of their views.

Dr Edgington, Head of the Department of Physics at Queen Mary College, writes:

"Professor Bloor acquired first-hand experience of industrial strategies regarding characterisation and fabrication of devices. This was most valuable at a time when we were expanding our research activities in this area.... The contacts at GEC and elsewhere that Professor Bloor made will help us mount new collaborative programmes and initiate strategic research."

From the GEC Marconi Research Centre, Dr McGlade, the Manager of the Materials and Displays Division, writes:

"The area of molecular materials is one which we see as being of great future importance in electronics. Professor Bloor's Fellowship has from our point of view been an outstanding success."

And lastly, Professor Bloor writes:

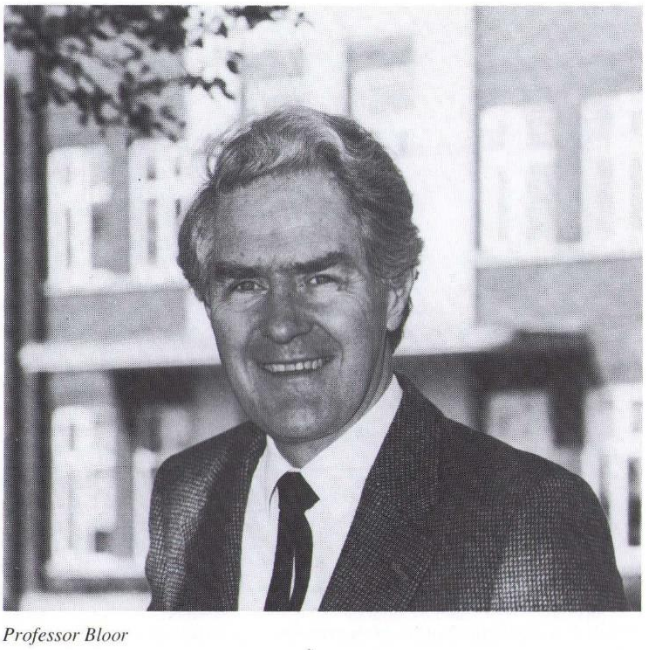
" Contact with the GEC staff involved in the construction of prototype devices and the assembly of advanced materials has been invaluable in the identification of opportunities for molecular materials in electronics and opto-electronics. This influenced the direction of my academic research at QMC. The continuation of my contact with GEC indicates how successful the Fellowship has been in building links between company and college.... The Fellowship was extremely valuable for me, and others should be made aware of the possibilities that a Fellowship offers."

Dr P Wakely

The Royal Society/SERC Industrial Fellowships are designed to help scientists, engineers and mathematicians to move, for between six months and two years, either from an academic institution into industry, or vice versa, to undertake a project of importance both to the academic institution and the company concerned. Typically, this project will be part of the company's engineering or science programme (but not necessarily research), or alternatively, it may consist of postgraduate course development.

Awards may be held on either a full-time or part-time basis. Fellows retain their permanent employment, so that their salary position and superannuation arrangements remain unchanged. The Fellowship stipend, which will normally be based on the appropriate academic scale, is paid direct to the Fellow's employer.

Further details and application forms are available from the SERC Fellowships Section at Swindon Office, telephone (0793) 411206.



Professor Bloor

Scanning transmission X-ray microscope

The scanning transmission X-ray microscope was designed and built at the Department of Physics, King's College, London, and is operated at Daresbury Laboratory's Synchrotron Radiation Source (SRS). This is the only soft X-ray source in the UK that is sufficiently bright for the operation of the X-ray microscope to be feasible. It is described here by Ron Burge and Bob Simmons of King's College, London, and Phil Duke of Daresbury.

Principles of operation

The main elements that make up the X-ray microscope are shown in figure 1. Although the operating principles are quite simple, the practical realisation is considerably more complicated.

Step 1: An intense monochromatic beam of soft X-rays from a magnetic undulator located in the SRS is brought to a small focused spot by means of a Fresnel zone plate. The size of this X-ray probe is determined by the width of the outermost zones of the zone plate, and it is the smallness of this probe which ultimately limits the image resolution.

Step 2: The specimen is mounted on a 3 mm diameter support grid (similar to those used in transmission electron microscopy) and is then scanned in raster fashion through the stationary X-ray beam. This is achieved using either a stepper-motor driven coarse stage (minimum step size about 0.1 micron) or a fine stage mounted on the coarse stage, and driven by piezo-electric transducers (minimum step size 10 nanometres).

Step 3: The X-ray intensity transmitted by each point on the specimen is detected by a gas flow proportional counter and then converted into a digital signal which is used to build up an image on a video framestore synchronously with the mechanical scan. The result is a two-dimensional map of the X-ray transmittance of the specimen.

All of the microscope operations and acquisition of data are under computer control. The direct availability of the data in digital form greatly facilitates both on-line and subsequent off-line analysis of the images.

Motivation

Radiographic methods which involve no focusing of the X-rays are well known in both medical science and industry. However, two important developments were required before a high resolution X-ray microscope with a focused X-ray beam could be realised:

- *Advanced microfabrication techniques*
Conventional refracting lenses cannot be made for use with X-rays, so it is necessary to use diffraction or reflection methods to focus them. By using electron beam lithography, Fresnel zone plates (a type of circular diffraction grating) small enough to operate at soft X-ray wavelengths are being made at King's College.

- *High brilliance X-ray sources*
The combination of an electron storage ring such as the SRS at Daresbury Laboratory, an undulator to enhance the synchrotron radiation output and a monochromator to select a narrow wavelength range can now provide the intense source of soft X-rays that is needed to allow X-ray images to be acquired in a reasonable time.

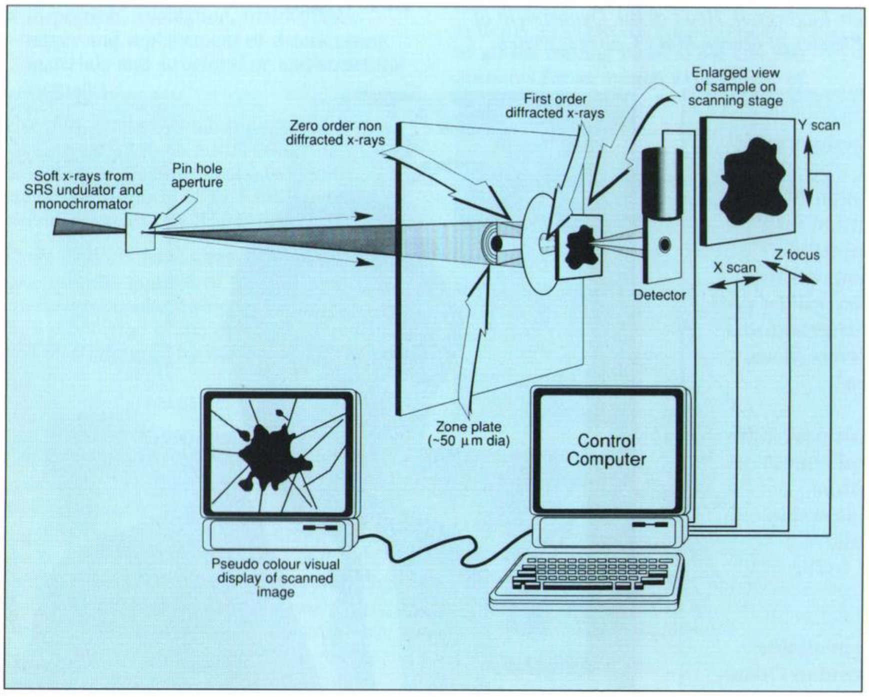


Figure 1: A schematic diagram of the scanning transmission X-ray microscope.

Description

Soft X-ray microscopy using photons in the energy range 100 eV to 1 keV is a technique that fills a niche between optical and electron microscopy, combining some of the advantages of both these techniques with unique capabilities of its own. The short wavelength of X-rays means that sub-optical resolution is possible in specimens which need not be transparent to visible light. As photo-electric absorption is an important beam-specimen interaction, it is possible to produce image contrast even from materials containing elements close together in the periodic table; most elements of low atomic number have a K or L absorption edge in the soft X-ray region. Further, as the interaction cross-section is smaller than that for electron scattering, the X-rays can pass through several millimetres of air and it becomes feasible to examine much thicker specimens (perhaps up to 5 microns thick) than is possible in a 100 keV transmission electron microscope, without needing to maintain the specimen in a high vacuum.

A particularly attractive consequence of this is the ability to examine unstained biological material in an aqueous medium by using X-rays in the so-called 'water-window' (between the carbon and oxygen K absorption edges which are at 284 eV and 543 eV respectively) to obtain strong contrast from organic material without too much absorption by the surrounding water (figure 2).

Results

Study of wet specimens
As a prelude to the study of wet biological specimens at high resolution, a simple

moisture-retaining chamber is being developed. Figure 3 shows an example of an image of fibroblasts from the dorsal root ganglia of a chick embryo, obtained with a preliminary version of the environmental chamber. The fibroblasts were stained with gold-labelled antibodies to the protein vimentin which is a high molecular weight protein responsible for cellular structure in many types of biological cells and is often found to be co-polymerised with other cytoskeletal proteins. The chamber and specimens were prepared in the Department of Biophysics and Medical Research Council Unit, King's College.

Hydrated cement

Although one of the prime reasons for developing an X-ray microscope is to use it to examine biological material in close to its natural state, there are also applications in materials science, where the instrument's ability to examine relatively thick specimens under ambient conditions can be important. For example, finely ground particles of ordinary Portland cement were hydrated in a 5:1 water:cement mixture and then examined in the X-ray microscope at 12-hour intervals over a period of 48 hours. As the hydration process continues there is a steady progression from individual, almost spherical, cement particles to a form where filaments or tubules have grown from them. These fine interlocking tubules are ultimately responsible for the strength of the hardened cement, yet the growth mechanism is still not well understood because of the difficulty of observing wet processes at high resolution in either the optical or electron microscope. As the timescale for these changes is of the order of hours rather than minutes these changes can be followed as they take place.

The image shown here (figure 4) was taken with the King's College-Daresbury scanning transmission X-ray microscope after the cement had been hydrated for 48 hours and shows clearly an extensive network of long filaments emerging from a few isolated cement particles.

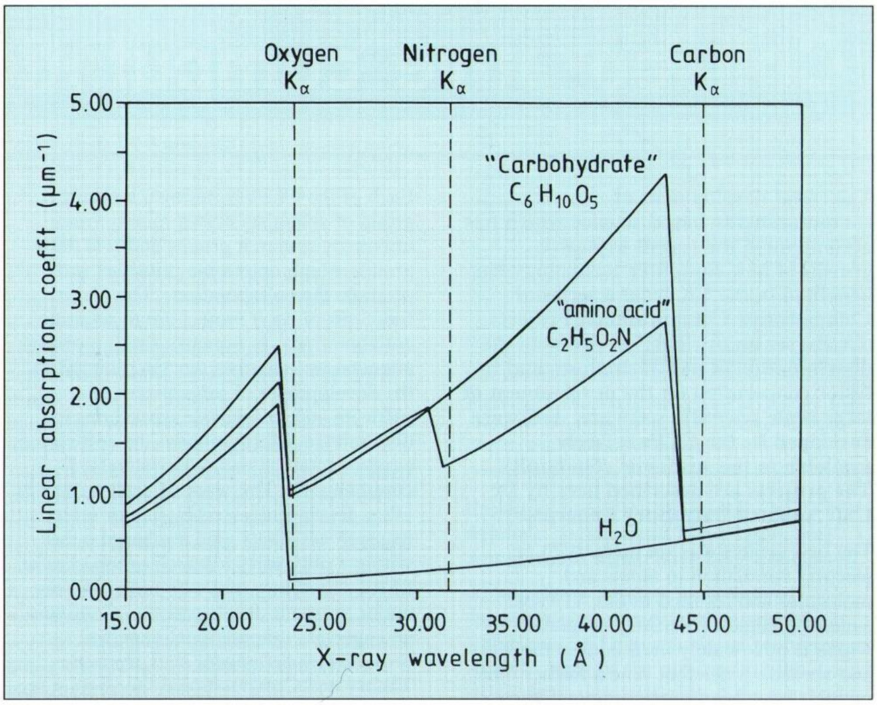


Figure 2: A graph showing the relatively strong absorption by organic material compared to water for wavelengths within the 'water-window', between the oxygen and carbon K absorption edges.

Conclusion

There are currently only three working X-ray microscopes in the world. These are the King's College-Daresbury microscope described here, another scanning microscope based at the National Synchrotron Light Source, Brookhaven, USA and a microscope built by a group at the University of Göttingen and used at the BESSY synchrotron radiation source in Berlin, West Germany. Other instruments are under development in Japan, Italy, and the People's Republic of China. The continuing development of this programme at the SRS will enable the UK to stay at the forefront of this important new activity.

Professor R E Burge and
Professor R M Simmons
King's College, London

Professor P J Duke
Daresbury Laboratory

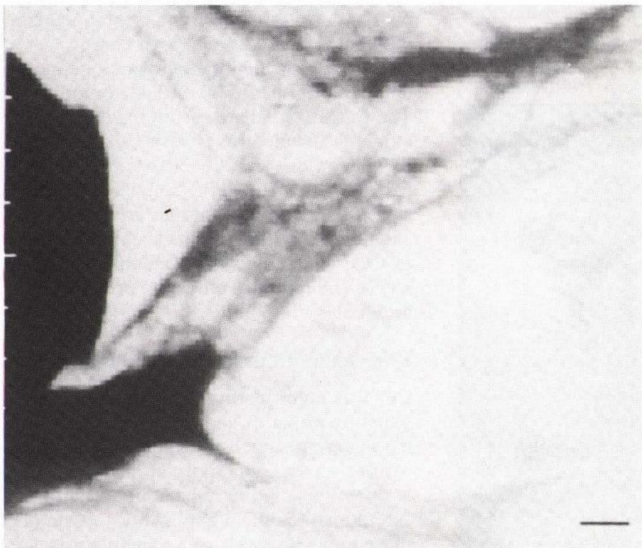


Figure 3: Wet, stained, chick embryo fibroblasts imaged in the wet specimen chamber described in the text. Field size 64 x 64 μm^2. The X-ray energy was 379 eV. The length of the scale bar in the figure is 5 μm.

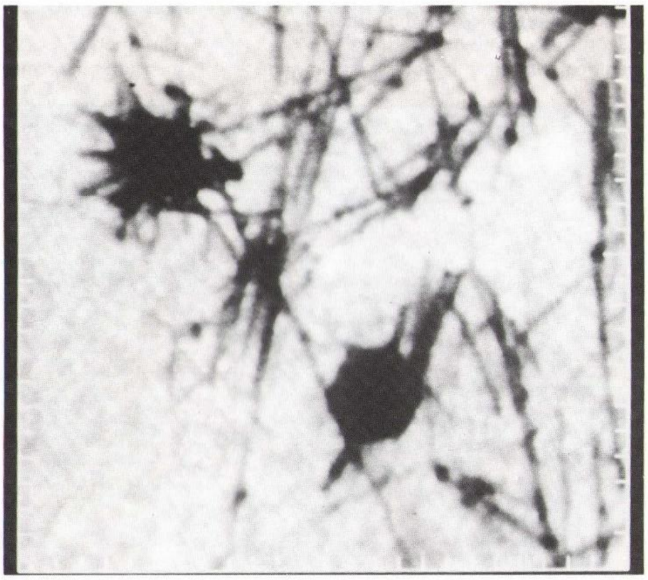


Figure 4: An X-ray image of cement particles after 48 hours hydration. The X-ray energy was 351 eV. The field size was about 20 x 20 μm^2.

Collaborative computational projects

The rapid development of computationally based science which has accompanied the recent explosive growth of new computer technology has benefited in the UK from a series of Collaborative Computational Projects (CCPs) set up by SERC to promote the dissemination of new techniques and to foster cooperation on the development of large-scale scientific software. Software developed by the CCPs is freely available to the academic community. The projects are described here by Dr Cliff Noble of Daresbury Laboratory.

The first project was set up in 1974 on electron correlation in atoms and molecules and resulted in the ATMOL suite of quantum chemistry programs which is now widely used both in the UK and abroad. Since that time a further nine projects have been initiated on a diverse range of topics covering aspects of atomic and molecular physics, solid state and surface physics, protein crystallography, nuclear physics, astrophysics and plasma physics. Additional projects are currently under consideration which will broaden this already wide range of subjects to include further biological and engineering sciences.

Recent more wide-spread interest in the CCP concept, including the development of links to other European countries, the US and Japan, reflects an appreciation that taking full advantage of the scientific opportunities offered by new massively parallel computer architectures, the increased availability of powerful graphics workstations and other technological developments, demands broadly based collaborations to create the required scientific software and to distribute technical expertise as quickly as possible.

Each of the CCPs is run by a working group of scientists drawn mainly from university research groups and it is these groups which determine priorities and promote the collaboration. The major functions of each project are to promote collaborations, to organise small meetings attended by scientists working jointly on the development of large pieces of software and to organise workshops to disseminate information on the software to experimentalists and other interested communities. The work of each project is often greatly enhanced by one or more research assistants who are based either within a university research group or at an SERC laboratory and who undertake the major program developments. Continuity and special computational expertise is provided by permanent staff from the Theory and Computational Division at the Daresbury Laboratory and from the Central Computing Division at the Rutherford Appleton Laboratory (RAL).

Review of the entire CCP programme is provided by a steering panel reporting to the Science Board Computing Committee. The panel ensures the overall balance of the CCP programme and promotes cooperation between the CCPs. It has also arranged summer schools to teach computational and numerical analysis techniques to graduate students beginning studies in the areas covered by the projects. Most of the UK CCPs include foreign scientists as members of their working groups and maintain close connections with overseas research groups. The possibility of establishing CCP-type collaborations throughout Europe is presently under investigation.

The true success of the programme may be measured in terms of the new scientific results which have been produced. Of the many exciting developments, we can give just a few illustrations here.

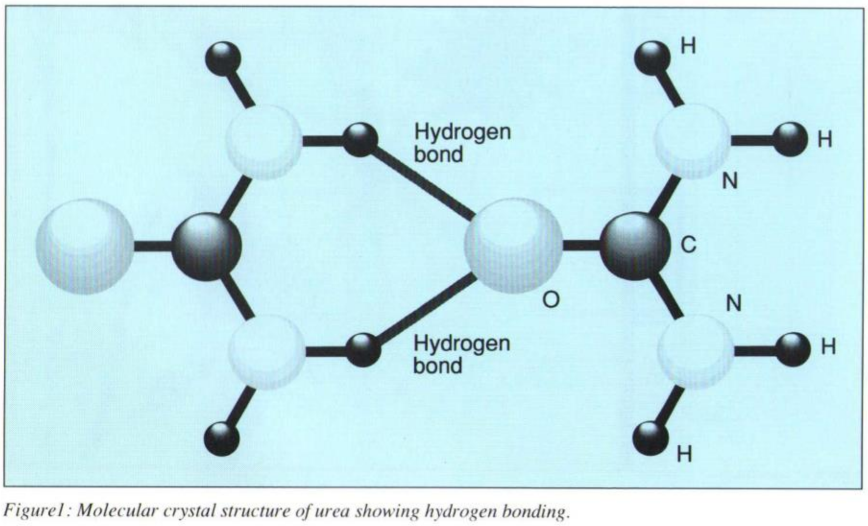


Figure1: Molecular crystal structure of urea showing hydrogen bonding.

Properties of molecules

Many of the CCPs are concerned with questions of how atoms are held together either as molecules or as crystalline solids. Frequently the most interesting properties are associated with determining the particular arrangements of the nuclei and electrons which minimise the energy of the system as these correspond to the most stable configurations or states. CCP1, the first of the projects, has developed highly sophisticated techniques and computer programmes for determining the properties of molecules and these methods have recently been extended to describe certain types of crystal.

A crystalline solid is characterised by a specific local arrangement of atoms, termed a unit cell, which is repeated periodically throughout the crystal. The power of the new methods is seen in the results of test calculations on the biologically important crystal urea. In this case the unit cell contains two urea molecules, $CO(NH_2)_2$ as shown in figure 1. It is generally assumed that the crystal is stabilised by the formation of hydrogen bonds as illustrated. The numerical calculation is able to predict accurately the heat of sublimation (the energy required to convert the crystal urea to a gas of urea molecules) and other properties as well as giving insight into the forces giving rise to the formation of the crystal. The detail which is possible is shown in figure 2 which shows contours for the difference in charge density between the crystal and free molecules of urea. Increased charge density is indicated by solid contours and depletion of charge by dashed contours. The transfer of charge from the hydrogen atoms to the electronegative carbon and oxygen atoms gives rise to the formation of hydrogen bonds and the stable crystalline structure. These techniques are now being extended to other systems such as gamma-glycine which involves 30 atoms and is one of the building blocks of protein molecules.

High temperature superconductors

CCP9 is investigating the electronic structure of solids and has studied some of the materials which were found in 1986 to exhibit superconductivity at relatively high temperatures and may have important future technological applications. One of these new classes of superconductor is obtained by suitably doping the crystal La_2CuO_4 to replace some of the lanthanum atoms by barium (Ba) or strontium (Sr).

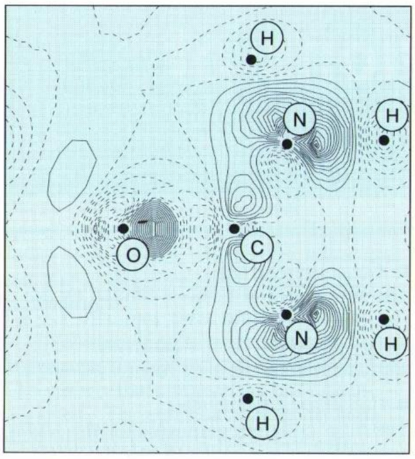


Figure 2: Charge density difference map for crystalline urea.

At present there is no detailed understanding of the mechanism which gives rise to the superconducting state.

It is hoped that this understanding will eventually result from a more detailed knowledge of the system including that of the undoped crystal. Information on the structure of this crystal has been obtained by calculating how the volume of the crystal varies with pressure. The results are shown in figure 3 and are seen to be in good agreement with values measured using energy dispersive diffraction facilities available on the Daresbury Synchrotron Radiation Source. It is clear therefore that certain properties of these substances may be understood in detail. This success is tempered by the failure of these same calculations to correctly predict the magnetic properties of the crystal. This failure seems to be a consequence of the approximate treatment within present calculations of the correlated motion of many electrons. These indications are useful pointers towards new improved treatments of many-body effects.

Complex crystal structures

The determination of the structure of crystals is also central to the activities of CCP4 which is concerned with protein crystallography. This project has collected and maintains an extensive library of computer programs which has been instrumental in analysing complex crystal structures from data collected both in the UK and abroad. It is forging close links with laboratories in other European countries which wish to participate in these program developments, through an association sponsored by the European Science Foundation. The symbiosis which exists between most CCPs and various experimental programmes under way within the UK is well illustrated by the use of this program library to analyse data taken on the SRS at Daresbury by a group from Oxford University and from Wellcome Biotech which has led to a determination of the structure of the foot-and-mouth disease virus. Viruses consist mainly of a nucleic acid core surrounded by a protective coat of protein molecules. Such structure determinations provide information on the site at which the virus binds to its host and therefore clearly pave the way for the design of drugs to combat the diseases associated with the virus.

Zeolite catalysis

CCP5 is a project concerned with the computer simulation of condensed phases by molecular dynamics, Monte Carlo and energy minimisation techniques. Simulation studies are currently having a major impact in the field of zeolite catalysis. Zeolites are microporous aluminosilicates which allow large molecules to diffuse into their pores where they may undergo a variety of catalysed reactions. The nature of the products is largely controlled by the ability of reactant and product molecules to diffuse to and from the active site. Simulation techniques are being used to study *(i)* the structures of zeolites which can be accurately modelled using energy minimisation methods; *(ii)* the sorption of molecules and the identification of the lowest energy sites for their accommodation within the zeolite pores, and *(iii)* the diffusion of molecules within the pores. Quantum mechanical methods can then be used to study the behaviour of the hydrocarbon molecules.

Simulation studies of these systems are currently in progress at Bath, Keele, London and Oxford Universities and at the Royal Institution. Recent work involving the Royal Institution and Bath has investigated the reaction of hydrocarbon molecules in the zeolite ZSM-5 (which catalytically converts methanol to gasoline). The coloured simulation on the front cover shows the energy minimised configuration for methane in the pores of this zeolite. The calculations have also revealed the way in which the larger molecules accommodate their geometry to that of the zeolite pore.

. . . and many more

These examples reflect only a fraction of CCP activities. CCP7 has developed tools for the analysis of stellar atmospheres and has made major contributions in the areas of planetary nebulae, circumstellar shells and interstellar chemistry. There are two projects concerned with collisions involving atoms and molecules. One of these, CCP2, is focused on those types of collision which depend principally on the electronic structure of the target such as electron-atom scattering or photoionisation. The second, CCP6, is on the topic of heavy particle dynamics and so focuses on collisions where the motion of the nuclei provide the dominant effects such as reactive scattering and charge transfer processes. The most recently established project, CCP10, is in the area of plasma physics, is supported by staff from RAL and has close links with the Central Laser Facility at that laboratory.

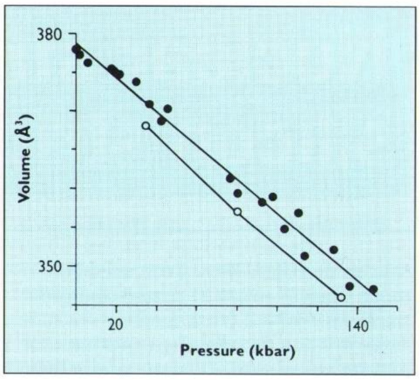


Figure 3: Variation of the volume of La_2CuO_4 with pressure. Theoretical results are shown as open circles, experimental results as closed circles.

Problems involving magnetohydro-dynamic stability and X-ray lasers are among those which have been considered.

Although the projects have diverse scientific aims, many of the underlying techniques and computational problems are shared. Most of the projects use the supercomputers available at the national computing centres and have been involved in the vectorisation of programs to exploit computers such as the Cray X-MP to the full. A number of groups have also obtained parallel computers through the SERC Computational Science Initiative. As massively parallel computers become more widely used and scientific computing involves more extensive use of sophisticated visualisation techniques, the technical problems of effectively utilising the available tools become more complex. Consequently the need to use the available effort as efficiently as possible becomes even more imperative. The Collaborative Computational Projects will almost certainly play an increasingly important role in this process and proposals for new projects will be welcomed by the steering panel.

Dr C J Noble
Daresbury Laboratory

Currently active CCPs

CCP1:	Correlated Wave Functions
CCP2:	Continuum States of Atoms and Molecules
CCP3:	Computational Studies of Surfaces
CCP4:	Protein Crystallography
CCP5:	Computer Simulation of Condensed Phases
CCP6:	Heavy Particle Dynamics
CCP7:	Analysis of Astronomical Spectra
CCP9:	Electronic Structure of Solids
CCP10:	Plasma Physics

Nuclear structure applications of silicon strip detectors

Silicon detectors have been used for more than 30 years to detect charged particles emitted from nuclear reactions. Over the last decade, the experimental and technical requirements of particle physics research programmes have prompted the development of a new class of detectors which combine the advantages of conventional detectors with the current silicon processing techniques of the semiconductor industry. By using such techniques it is possible to manufacture many closely spaced, independent detectors on a single silicon wafer. These detectors are usually configured as series of strips with widths ranging from tens of microns to several millimetres. These silicon strip detectors (SSDs) are now also being used in nuclear structure experiments where their unique combination of characteristics is enabling new types of research to be performed, as described here by Professor Alan Shotter and Dr Thomas Davinson of Edinburgh University.

The study of the low-energy properties of stable, or near stable, nuclei using light-ion accelerators or low-duty cycle electron accelerators has in the past provided the foundation of our understanding of nuclear matter. With the advent of a new generation of facilities such as the heavy-ion accelerator at the Nuclear Structure Facility at Daresbury Laboratory and the 100% duty cycle electron accelerator at the Institut für Kernphysik, Mainz, it is now possible to extend our studies to nuclei which are at the extreme limits of stability, to nuclei which are highly excited and to nuclei which are rapidly spinning. Such studies are revealing new phenomena as well as greatly increasing our knowledge of the landscape of nuclear properties. These new results are challenging existing theories to the extent that in some cases new theoretical ideas are clearly needed.

Detection of charged particles

Experiments performed at these new facilities often give rise to many different types of nuclear reactions when in practice we wish to isolate and study just one type of reaction. The identification of a particular type of reaction frequently involves the the detection of charged particles. It is in the detection of the charged particles from such reactions that the new generation of silicon strip detectors is beginning to play a significant role. The characteristics of SSDs that are of particular value in such experiments are:

- *Large active area*
The active area of SSDs is limited by the size of silicon wafer used, typically 3 or 4 inches diameter. In experimental applications this implies large solid angles.

- *Customised geometries*
The most common geometry for the active area of SSDs is a series of parallel strips on a constant pitch. However, because the active area is defined by high precision photomasks it is possible to design other types of geometry to customise an SSD for a particular application — for example, the active areas could be of variable size, width or pitch and of various shapes.

- *Independent detector elements*
This has the advantages of position resolution, high data throughput and high multiplicity event detection — that is, one silicon wafer can be used to detect and independently process many events simultaneously.

- *Low reverse current*
Reverse currents are typically 1-10% of comparable conventional silicon detectors and therefore the electronic noise is lower, which improves energy and timing performance.

- *Small inter-strip separation*
The low spatial separation of the detector elements maximises the active area:dead area ratio and provides high detection efficiencies for nuclear reactions producing two or more particles with a small angular separation.

Speed and precision

In particle physics experiments, SSDs are primarily used to determine the position of a particle. Measurements of the energy deposited or the time of interaction are not generally so important. Further, the low duty cycle of the accelerators used means that relatively long integration and readout times are normal. In contrast, nuclear structure applications require the fast,

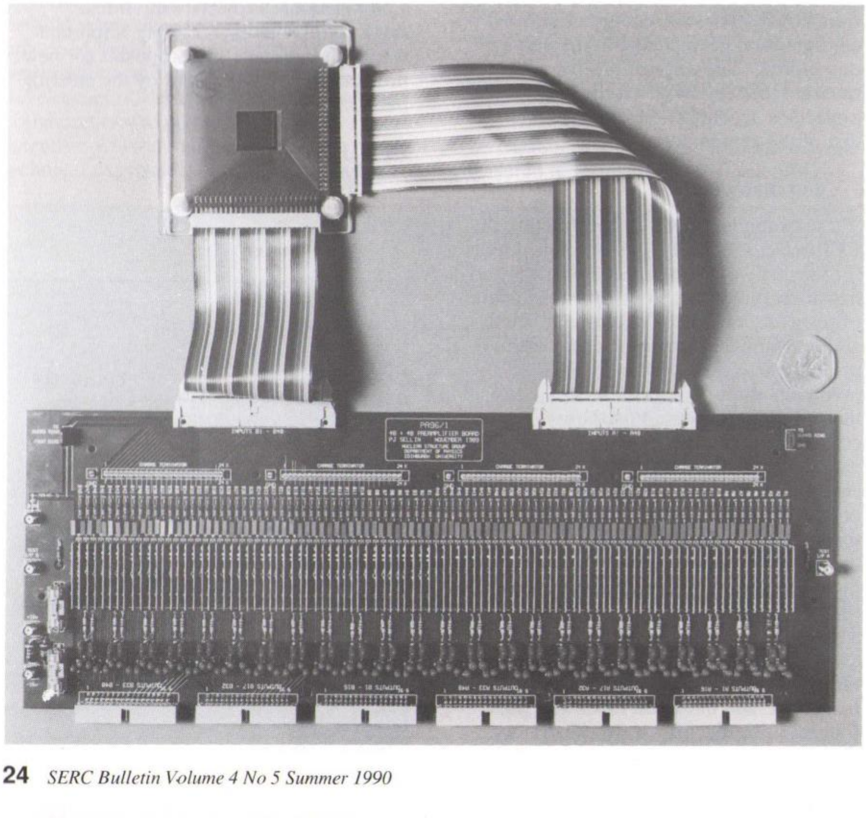


Figure 1: The detector and instrumentation to be used to study proton radioactivity, showing the 96-channel charge-sensitive preamplifier PCB (size 415 mm x 155 mm) on which the Edinburgh/RAL thick-film hybrid preamplifiers are mounted. The PCB is shown fully loaded and connected to a double-sided SSD. The silicon wafer of the detector measures 15 mm x 15 mm and is 87 microns thick. The detector has 48 strips on the front of the wafer and 48 orthogonal strips on the rear of the wafer. The strips are 300 microns wide and are on a pitch of 335 microns. The detector was designed and manufactured to the Edinburgh group's specification by Micron Semiconductor Ltd, Lancing, Sussex.

high-precision and simultaneous measurement of energy, position and time. To achieve this, and to exploit all the advantages of SSDs fully, requires fast and parallel readout of all detector elements of the SSDs with high quality instrumentation optimised for nuclear structure applications. The very high cost and low channel density of conventional instrumentation has forced the adoption of newer technologies which offer lower cost and higher densities while maintaining performance.

In collaboration with the electronics division of the Rutherford Appleton Laboratory, these objectives have been achieved. The instrumentation has been implemented by using thick-film and surface mount circuitry. Although this approach has necessarily sacrificed some of the convenience and flexibility of conventional instrumentation, it offers good performance, higher densities and lower costs. An example of the detectors and instrumentation is shown in figure 1.

Edge of nuclear existance

To illustrate the application and potential of SSDs in nuclear structure physics, we will briefly describe the research of Phil Woods and Paul Sellin of the Edinburgh group. The objective of their research is to study the radioactive decay by proton emission of nuclei which are at the extreme edge of nuclear existence. These highly proton-rich nuclei are produced at the Daresbury Nuclear Structure Facility, by bombarding thin targets with high-energy heavy-ion beams. About 1 in 10^5 of the incident heavy-ions fuse with target nuclei to form highly excited compound nuclei recoiling in the direction of the primary beam. The compound nuclei lose excitation energy by emitting light particles and gamma-rays to produce a range of proton-rich nuclei in their ground states. The rapidly decaying ($t_{\frac{1}{2}} \ll 1s$) proton radioactive nuclei represent about 1 in 10^8 of the nuclei produced in this way.

The Daresbury Recoil Separator uses a pair of orthogonal electric and magnetic fields to select the slowly recoiling nuclei from the intense flux of fast primary beam particles and then uses a dipole magnet to separate the recoiling nuclei according to their mass. The total time required to transport the recoiling nuclei to the focal plane is about 1 microsecond. At the focal plane these nuclei are implanted into a thin double-sided SSD (see figure 2). This SSD has strips on both sides of the silicon wafer with the strips on one side being orthogonal to the strips on the other. The detector therefore behaves as a 'quasi-pixel' device and provides both x and y spatial information. The positional information is used to identify the mass of the implanted nucleus and to correlate implantations and subsequent decays occurring at the same location in the detector. These correlations are then used to determine the half-life and branching ratio of the radioactivity.

In comparison with conventional silicon detectors, double-sided SSDs offer much superior position and energy resolution performance. This greatly improves the sensitivity of the technique for measuring very weak ground-state proton radioactivity in the presence of intense background radioactivity. The Edinburgh group have also used SSDs to great advantage in a range of other applications, such as heavy-ion fragmentation, projectile alignment during scattering and measurements of (γ,p) and (p,γ) reactions.

Further applications and potential

The new generation of electron accelerators, combined with the use of SSDs, is enabling the most fundamental nuclear reaction (γ,p) to be studied with a precision which hitherto has not been possible. The Edinburgh group's use of SSDs in this way has helped to open up a whole new field of nuclear structure studies. The group has also used SSDs in other pioneering experiments at Daresbury, such as measuring the spin alignment of rapidly decaying nuclei emitted in nuclear reactions, and measuring the break-up characteristics of polarised projectile nuclei and relating this information to the inverse radiative captive processes of nuclear astrophysical interest. These and other experiments would have been difficult, if not impossible, to undertake if SSDs were not available.

SSDs are evolving into a powerful and general purpose tool for nuclear structure research and new applications are continuing to emerge which place even greater demands on detectors and instrumentation. The rapid advances in silicon processing techniques are already pointing the way to the next generation of silicon detectors and many research groups are already exploiting these advances. Instead of strips, it might be possible to manufacture pixels across the silicon wafer, and perhaps even to integrate instrumentation and detector on to the same silicon wafer. Clearly the development and applications of silicon detectors have an exciting future.

Professor A C Shotter and
Dr T Davinson
Department of Physics
Edinburgh University

The developments described in this article are the result of the efforts of the Edinburgh nuclear physics group, a group from the electronics division of the Rutherford Appleton Laboratory and Micron Semiconductor Ltd. The authors would like to acknowledge the many important contributions that they have all made.

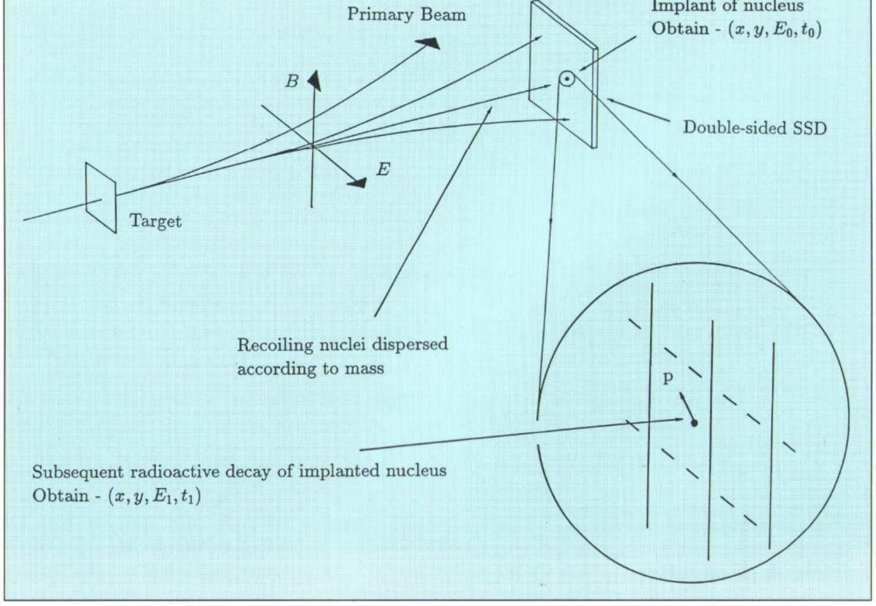


Figure 2: The experimental technique used to study proton radioactive nuclei. The primary beam of heavy ions is used to bombard a target. The Daresbury Recoil Separator uses a combination of electric and magnetic fields to select out the recoiling nuclei and to disperse them according to their mass. At the focal plane the recoiling nuclei are implanted into a double-sided SSD (enlarged view) where signals from the front strips (bounded by solid lines) and the orthogonal back strips (dashed lines) of the detector provide the position (x,y), energy (E_0) and time (t_0) of the implant. Protons subsequently emitted from the implanted nuclei at a later time (t_1) also produce position (x,y) and energy (E_1) signals. Precise positional correlations between the two types of event can be used to determine the half-life of the proton-emitting nucleus.

Earth observation and the global environment

Observations of the Planet Earth from orbiting spacecraft have taken on a new significance in the current growing awareness (at both political and public levels) of problems of the global environment. However, it is not widely appreciated that SERC, through its support of atmospheric science for almost two decades, has funded world-class research projects in this area, and continues to do so, writes Professor John Harries of Rutherford Appleton Laboratory.

The key issues as far as SERC interests are concerned are two-fold. First, the problems facing the environment are global, and measurements on a global scale can really only be carried out from satellites. SERC groups have an internationally renowned expertise in this field. Secondly, the problems require a profound understanding of the underlying basic physics, chemistry and mathematics followed by a complex synthesis of these basic processes into a highly interactive, coupled system exhibiting many feedback channels.

The ozone 'hole' phenomenon

To illustrate the complexity of the Earth's climate system, and indeed its global nature, figure 1 shows a diagram of the major processes at play. The whole system is driven energetically by the Sun, and the incident flux of solar radiation is shared between the atmosphere, clouds, and the surface in a complex and somewhat variable way. Processes occurring within the atmosphere are important — for example the production of reactive chemicals which make for a fascinating photochemical 'soup' under certain conditions. Some of these give rise to the tenuous layer of ozone located between 20 and 30 km high in the stratosphere, which actually screens the surface from energetic short-wave ultraviolet radiation. Scientists were caught completely unprepared when it was discovered by a group from the British Antarctic Survey in 1985 that vast depletions of this protective layer were taking place annually over Antarctica. That problem, and whether it is worsening or not, is still not completely understood. The Upper Atmosphere Research Satellite (UARS) to be launched in 1991 will make a major study of this phenomenon, using a battery of highly sophisticated instrumentation, important elements of which were produced by the UK. More of this below.

Figure 1 indicates a further aspect of the global environmental system that is not well understood. That is the effect of the world's oceans on the atmospheric climate. We do know, for example, that the oceans take up a good deal of the incoming solar radiation, by direct absorption. We also know that the global redistribution of the energy that arrives predominantly at low latitudes is carried out roughly equally by the oceans and by the atmosphere.

The flux of heat, latent heat, moisture and momentum from ocean to atmosphere is also important. However, we are a long way from achieving an acceptable quantitative descriptive model of this interface, despite considerable work by scientists in many countries, including the UK. The European Space Agency (ESA) has pinpointed this particular area as the focal theme for their first European Remote Sensing satellite, ERS-1, which will be launched late in 1990 or early in 1991. This satellite will carry an assembly of powerful radar systems for studying the ocean surface. It will also carry a new instrument developed by the UK, with help from Australia and France, for measuring the temperature of the ocean surface with unprecedented accuracy. The picture on the back cover shows a global temperature map obtained from existing satellite systems which, though having fairly poor absolute accuracy, indicates the complicated temperature structures that occur across the Pacific Ocean, structures which are quite variable from year to year, and which drive the climate on a near-global scale, giving rise to often severe climatic events such as 'El Niño' — a climatic event in the tropical Pacific in which the normal West-East equatorial gradients of surface temperature are disturbed, leading to quite severe weather fluctuations as far afield as Australia, Indonesia and California.

Along with the vital development of better ways of observing our global environment, accurately and precisely, it is important to recognise some other aspects of the problem. First, we need to develop the data systems which are going to be able to store, and provide efficient access to, the new global data sets which we will be providing, not only from space but also from all other useful sources (such as surface observations). Secondly, we need to provide the human resources that are required not only for the observation, and the data processing, but for the interpretation, modelling and understanding. The subject is highly interdisciplinary, and we must ensure both that new scientists are brought into the field, and that institutions are organised to allow disciplines to work easily beside and with each other. These developments, balanced between observations, data handling and interpretation, require increased funding over present levels, and require (just as importantly) coordination of our mechanisms for funding and carrying out research. Support for Earth observation is shared between SERC, the Natural Environment Research Council, the Department of Trade and Industry and

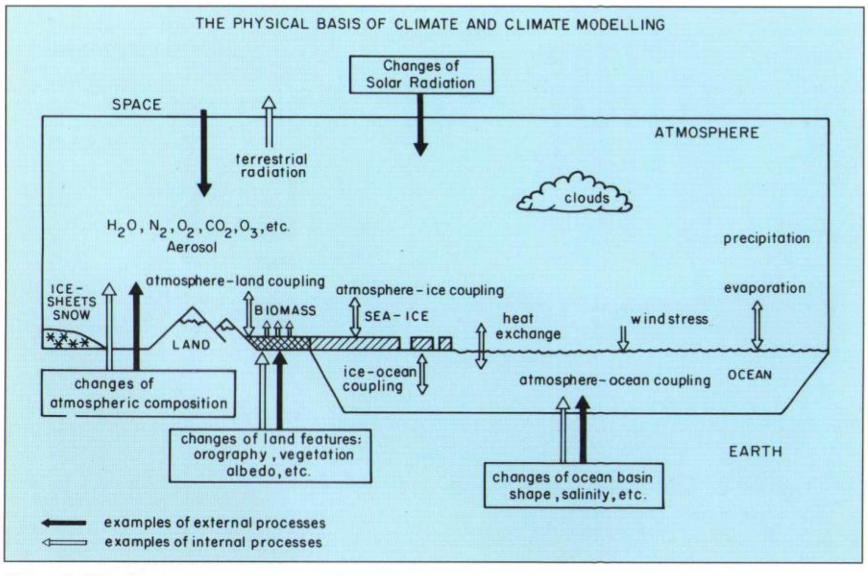


Figure 1: The climate system

the Ministry of Defence and is linked together by the Earth Observation Board of the British National Space Centre.

SERC is currently funding some very exciting and progressive projects — new satellite sensors that are being developed within SERC in support of international programmes.

Upper Atmospheric Research Satellite

The stratospheric ozone problem, as we have mentioned, will be attacked vigorously by the UARS project. This is primarily a NASA project, but some countries other than the US (notably the UK and France) are making contributions to the instuments flown on board. UARS will carry ten sensors and will measure a wide range of trace gases of direct importance in the ozone problem, plus related parameters such as atmospheric temperatures, solar radiation and particle fluxes. UARS will be large — it will just about fill a Shuttle cargo bay.

The UK will be providing a particularly novel infrared sensor, the Improved Stratospheric and Mesospheric Sounder, developed by a consortium consisting of Oxford University, British Aerospace, Reading University and Rutherford Appleton Laboratory, under RAL management. This sensor will make measurements using the technique of pressure modulated radiometry (PMR), and will rely on Stirling cycle coolers to enhance detector sensitivity. Both PMRs and the coolers are British inventions, developed with SERC support. Also on board will be a largely US instrument called the Microwave Limb Sounder, which operates in the 30-200 GHz region. A UK partnership between Heriot-Watt and Edinburgh Universities and RAL has successfully provided key high frequency (183 GHz) mixer components to the Jet Propulsion Laboratory team that is leading this project. The UK is also involved, in a non-hardware role this time, in the science teams of two of the other projects on board — the Halogen Occultation Experiment (HALOE), and the High Resolution Doppler Imager (HRDI) — and provides scientific expertise in measurement interpretation to those projects.

Figure 2 shows a sketch of the UARS spacecraft, and indicates the position of these four experiments. UARS will provide comprehensive and global data on many of the problems in atmospheric science currently facing us. We must be sure to be capable of exploiting those data when they come.

Along-Track Scanning Radiometer

UK studies of the ocean-atmosphere feedback, from space, are also a major effort. The ERS-1 satellite carries a 'core' payload of radar instruments but, as a result of a Europe-wide competition, two additional experiments are to be flown. One, quite small, is a German radio system for precise positioning. The other is the Along-Track Scanning Radiometer (ATSR), provided by a UK consortium of University College London Mullard Space Science Laboratory, the Meteorological Office, Oxford University, British Aerospace and RAL. Important contributions to the hardware have also come from Australia and France.

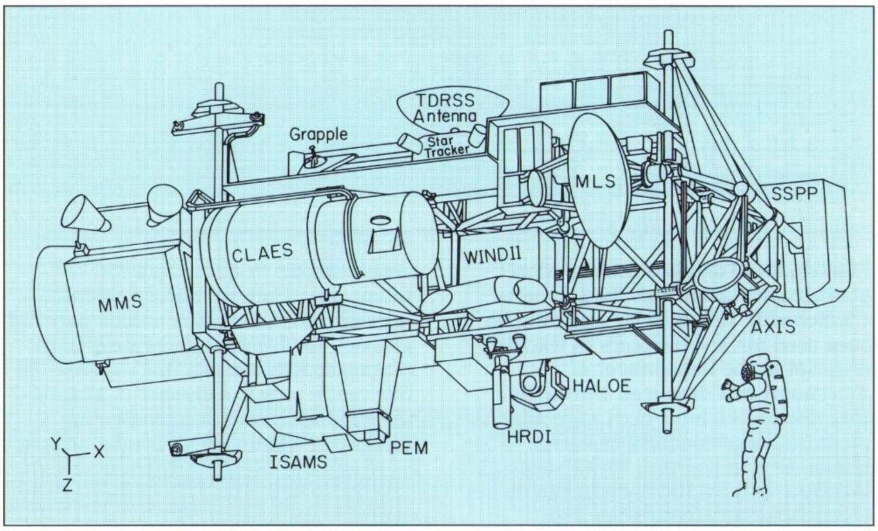


Figure 2: The Upper Atmosphere Research Satellite, showing the Improved Stratospheric and Mesopheric Sounder (ISAMS); Microwave Limb Sounder (MLS); Halogen Occultation Experiment (HALOE); and High Resolution Doppler Imager (HRDI).

ATSR is quite simply the most accurate infrared radiometer ever to be put into space (as has been confirmed now by our programme of laboratory tests), and will make measurements of the global ocean surface temperature to something like ±0.2 to 0.3°C in absolute temperature. It will also provide data on cloud distributions, temperatures and types. It can easily be seen that such data provide an important basis for a global climate model. Current plans within ESA recognise the fundamental importance of these measurements and call for a second ATSR to fly on the follow-on mission, ERS-2, to provide data continuity for global climate researchers.

In addition, British groups have strong interests in studying the data on ocean surface topography to be provided by the radar altimeter on board ERS-1; these data can be interpreted in terms of ocean dynamical phenomena. Researchers will also be interested in surface wind and wave data from the other radars on board. Figure 3 shows a view of the ERS-1 satellite, with the ATSR instrument in place.

The future

What of the future? Based on the excellent track record of UK groups, only some of which have been described here, both NASA and ESA have made their preliminary selections for instruments to fly on their polar platforms from about 1997 onwards. In those selections, UK groups were wholly successful, and currently there are at least five proposals for involvement in important new projects. These will study new aspects of ozone photochemistry, of atmosphere dynamics, and ocean-atmosphere interaction.

Global environmental problems are increasing in importance. Our children and grandchildren will find it amazing if today we are unable to order our priorities properly to give global environmental research a much larger part of our R&D budgets. They will also be heavily involved in trying to overcome the difficulties, and possibly disasters, that could be averted if we tackle the problems now, and with full commitment. It is exciting to realise that the problems we face also demand excellent science, and excellent science is what the UK is seeking to do, with support from the SERC.

Professor J E Harries
Rutherford Appleton Laboratory

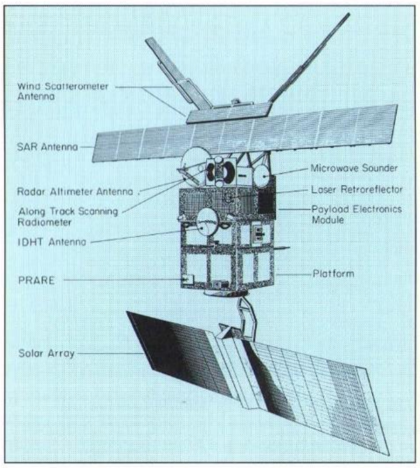


Figure 3: The European Remote Sensing Satellite, showing the Along-Track Scanning Radiometer.

Edinburgh astronomy teaching packages

Film copies of original astronomical photographs taken with the 1.2 metre UK Schmidt Telescope in Australia have been used for several years as teaching material in the Department of Astronomy of Edinburgh University. Two sets of film have been selected and made into teaching packages with accompanying booklets which suggest exercises suitable for undergraduate use. Other films have been made into packages which are mainly designed as visual aids for use by schools, colleges and amateur groups. These packages can all be purchased from the Royal Observatory, Edinburgh, writes Sue Tritton of ROE.

The UK Schmidt Telescope

The UK Schmidt Telescope (UKST), at Siding Spring Observatory, Australia, produces the finest wide-field photographs of the sky and has been used to carry out various surveys of the southern skies in different coloured light. The original photographs are taken on glass and these are reproduced on film and distributed to observatories all over the world. The copies are made with extreme care so that every detail on the original is retained and these copies therefore represent the highest quality research material. Each photograph is 356 x 356 mm and covers an area of sky 6.5° x 6.5° (about 150 fullmoons). Each photograph records between 100,000 and one million stars and galaxies; the faintest objects are of 23rd magnitude which means that stars like the Sun can be seen to a distance of a hundred thousand light years and galaxies to a distance of a thousand million light years.

The UKST also takes photographs, on request, for the individual research projects of astronomers in the UK and worldwide. Some of these photographs are taken with an objective prism fitted to the telescope. This means that the image of each star or galaxy is stretched out into a tiny spectrum. The dispersion is very small but the dominant features can be seen easily and different types of stars recognised. It is also possible to identify quasars from their peculiar emission-line spectra. Some of these photographs have also been reproduced on film.

The packages

In recent years selections of films have been made available to universities, colleges and schools for use as teaching aids. Unlike much of the material currently available to students, which is specially made for laboratory use, these films are identical to those in use by professional astronomers for their own advanced research projects.

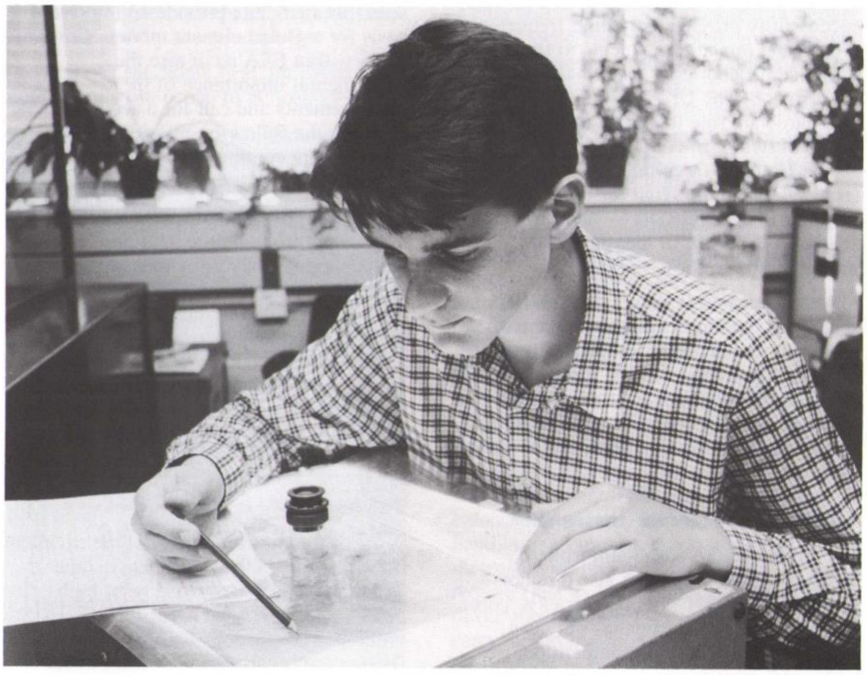
The films intended for university use have been carefully selected so that different exercises can be carried out; some exercises are elementary and can be completed by first-year students in one session while others are suitable for longer or more advanced projects. Some of the simpler exercises have been done as final-year school projects. The only equipment required for most of the exercises is a millimetre ruler, a light box and a hand lens (preferably fitted with a graticule).

The films include examples of many different astronomical objects ranging from asteroids and comets to galaxies and quasars. Much of the research carried out by professional astronomers using UKST plates involves measuring dimensions of features, counting numbers of objects and classifying objects; the exercises in the packages also involve measuring, counting and classifying. A few of the possible exercises are described here.

The Solar System

Two of the simplest exercises involve asteroids and comets. Asteroids are in motion relative to the background stars and result in trails rather than dots on the photographs. From the length of the trails

The filaments seen in this photograph are the remains of a supernova explosion which took place in the constellation Vela 12,000 years ago. Measurements made using this photograph and data obtained from radio observations can enable linear dimensions of the shell to be calculated.



Nicholas Riley completes an exercise using a film copy from one of the Educational Packages for Schools

New era for six-pips time signal

From 5 February 1990, the BBC took over the responsibility of originating the famous 'pips' time signal from SERC's Royal Greenwich Observatory (RGO). The pips were first supplied to the BBC at the request of the then General Manager John (later Lord) Reith on 5 February 1924. The last pips to be generated from the RGO were at 13.00 and the first by the BBC at 13.15.

The handover was marked by a special ceremony at RGO, during which Duncan Thomas, Director of Radio Resources at the BBC, presented Professor Alec Boksenberg, Director of RGO, with a model microphone, and Professor Boksenberg presented Mr Thomas with a phonic motor. In addition, Tony Seabrook, who for 20 years looked after the Time Department apparatus at RGO, received a radio-controlled clock.

The accurate determination of time has been an important part of the work of RGO since its foundation by Charles II in 1675. Until the late 1950s, precise timekeeping was done by making astronomical observations of the Earth's rotation about its axis, but now hundreds of atomic clocks working in an international programme provide a more uniform timescale for scientific and technical purposes. This timescale also has important commercial and navigational uses.

As it is not the most appropriate base in the UK for the further development of this kind of work on timescale standards, RGO no longer takes part in this programme. However, RGO will continue its programme of the precise measurements of the Earth's rotation using its Satellite Laser Ranger, which remains based at Herstmonceux although the rest of the Observatory has now moved to Cambridge. One object of these measurements, which are also associated with several international programmes, is to relate the time of day as defined by the Earth to the readings of the atomic clocks. This establishes the composite timescale for general use that is usually known as Greenwich Mean Time (GMT).

At the handover ceremony: Duncan Thomas (left) and Alec Boksenberg with, in the background, Tony Seabrook and SERC Chairman William Mitchell.

Astronomy teaching packages continued

the distances of the asteroids from the Sun can be easily calculated (assuming circular motion and using Kepler's third law). Films of Comet West and Comet Halley are provided and one exercise is to show that the comets' tails point away from the Sun and to calculate the length of the tail.

Galactic objects
Films are provided which show typical constituents of the Milky Way such as star clusters, dark clouds and reflection nebulae. The apparent dearth of stars in some areas of the Milky Way is caused by the light of stars behind being obscured by clouds of small dust particles. By counting the numbers of stars inside and outside the areas of a cloud, it is possible to calculate the fraction of light being removed and to estimate the total number of dust grains in the line of sight and hence the mass of the cloud. The Vela Supernova Remnant happens just to fill one photograph; the linear dimensions of the shell and the displacement of the pulsar (the remains of the star which exploded 12,000 years ago) can be calculated.

Films taken with the objective prism of part of the Milky Way and an area of sky far away allow classification of stars into the main spectral classes. Comparing the results from the two areas shows that the population of stars is quite different in the two directions.

Extragalactic
Films of clusters of galaxies provide many exercises. One is to classify the galaxies according to the 'tuning fork' scheme which distinguishes elliptical from spiral galaxies. The diameters of the galaxies can be measured and estimates made of their linear dimensions. By counting the numbers of background galaxies in an area away from the cluster it is possible to estimate the number of galaxies in the cluster and the total mass of the cluster.

Of course, these films have been used by many students and also by professional astronomers and one might think that everything of interest has already been found. But each film contains several hundred thousand stars and galaxies and much of interest remains to be discovered. It may well be a keen-eyed student who notices that one of the small black images is peculiar. The image may turn out to be a new kind of star, a very close asteroid or the most distant quasar yet discovered.

There are, at present, three different packages available. Two packages, the Edinburgh Astronomy Teaching Package for Undergraduates and the Edinburgh Astronomy Spectroscopic Teaching Package are primarily intended for university use. The Edinburgh Astronomy Educational Packages for Schools (five separate packages are available) are mainly designed as visual aids for use in colleges, schools or by amateur groups.

Leaflets giving fuller details of the various packages, including details of the films included, brief descriptions of the suggested exercises and the costs can be obtained from the UKST Unit, ROE.

S B Tritton
Royal Observatory, Edinburgh

Eurogam agreement signed

The world's most sensitive gamma-ray detector for unravelling the secrets of nuclear matter is to be built jointly by teams of UK and French scientists.

On 27 February Professor William Mitchell, Chairman of SERC, and Professor Pierre Lehmann, Director of Particle and Nuclear Physics at the Centre National de la Recherche Scientifique (CNRS), signed a £5 million agreement which recognises the current interest in the development of facilities for gamma-ray spectroscopy in Europe. The agreement provides for the development, construction and utilisation of a gamma-ray detector array, Eurogam, and is a dual investment by SERC and the Institut National de Physique Nucleaire et Physique des Particles (IN2P3) of CNRS.

The proposed array will be at least two orders of magnitude more sensitive than any of the current arrays in Europe or elsewhere. For UK scientists this represents the culmination of almost 10 years of development work in gamma-ray spectroscopy carried out by Daresbury Laboratory in collaboration with Liverpool University.

Professor Mitchell said that, in addition to Eurogam's key scientific role in studying the limits of stability of nuclei, it would be an interesting and new way of working, to have a medium-sized piece of equipment shipped between two sites where complementary studies were to be undertaken. The host machines at those sites would continue to be at the forefront, and he expected strong collaborations to be developed between UK and French scientists.

The first phase of Eurogam will be ready in the late summer of 1991 and will be sited at Daresbury for 12 months; when combined with the Daresbury accelerator and recoil mass spectrometer, it will offer unique experimental opportunities to nuclear structure scientists.

This radically new device will study the most exotic forms of nuclear matter including the superdeformed 'nuclear pulsars', first discovered in 1986 by Liverpool and Daresbury scientists. Other areas of study, in which Manchester and York Universities are among the world leaders, will include measurements on nuclear processes taking less than a pico second and the investigation of the properties of the rarest radio isotopes existing at the very limits of nuclear stability.

The Eurogam array will have built up to its full complement of 70 detector systems when, for its second year of operation, it moves to the Vivitron, a new accelerator being constructed on revolutionary principles at Strasbourg. At Strasbourg, Eurogam is confidently expected to make an ever-growing impact on the future of nuclear physics.

Professor Alan Leadbetter, Director of Daresbury Laboratory, and Professor Peter Twin of Liverpool University, Chairman of SERC's Nuclear Structure Committee, said at the ceremony that they were delighted at the opportunity that this agreement provided to ensure that the UK physics community remained firmly at the forefront of research in gamma-ray spectroscopy.

The Eurogam project will be financed by Britain and France alone but it is intended to encourage nuclear physicists from all over Europe to participate in the research programmes. The project is seen as part of the continuing renaissance in European sciences based on international collaboration. The British and French scientists involved see this *entente cordiale* as leading to a major step forward in gamma-ray spectroscopy and hope that it will provide a springboard for even greater advances in the future.

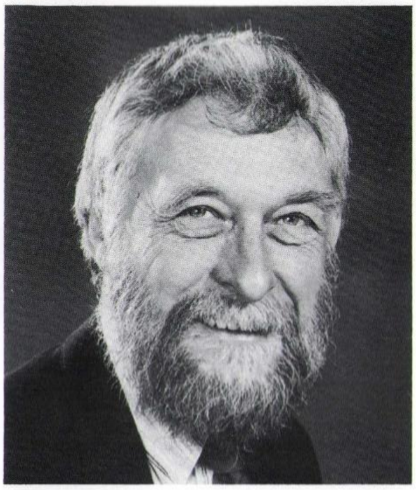
Professor Mitchell (seated left) and Professor Lehmann shake hands. Standing (left to right) are Professor Leadbetter, Dr William Gelletly, Head of the Nuclear Structure Facility, Daresbury, Dr David Thomas, Head of SERC's Nuclear Physics Division, Professor François Kourilsky, Director General of the CNRS, Professor Alexander Donnachie, Chairman of SERC's Nuclear Physics Board, and Professor Twin.

UK-Japanese research project

SERC and the Japanese Research Development Corporation (JRDC) formally exchanged letters in March in acknowledgement of the agreement reached between the JRDC and the Imperial College of Science, Technology and Medicine and Cambridge University to collaborate on a joint programme of research entitled ***Atom arrangement: design and control for new materials.***

Financial support previously supplied by SERC to the two UK universities has contributed to their ability to participate in the project.

SERC Chairman Professor Mitchell believes that the proposed joint research programme will contribute both to scientific research in this area and to the development of scientific cooperation between Japan and the UK.



Dr Roger Burdett

New Industrial Affairs Unit set up

SERC's commitment to academic/ industrial collaboration can be seen by the number of tailored schemes which it has devised. These include Cooperative Awards in Science and Engineering (CASE), Cooperative Research Grants, Industrial Fellowships, Teaching Company Schemes, Integrated Graduate Development Schemes and LINK Programmes.

In an attempt to coordinate SERC's interactions with industry better and provide a first point of contact (especially for small and medium-sized enterprises), SERC has set up an Industrial Affairs Unit.

The new unit, which has absorbed the activities previously carried out by the SERC LINK Unit, is led by **Dr Roger Burdett**, who can be contacted at SERC Swindon Office, telephone (0793) 411173.

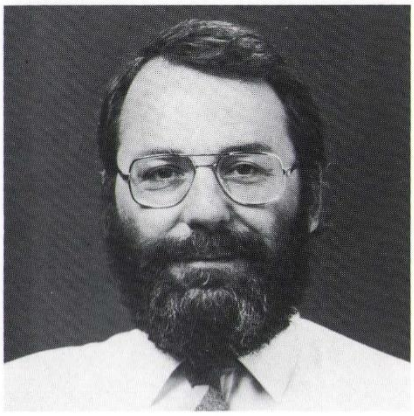
Coordinator for Nonlinear Optics Initiative

Professor Peter Knight has been appointed Coordinator for the Science Board's Nonlinear Optics Initiative. For an average of two days a week Peter will dedicate his time to the promotion of the nonlinear optics research base within the UK, building on the founding work of the previous Coordinating Panel of which he was a member. Among his many tasks will be the discussion of proposals with investigators and the encouragement of appropriate collaborative projects.

Professor Knight holds the Chair of Quantum Optics at Imperial College; his current research interests lie in theoretical aspects of non-classical light, squeezed light and quantum effects in atom-field interactions, and also in the theory of multiphoton processes in ultra-intense laser fields. He is Chairman of the European Physical Society Quantum Electronics Division; editor of the *Journal of modern optics*; review editor of *Contemporary physics*; and advisory editor of Cambridge University Press *Studies in modern optics* and *Monographs on atomic physics*.

The Nonlinear Optics Initiative was established by the Science Board in 1987 and is supported jointly by the Board, the Physics Committee and the Materials Science and Engineering Commission, and at present it has an annual commitment of around £2 million. The Initiative aims to encourage and strengthen work in the two complementary areas of the underlying physics of miniature all-solid-state (holosteric) lasers and the novel physics arising from the application of laboratory-based laser systems.

Scientific queries regarding the NLO Initiative should be addressed to:



Professor Peter Knight

Professor Peter Knight, The Blackett Laboratory, Imperial College,
Prince Consort Road, London SW7 2BZ
Telephone 071-225 8842;
Fax 071-589 9463.

Any administrative and general questions may be addressed to: Dr R A Innes, Secretary, Nonlinear Optics Initiative, SERC Swindon Office
Telephone (0793) 411441.

Some new publications from SERC

Unless otherwise stated, all publications are available free of charge from SERC Swindon Office, telephone (0793) 41 + extension number.

Biotechnology
Copies of the Biotechnology Directorate's *Town Meeting report* and the latest issue of the *Biobulletin* are available from Sheila Blakeman, ext 1495.

ACME Directorate
Copies of the following publications are available from Gay Ford, ext 1106: *ACME annual report 1989; Report of the Nottingham Workshop: CAPM reference models derived from control theory concepts*; *Proceedings of the CAPM Supply Industry Research Conference*; *ACME Newsletter*, issue 16.

Materials
The following publications are available from Jane Sullivan, ext 1435: *Announcing the new SERC Materials Science and Engineering Commission*; *Synthesis and evaluation of materials for the 21st century*; and *MSEC grants awarded 1988-89*.

Physics
Copies of *Highlights in physics* and the nonlinear optics newsletter *NLO update* are available from Dr Robert Innes, ext 1441.

Nuclear physics
Copies of the *Nuclear Structure Committee report 1988-89* are available from Tracey McGuire, ext 1008.

Biological sciences
Copies of *Biological Sciences Committee themes* are available from Dr Steve Milsom, ext 1136.

Five winners visit LEP

Five secondary-school students enjoyed an all-expenses paid trip to CERN, the European Laboratory for Particle Physics, to see the Large Electron Positron Collider — the largest scientific machine in the world — as a prize for winning entries in a SERC-sponsored competition. The winners, who come from Northern Ireland, Scotland, Wales and two from England, visited CERN on 23 and 24 February. The expenses of one parent or guardian were also paid.

The competition, run in collaboration with the Institute of Physics's publication for physics teachers, *Snippets*, was to write a letter to the Chairman of SERC, Professor William Mitchell, outlining why they would like to visit CERN, and what effects the Large Electron Positron Collider would have on the advancement of science.

Commenting on the competition, Professor Mitchell said: "The quality of all the entries was very high and exceptionally so in the case of the winners. I and my fellow judge had much difficulty in separating two winners from the runners-up and as the quality of the entries was so good we decided that the runners-up should also have a trip to CERN. In these days when science seems to be struggling for survival, these entries show science is alive and kicking in our schools."

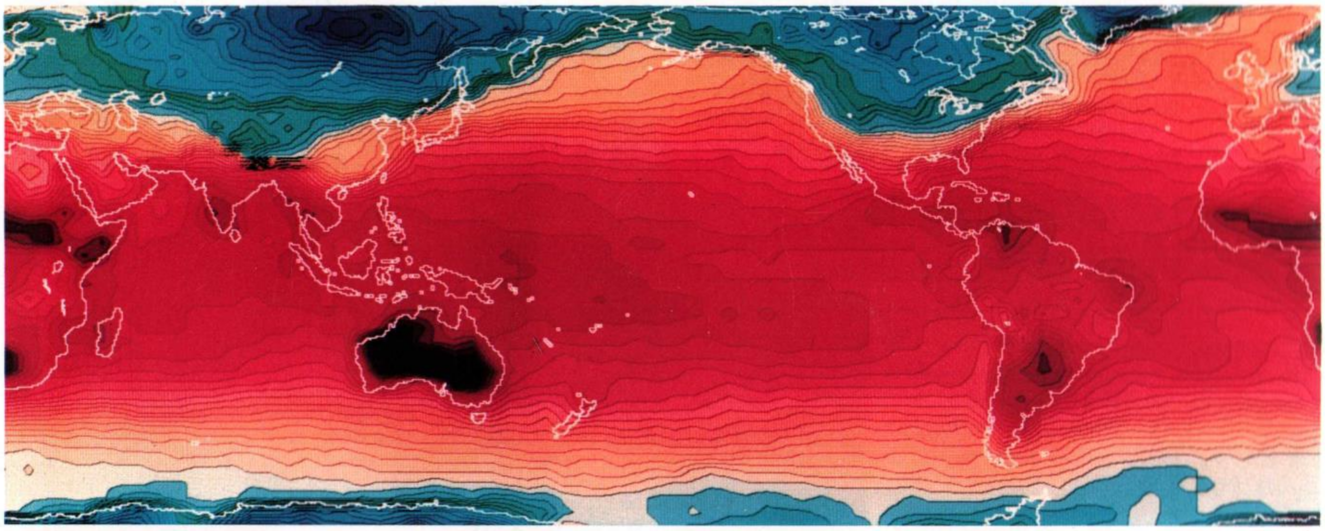
All entrants received a year's subscription to *Physics world* — the IOP monthly journal — and a copy of the book *Particle explosion*. In addition, the prizewinners each received £100 for books.

The joint winners were 16-year-old Eithne Mitchell from Loreto College, Coleraine, Co Derry, and 16-year-old Gareth Leyshon from the Craig Comprehensive School, Pwll, Llanelli, Dyfed. The three runners-up who also visited CERN were: Charlotte Hepworth (16), King's High School for Girls, Warwick; Nigel Morton (17), Daniel Stewarts and Melville College, Edinburgh; and Anna Stacey (18), North London Collegiate School, Edgware, Middlesex.

The party had lunch with Dr John Thresher, one of CERN's Directors of Research, and Nobel Prizewinner Professor Jack Steinberger and were taken on a tour of LEP by CERN physicists. They visited two of the three gigantic underground experiments — DELPHI and ALEPH — in which the UK is playing a major part.

The prizewinners in the LEP tunnel at CERN.

Earth observation and the global environment



A global temperature map, which shows the complicated sea surface temperature structures that occur across the Pacific Ocean. Existing satellite systems give fairly poor absolute accuracy, but a new instrument for measuring the temperature of the ocean surface with unprecedented accuracy will be launched in late 1990 or early 1991, aboard the first European Remote Sensing satellite (ERS-1), described on page 26.