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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; price £6.00) 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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RGO stone-laying

On 27 October 1988 Robert Jackson MP, Parliamentary Under Secretary of State in the Department of Education and Science, laid the foundation stone for the new Royal Greenwich Observatory (RGO) building at Madingley Road, Cambridge.

Professor Alec Boksenberg, director of RGO, welcomed representatives from SERC and guests from Cambridge University and the astronomical community to the site, next to the existing Institute of Astronomy (IoA). He stressed the importance of the event in the distinguished history of the RGO, reflected on the Observatory's recent achievements and looked forward to a long and fruitful association with Cambridge. Mr Michael McCrum, Vice Chancellor of Cambridge University expressed the University's pleasure in welcoming RGO to Cambridge, and Professor Bill Mitchell, Chairman of SERC, stressed the importance of this co-location.

Mr Jackson revealed that he was a great-nephew of the late Sir Richard Woolley, past Director of RGO and Astronomer Royal, thus making his presence doubly appropriate.

Footnote

A few days before the stone-laying ceremony came the announcement that the sale had been agreed by SERC of Herstmonceux Castle and estate to James Developments. The company hopes to introduce a leisure scheme with a scientific background at the site, which has been the home of the Royal Greenwich Observatory since 1948. The final move of the Observatory to the Cambridge site is not due to be completed until 1990.

The Science Minister, Robert Jackson MP, laying the foundation stone for the new RGO building at Cambridge.

US Government honours IUE scientists

Six space research scientists working at Rutherford Appleton Laboratory were honoured in November 1988 by the US Government for their work on the outstandingly successful International Ultraviolet Explorer (IUE) project. The Explorer astronomical observatory was launched into geosynchronous orbit at about 22,300 miles above the Earth in 1978 (see *SERC Bulletin* Volume 3 No 10, Spring 1988). Its design life was supposed to be between three and five years. But more than ten years on it is still producing valuable scientific data on the stars, nebulae and galaxies and how they develop.

The project was one of ten winning designs selected from over 500 entries for the coveted US Presidential Design Awards. The awards were set up in 1984 by President Reagan and are held every four years. Their purpose is to recognise design excellence in various fields of US federal design, ranging from architecture and graphics to engineering and product design.

The RAL scientists were among an eight-strong SERC team which collaborated on the project with the European Space Agency and NASA. The SERC Project Director was Professor Robert Wilson of University College London, and the Project Manager was Peter Barker of RAL.

Front cover picture shows (left to right):

Michael Sandford, Peter Vaughan, Eric Dunford, Harry Bevan and Jim Hall of the IUE team. (Photo: Oxford Mail).

Council commentary

Biotechnology review

A review of the SERC Biotechnology Directorate, carried out for the Council by a Biotechnology Review Panel chaired by Professor Tom Blundell FRS, was discussed in November. The Council accepted the main recommendation of the Panel, that SERC should continue to support biotechnology through a separate Directorate for a further six years, until 1995. The Panel considered that biotechnology research was at a critical stage and that further developments of the active underpinning of industrial possibilities still needed fostering by the Directorate approach through the higher education institute/ industry 'clubs'.

It was also agreed that SERC should work towards closer links on biotechnology with the Department of Trade and Industry by the formation of a joint advisory structure.

The ten Review Panel members represented a wide range of expertise in biotechnology from industry, universities and government. Companies represented were ICI and Celltech, and the academics were from Birkbeck College and University College London, Leicester, Birmingham, Cambridge and Warwick Universities. The Laboratory of the Government Chemist and Imperial Cancer Research Fund were also represented. The report is to be published shortly.

ESPRIT II: boost for the academic community

The Council welcomed the significant increase in the participation of UK academics in the second phase of ESPRIT. The UK academic share rose from 10.6% (15.5 million ECU) in ESPRIT I to 19% (26.6 million ECU) for ESPRIT II's first call for research proposals.

Considerable use was made of the Joint Research Councils' Brussels Office (see page 22).

Review of CASE scheme

A review of the operation of the Cooperative Awards in Science and Engineering (CASE) scheme by the Technical Change Centre was discussed by the Council. One of the major recommendations of the Centre was that the industrial contribution to the academic department involved in a CASE studentship should be increased by around 50%, and that a payment to the student should be made mandatory. The Council agreed to give the report further consideration and to consult further.

Additional £3 million for equipment

The Secretary of State for Education and Science announced on 2 November 1988 an additional £3.05 million for SERC expenditure on equipment in the current financial year. These funds will be used to bring forward planned projects on the Rutherford Appleton Laboratory and Daresbury Laboratory mainframe computers and also for equipment on the spallation neutron source (ISIS) and William Herschel telescope. The same amounts will be deducted from future budgets of establishments and used to support equipment on research grant projects.

Membership of ESRF

Negotiations for full UK membership in the European Synchrotron Radiation Facility (ESRF) at Grenoble have been completed, the payments up to 1992 having been agreed. A tripartite agreement has been signed with France and West Germany on the phasing of the UK payments up to 1992 to accommodate the increase in the subscription level from the current 10% level.

Visit by Hungarian scientists

A party of ten Hungarian scientists led by Professor Marta, Vice President of the Hungarian Academy of Science, recently visited and held discussions with staff at the Daresbury and Rutherford Appleton Laboratories.

LINK grants approved

Four grants under the Government's LINK programme in Selective Drug Delivery and Targeting were approved by the Council in October 1988.

The programme involves SERC, the Department of Trade and Industry, the Medical Research Council and 11 pharmaceutical companies contributing a total of £1 million over four years.

The grants awarded were:

Professor R J Flower *et al*, Bath University: *Recepto-medicated transport processes and drug targeting* £397,100 over three years;

Professor M Rowland, Manchester University: *Pharmokinetics of selective drug delivery and targeting* £394,300 over four years;

Professor C R Hopkins *et al*, Imperial College of Science and Technology: *Identification of transcellular routes for hydrophyllic macromolecules in polarised monolayers of enterocytes* £353, 400 over four years;

Dr B H Hirst *et al*, Newcastle-upon-Tyne University: *The gastrointestinal epithelia barrier: a research centre* £519, 600 as a special grant over four years (plus overheads).

UK to stay in CERN

The Secretary of State for Education and Science announced on 15 December 1988 that the UK intended to remain a member of CERN, the European laboratory for particle physics at Geneva.

Professor Bill Mitchell, Chairman of SERC and the UK delegate to the CERN Council, announced the Government's decision to the CERN Council at its meeting the same day. A year previously, he recalled, he had announced that the UK would remain in CERN while discussions took place about implementation of changes recommended by the CERN Review Committee, which it was hoped would lead to a substantial reduction in the cost of UK membership and to improvements in the management and general cost-effectiveness of CERN. Since then, a new and fairer method of assessing Member States' contributions had been agreed and an 'early departure' scheme had been instituted. With these and other improvements, said Professor Mitchell, the UK Government considered that the right conditions now existed for UK scientists to continue in partnership with their European colleagues in the CERN scientific programme. In particular, the UK believed that the LEP project (which begins operation this year) represented an exciting leap forward in particle physics and will set new world standards.

The most immediate impact of the changes that have been agreed at CERN will be on the cost of the UK's annual subscription. This will reduce in 1990 by about £10 million (almost 20%) from the current high of almost £55 million. The early departure scheme will assist in achieving a reduction of 200 CERN staff posts by 1990, and a total reduction of nearly 20% in the complement to below 3000 by the mid-1990s. Savings of about 30 million Swiss Francs a year will feed through into the budget once the costs of the scheme are covered by the gross savings.

Superconductivity IRC opened

The Secretary of State for Education and Science, Kenneth Baker MP, opened the Interdisciplinary Research Centre for Superconductivity at Cambridge on 16 November 1988. The Centre is the first of a new generation of multidisciplinary research units which focus on strategically vital areas of science (see *SERC Bulletin* Volume 3 No 11, Summer 1988).

Funded by a £5.3 million SERC grant to be paid over the next six years, the Centre will receive further support from industry in the form of staff and equipment. It is currently housed at the Cavendish Laboratory in West Cambridge, where additional space is available for projected expansion. The new Centre will take up over a third of the total SERC budget for superconductivity research and will play a central role in the future of British development in the field, a field where, as Mr Baker pointed out in his opening speech, UK scientists had been quick to recognise the opportunities. The Chairman of SERC, Professor Bill Mitchell CBE, FRS, welcomed the new centre, which is expected to have a 'life' of ten years:

"The Cambridge High Temperature Superconductivity IRC is the first of five that have been established by SERC in 1988 and the Council is in active discussion with higher education institutes to set up a further seven in 1989. That this IRC was set up so quickly, in response to a perceived need, is a tribute to the staff at both Cambridge and SERC. I am confident that this IRC will make a major contribution to the research effort in what is an area of key importance to the UK."

Dr Peter Duncumb and Dr Ekhard Salje accompany the Secretary of State on his tour of the new Centre.

In reply, the Director of the new Centre, Dr Peter Duncumb FRS, said: "Our aim is to unite in one programme the wide range of skills which exist across the University, as well as linking with other centres of excellence and working with them."

Superconductivity research has received a major boost in the past two years with the discovery of high temperature superconductors. Perfect electrical conduction can now be achieved at liquid nitrogen temperature; liquid nitrogen is cheap and, with a boiling point of -196°C, easy to handle. As Mr Baker said: "This research is still in its infancy. The Centre will have plenty of exciting science and technology to pursue in the next few years, with the prospect of room temperature superconductivity a possibility in the more distant future."

The other IRCs set up in 1988 were: Engineering Design (based at Glasgow University); Surface Science (based at Liverpool University); Molecular Science (based at Oxford University); and Novel Materials and Semiconductors (based at Imperial College of Science and Technology).

Engineering Design IRC grant announced

A grant from SERC of £6.3 million to create the UK Interdisciplinary Research Centre (IRC) in Engineering Design based at the University of Glasgow began on 1 December 1988.

The Director is Dr Bernard Capaldi, formerly with the Manufacturing and Product Design Division of P-E Inbucon Group and founder of Berric Systems Design Ltd. He will be responsible for the Centre's research programme to a Management Board chaired by Lord Weir and drawn from SERC, industry and the academic community.

The Centre, which will have a threefold structure for research, industrial projects and education and training, will be based at Glasgow University as host institution for a Scottish consortium. Research groups and facilities will also be based at the other members of the consortium, namely Heriot-Watt and Strathclyde Universities, Paisley College and at the Napier Polytechnic of Edinburgh. A comprehensive distributed computer network will be used to maintain close links between the Centre and the satellite design groups and with major industrial partners, giving the members of the consortium an unrivalled capacity for advanced engineering design work.

The importance of good engineering design to the UK economy can hardly be exaggerated and through this Centre SERC aims to create, in close collaboration with industry, a world-class design research facility to help UK manufacturers to succeed in today's intensely competitive world markets. There is an urgent need to reduce the time from first perception of market opportunity to product delivery and to speed the incorporation of emerging technologies in new products. The Engineering Design Research Centre (EDRC) is seen as a vital link in the process of achieving these aims. Funding from SERC will be augmented by support from other bodies and from industry.

Italian spectrometer for ISIS

PRISMA, an Italian-built spectrometer designed for single crystal inelastic measurements, was inaugurated at Rutherford Appleton Laboratory's pulsed neutron source ISIS on 4 November 1988 by Professore Luigi Rossi Bernardi, President of SERC's Italian counterpart, the Consiglio Nazionale delle Ricerche (CNR). Also attending from outside SERC were Dr Fulvio Muzi-Falconi, Chargé d'Affaires at the Italian Embassy in London, Science Minister Robert Jackson, and Lord Glenarthur, Minister of State at the Foreign and Commonwealth Office.

PRISMA (Projetto dell'Istituto di Struttura della Materia) has been designed by British and Italian scientists in the first formal collaboration of its kind to take place at ISIS. The construction costs of the spectrometer — 1,950 million Lire (about £800,000) — were met by the CNR and work took place in Frascati, Italy. The instrument arrived at RAL in June 1987 and by November had been installed on its ISIS beamline.

Measuring phonons and magnons

PRISMA has been designed to measure the vibrational atomic waves (phonons and magnons) in single crystal samples.

The first phonon and magnon measurements were made in the late 1950s on a spectrometer known as the Triple Axis. The name derived from the three independent rotational axes of the crystal monochromator, the sample and the crystal analyser. The Triple Axis design was simple and flexible and extremely successful. It has remained, with certain developments, a standard spectroscopic instrument and is used on a continuous reactor neutron source.

In the past decade, the advantages promised by pulsed neutron sources in achieving higher data rates in neutron spectroscopy have begun to be seriously exploited. But the measurement of phonons and magnons has been widely recognised as the most difficult area in which pulsed neutron sources could advance the existing spectroscopic capability.

A new design

PRISMA is a relatively new type of spectrometer. Only one other similar instrument exists, the MAX spectrometer at the KENS pulsed neutron source in Japan. There is also the Constant-Q at the Los Alamos National Laboratory's pulsed neutron source, LANSCE. Like PRISMA, the Constant-Q is designed for single crystal inelastic measurements, but PRISMA's construction is quite different.

PRISMA is an inverted-geometry inelastic spectrometer. In other words, neutrons of all energies produced by the ISIS target are allowed to strike the sample, but only those that are scattered from the sample with a given final energy are counted by the detector.

Since ISIS produces neutrons in pulses, it is possible to calculate the energy loss or gain made from the sample by the neutrons. This is done by looking at the time of flight of the neutrons from the target through the sample to the detector, together with the final energy.

Analyser crystals

On PRISMA it is possible to select and to vary the final energy of the neutrons to be detected by using analyser crystals. The orientation of these analyser crystals to the scattered neutron beam can be changed to reflect neutrons of different energies.

There are 16 germanium analyser crystals on PRISMA, mounted on a scattering arm which can be rotated about the axis of the sample. Attached to the scattering arm are 16 smaller analyser-detector arms, each with a detector on the end. These smaller arms can also be rotated, in this case about the axis of their respective analyser crystal, to count the neutrons which are reflected out by the crystal. In order to maintain the mirror geometry, the analyser-detector arms have to be rotated when the analyser orientation is changed.

Measurements on PRISMA are taken by rotating the sample so that the incident neutron beam from the ISIS target is parallel to the desired direction in the crystal. The scattering arm, the analyser crystals and the analyser-detector arms are then rotated about their axes to a configuration in which each detector measures the neutrons scattered by excitations along the desired crystallographic direction.

The spectrometer is fully computer-controlled, and the angles of the sample, analyser crystals and detector arms are calculated by the computer simply by entering the desired crystallographic direction for the measurement.

Detecting the first phonons

Since November 1987 when it was installed on its ISIS beamline, PRISMA has been in a development state. The test measurements taken over the first three months were very basic and included testing the detector electronics and measuring background.

However in February 1988, just before the end of the final ISIS cycle of 1987-8, the first inelastic measurement on PRISMA was made using a single crystal of copper. To the surprise and delight of all concerned, phonons were observed at this first attempt.

Encouraged by this success, a major programme of improvements was carried out during the ISIS shutdown between March and May. The development phase has since continued, with further efforts to reduce the background count level on the detectors and to establish a set of control routines to make this sophisticated and flexible instrument simple to use.

A promising start

The early measurements on copper have been repeated and improved upon, and the high quality data have been analysed to yield PRISMA's first phonon dispersion curve. Recently, promising measurements have also been made on crystals of beryllium and potassium tantalate.

Although the speed at which measurements can be made varies from sample to sample, so far it has been possible to map out a dispersion relation along a particular crystallographic direction in less than 12 hours of counting — a much greater rate than has been achieved on either MAX or Constant-Q.

Further test measurements and improvements remain to be carried out on PRISMA but, if these proceed successfully, a full programme of experiments proposed by users from universities and research institutes is expected to begin early in 1989.

Technical specification of PRISMA

Moderator — **Methane at 90 K**
Incident neutron flight path — **9.035 m**
Sample to analyser flight path — **0.573 m**
Analyser to detector flight path — **0.209 m**
Detectors — **16 He 3 detectors, 2 scintillator monitors**
Analyser crystals — **16 Ge crystals using either [1,1,1] or [3,1,1] planes**

D A Gray
Rutherford Appleton Laboratory

The Inter-University Biotransformations Centre

Work began at the new Inter-University Biotransformations Centre in October 1988, with teams of scientists at Kent, Warwick and Exeter Universities. The aim of the centre is to work with industry to exploit the millions of years of evolution which have produced enzymes — natural catalysts far more specific and efficient than man-made catalysts and able to catalyse reactions at much lower temperatures and pressures, thus saving precious energy. The background and work of the Centre are described here by John Newell.

Enzyme transformations

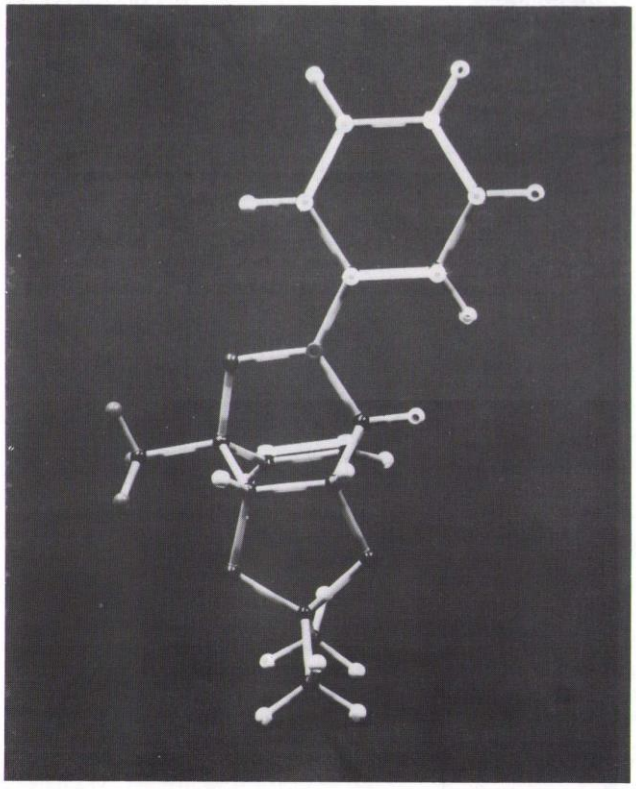
Biotransformations are involved in converting simple compounds to more complex compounds, using living cells or isolated enzymes. Often, it is now becoming clear, the best route for chemical industry to take in making a product is to use conventional synthetic chemistry to make a relatively simple, achiral or racemic compound which is then made into a more complex, homochiral compound by an enzymic reaction. Enzymic reactions are often more attractive to consumers, especially in making food products or cosmetics. Because they work at relatively low temperatures and pressures, they are more energy-economic and safer. Their ability to make optically pure compounds is increasingly recognised as economically valuable.

University scientists' initiative

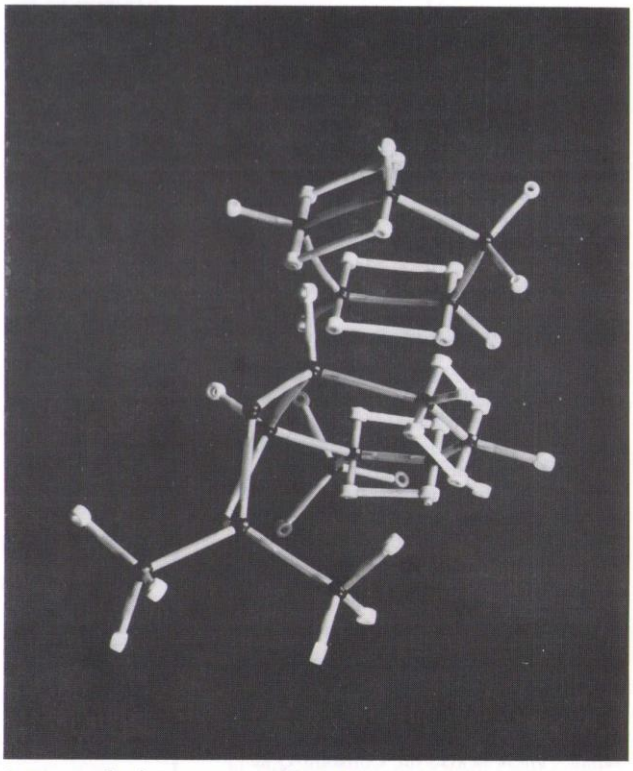
The concept of the Centre was born in 1986 out of discussions between Professors Howard Dalton and David Crout of Warwick University, and Professors Stan Roberts of Exeter University and Chris Knowles of Kent University. Roberts, who had just left Glaxo for an academic post, saw growing interest in industry. Crout saw the potential for enzymes in biosynthesis, especially after his experience in antibiotic synthesis, Dalton in performing selected oxidation reactions and Knowles in the treatment of cyanides. All four scientists saw the interests and expertise of their groups as complementary rather than competitive. They talked to Dr Maurice Lex of the Biotechnology Directorate and Dr Peter Baker of the Department of Trade and Industry (DTI), who were supportive. Out of this timely cooperation, the concept of the Centre was born.

Ten companies in the LINK project

The Biotransformations Centre is the first project to be set up under the LINK Biotransformation programme as part of the Government's efforts to promote collaboration between industry and universities. It is being funded 25% by SERC through the Biotechnology Directorate, 25% by the DTI and 50% by industry. So far, ten companies are involved: Glaxo, Beecham, ICI, Pfizer, Quest International, BP, Shell, Courtaulds, Enzymatix and International Biosynthetics. Several more are showing strong interest. Almost £1 million of funding from Government and industry is already guaranteed, to support the Centre's work for the next three years, roughly in the proportions Warwick £350,000, Kent £300,000 and Exeter £250,000.



A simple benzene derivative prepared by a combination of a biotransformation and a simple chemical reaction.



A more complex derivative prepared from the one shown left by sophisticated chemistry. The reactions illustrate the need for biotransformations and synthetic chemistry to work in harness.

How to participate

There are several different ways in which companies can fund and benefit from research at the Centre. By paying only £15,000 a year they can gain access to the proposed core research programme, in precompetitive areas which will concentrate on several promising projects selected jointly on the basis of university expertise and industry's perception of future markets.

For a further £5,000 annually a member company can have a postgraduate research assistant working on an agreed project. For £10,000 more — an annual subscription of £30,000 — a company gets, as well as access to the core programme, a postdoctoral research assistant working on an agreed programme, the results of which are not open to other companies supporting the Centre.

The core programme

The core programme of research will concentrate in three main areas. One of these involves persuading enzymes to work in low-water systems. In this, studies will be made of the use of lipases for esterification and transamidation, and of oxidases working in oxygen-carrying flourocarbon solvents. Fundamental questions remain to be answered in this area, although the use of enzymes in low-water systems is looking very exciting. The core programme will study novel 'reversed enzyme' reactions in great detail, so as to discover how much water is needed for such reactions to proceed, and whether the fundamental dynamic and structural properties of the enzymes are altered in abnormal conditions.

A second main area of the core programme for the Centre is the synthesis of carbon-carbon bonds. Rabbit muscle aldolases are high on the list for investigation here. The use of enzymes to perform vital syntheses involving the creation of carbon-carbon bonds will involve persuading enzymes to work on unnatural substrates — which they have proved more willing to do than expected — and identifying novel enzymes to perform wanted reactions for which no known enzyme exists. This, in turn, will involve examining biosynthetic pathways in micro-organisms and looking for the key enzyme responsible.

The third main area in the core programme is in novel redox (oxidation and reduction) reactions. One main use for such reactions is in making optically active materials. There is a great and growing demand for homochiral products, which avoid the need for expensive separations of the unwanted optical isomer or the making of useless substances. The demand for homochiral compounds for use as intermediate stages in making pharmaceuticals, pesticides, herbicides, flavourings and fragrances is growing rapidly.

The scientists involved are enthusiastic about British expertise in all these and other areas in biotransformations. Britain can steal a lead in this area, they stress. Now it is vital for more companies to become conscious of the potential value of enzymes in making these products.

Further information about the Centre and the LINK programme may be obtained from the Programme Manager, Dr Mike Turner (telephone 01-387 7050 ext 2493) or Dr Maurice Lex at the LINK Biotransformations Programme Secretariat, SERC Swindon office, telephone 0793 411410.

John Newell
Editor, Biobulletin

Prime movers in the Biotransformations Centre at the launch on 26 October 1988. Standing: Dr D Hutchinson and Professor D Crout (Warwick University); Professor S Roberts (Exeter); Dr M Turner (Programme Manager). Seated: Professor H Dalton (Warwick) and Professor C Knowles (Kent).

Dielectric studies of liquid crystalline polymers

Liquid crystalline polymers which have the mesogenic groups attached as side chains are currently the subject of intense research activity world-wide since they show promise as materials for high-density optical information storage and for non-linear optical processing. Most practical applications require the materials to be films 0.1 to 20 microns thick which have been aligned macroscopically using combinations of electrical and thermal treatments. A simple, direct and unambiguous method, for the determination of the nature and extent of alignment in these novel electroactive polymers, using dielectric relaxation spectroscopy, has been developed by Professor Graham Williams and Dr George Attard, who describe it here.

Comb-like polymers having mesogenic (liquid crystal-forming) groups in the side chains were shown by groups in Mainz and Moscow in the late 1970s to form liquid crystalline (LC) phases. Although films of these materials were shown to be electroactive and magnetoactive in the same sense as low molar-mass liquid crystals, their slow response to applied fields and the fact that they have a glass transition near to, or above, room temperature has precluded their use in dynamic optical LC displays. Instead, new applications have become apparent which take advantage of the property that aligned LC polymer films retain their alignment if the materials are kept well below the LC-to-isotropic liquid transition temperature, or in their glassy LC state. Using suitable electrical/thermal treatments, films of differing macroscopic alignment (and hence of different optical properties) may be prepared. Figure 1 sketches the arrangement of the mesogenic groups in the homeotropic and planar states of alignment. The H-monodomain is optically clear and is the normal starting material for the following applications of these polymers.

Optical information storage

A focused laser beam acting on a homeotropic-monodomain may either (i) melt the material locally, forming a scattering region; or (ii) cause photochemical changes in the polymer (eg in the pendant mesogenic groups); these changes lead to the formation of local regions which are optically dichroic and birefringent. The 'thermorecording' method (i) leads to digital or analogue information storage while the 'photorecording' method (ii) gives digital, analogue or holographic storage. Optical information storage devices may be constructed using either method, and storage densities of the highest levels are achieved, being limited only by the laser-beam dimension and sample diffraction effects. Importantly, the stored information may be selectively erased and updated. Thus, reversible high-density optical information storage with LC polymers is now a reality.

Non-linear optical processing

Incorporation into the polymer chain of pendant groups which possess very large non-linear molecular optical polarisabilities may give LC polymer materials which exhibit large first-order and second-order non-linear optical bulk susceptibilities which rival, or in many cases exceed, those of inorganic non-linear optical materials. In order for a polymer film to exhibit the second-order property, it must be electrically 'poled' in addition to being macroscopically-aligned. Such materials may be used for second harmonic generation of laser light. Third-order materials find applications for third harmonic generation and for degenerate four-wave mixing of laser radiation.

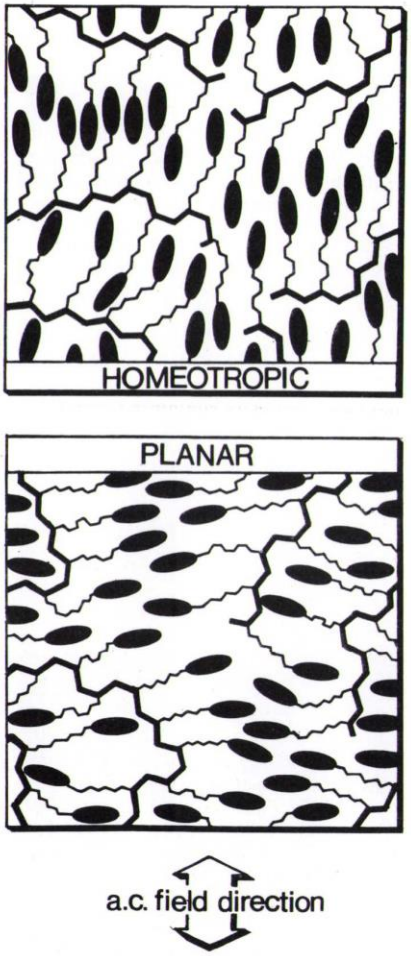


Figure 1: Schematic illustration of the arrangement of polymer molecules in the homeotropic and planarly-aligned states for a LC polymer.

The practical realisation of such applications is dependent on the synthesis of suitable side-chain polymers, and on the ability to form macroscopically-aligned films and to control the alignment. Electric-field-induced alignment is determined by the anisotropic dielectric properties of the LC phase, which are strongly frequency- and temperature-dependent.

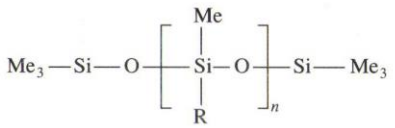
In order to examine the questions associated with alignment behaviour, we set up a study at Aberystwyth, in 1984, of the dielectric properties and the electric-field-induced alignment properties of new siloxane-chain LC polymers which had been synthesised and characterised by Professor Gray and Dr Lacey of Hull University. Our studies were supported by the Electroactive Polymers Specially Promoted Programme of SERC's Materials Committee while the synthesis programme at Hull was supported by SERC's Chemistry Committee.

Our initial studies at Aberystwyth aimed to obtain comprehensive dielectric data for different LC polymers over wide ranges of frequency (10^{-3} to 10^{7} Hz) and temperature, and then to try to align samples in electric fields to form homeotropic, planar and intermediate states of alignment, as predicted by the dielectric data. But how could we determine the nature and extent of the alignment present in a given film? Optical methods are qualitative and ambiguous, the conventional spectroscopic methods of infrared, Raman, ultraviolet/visible and nmr are mostly inappropriate or impractical for LC polymer films sandwiched between indium/tin oxide or metallic electrodes. However, we found that dielectric relaxation spectroscopy itself provided a simple quantitative method for determining the degree of macroscopic alignment of a sample. Furthermore, the

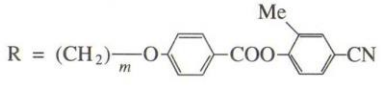
thinner the sample, the greater was the measured complex capacitance of a polymer film, so the dielectric method was ideally suited to the problem.

Dielectric relaxation spectroscopy is a well established method for studying the reorientational motions of dipolar groups in liquids and solids, especially polymeric solids. The complex permittivity $\varepsilon(\omega)$ is dependent on frequency ω, its real part is $\varepsilon'(\omega)$ (the 'permittivity') showing dispersion and its imaginary part $\varepsilon''(\omega)$ (the 'loss factor') showing an absorption peak. For liquid crystalline materials the anisotropy of the phase means that $\varepsilon(\omega)$ is a directional quantity. Measurement of $\varepsilon(\omega)$ parallel to and perpendicular to the direction of preferred alignment (figure 1) yields the principal components $\varepsilon_{\parallel}(\omega)$ and $\varepsilon_{\perp}(\omega)$ respectively and, due to the anisotropic motions of the dipolar mesogenic groups in a LC polymer, these have quite different frequency dependencies. The dielectric anisotropy $\Delta\varepsilon(\omega) = \varepsilon'_{\parallel}(\omega) - \varepsilon'_{\perp}(\omega)$ provides the torque for electric-field-induced alignment such that if $\Delta\varepsilon(\omega) > 0$ then homeotropic alignment is favoured and if $\Delta\varepsilon(\omega) < 0$ then planar alignment is favoured. Thus, if the dielectric properties of an LC polymer have been determined experimentally, it is possible to make predictions with regard to the macroscopic alignment behaviour in directing electric fields.

We have found that the LC siloxane polymer films could be readily aligned by cooling from the isotropic melt into the LC state in the presence of a strong ac or dc directing electric field. Different alignments were obtained by varying the amplitude and frequency of the field (two-frequency addressing principle). As one example, figure 2 shows the dielectric loss spectra for the following siloxane LC polymer:



where $n = 35$ and



with $m = 6$

at 307.2 K prepared in different states of alignment. The homeotropic and planar samples were prepared by cooling the 120-micron film from the melt in the presence of 300V/600 Hz and 300V/10 kHz respectively. Also shown is the spectrum for the non-aligned sample. Since the loss spectra are qualitatively different (but note the isosbestic point!) it follows that if the spectrum of a sample of intermediate alignment is measured, and any two of the three spectra are known as references, then the degree of

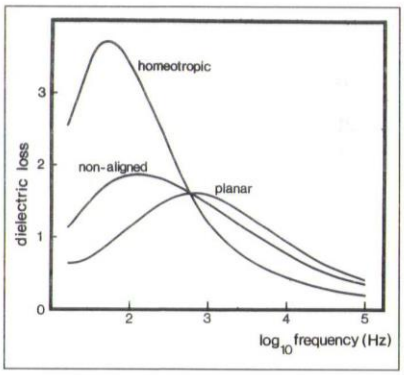


Figure 2: The dielectric loss spectra for homeotropic, planarly-aligned and nonaligned siloxane LC polymer at 307.2 K.

alignment of the 'unknown' sample may be determined. Using a simple theoretical model, we have shown that the complex permittivity $\varepsilon(\omega)$ is linearly dependent on $\varepsilon_{\parallel}(\omega)$ and $\varepsilon_{\perp}(\omega)$ and on a macroscopic 'director order parameter', which may be determined from the dielectric permittivity or loss factor values at each frequency ω.

Proceeding in this way, we have used dielectric relaxation spectroscopy to:

☐ determine the nature and extent of macroscopic alignment for LC polymers which were subjected to electric fields of different amplitudes and frequencies and to different thermal histories.

☐ reveal how the alignment properties depend on chemical structure. Thus siloxane homo polymers were difficult to align in the LC states, whereas siloxane copolymers were readily aligned in the LC state. Siloxane polymers having 'transverse' mesogenic head groups and malonate polymers containing chiral groups readily align in the LC state but disalign on removal of the field.

☐ monitor the *time dependence* of alignment following the application of dc or ac electric fields (see figure 3) or the long-term disalignment due to physical ageing.

☐ show that an aligned monodomain forms on cooling a partially-aligned film in the *absence* of an applied electric field ('memory' effect).

In parallel, we have developed, and applied to our data, a general molecular theory for the dielectric relaxation behaviour in partially-aligned LC polymers, involving the molecular factors of dipole moment, dipole group motions and local and macroscopic order parameters. Similarly, we have developed a macroscopic continuum theory for the time-dependence of alignment in a dc field and have applied it to our data.

Our studies have provided a deeper understanding of the molecular and macroscopic quantities involved in the

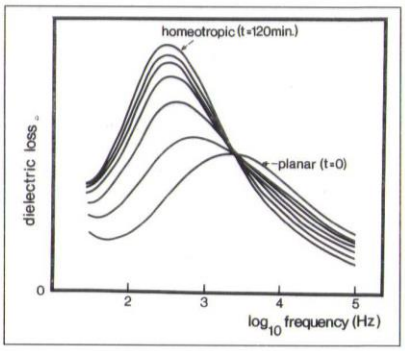


Figure 3: The change in the dielectric loss spectrum for the siloxane LC polymer at 315 K as the film (120 microns) is realigned from planar to homeotropic alignment in a directing ac electric voltage (300 V at 600 Hz).

dielectric properties and alignment behaviour of LC polymers. They have provided information which is essential for the applications of these materials in optical information storage and non-linear optical processing and act as a guide in the synthesis of new LC polymer materials. Progress in this area of molecular electronics is being made through collaborative research involving scientists from many disciplines.

We thank Professor John Lewis, coordinator of the Specially Promoted Programme on Electroactive Polymers, and Professor George Gray for their interest, encouragement and advice.

Professor Graham Williams
University College of Swansea

Dr George S Attard
University of Southampton

Colour alphagraphic active matrix display using 5-inch diagonal 256 x 256 pixel polysilicon active matrix. Research partly funded by JOERS-Alvey displays programme. (Photo: GEC Hirst Research Centre).

Interactions of high energy ions with nuclei

In the Autumn of 1986, fully stripped oxygen ions were accelerated at the CERN Super Proton Synchrotron to energies of 3.2 TeV (200 GeV/nucleon) and beams were provided to a number of electronic experiments as well as for exposures of emulsion stacks. This achievement was followed a year later by the provision of sulphur ion beams, again to 200 GeV/nucleon energy, that is to a total energy of 6.4 TeV. These particles possess by far the largest energies of any produced at accelerators and thus the main goal of most of the experiments has been the search for a quark-gluon plasma state. Such a deconfined state, completely different from the normal nuclear matter, is predicted by the theory of quantum chromodynamics (QCD) and may well have existed in the early stages of the Universe. Donald Davis and David Tovee of University College London discuss developments in that search.

It is assumed that the necessary conditions to bring about a phase transition from ordinary nuclear matter to that of a quark-gluon plasma state are a high energy density, some few GeV/fm ^{3} over a sufficiently large volume. The best chances of realising such conditions in the laboratory are therefore in central collisions of high energy heavy ions with heavy nuclei — a central collision being one in which all of the nucleons in the projectile nucleus take part in the interaction. This being the case all the experiments present heavy nuclear targets to the beam.

The first problem to be faced is that the numbers of particles produced in such central collisions are very large — typically some 200 or so charged pions in oxygen interactions and more for sulphur — and so fine segmented detectors and calorimeters are required for their detection. The photomicrograph figure 1 depicts a central sulphur-heavy emulsion nucleus (silver or bromine) interaction. The large number of forward-going shower particles is evident, the darker tracks at large angles to the incident ion's direction being those of the nuclear debris from the target.

What are we looking for?

The second problem is that there is at the moment no clear concensus among theoreticians as to what signal to expect as conclusive evidence for the production of a quark-gluon plasma state. Among those which have been suggested are changes in the spectrum of dileptons and directly produced photons; an increased yield of strange particles and production of hypernuclei; a lack of charmed or J/ψ particles; and larger than expected fluctuations in the distribution of particles as a function of rapidity. All the experiments attempt to measure at least one of these signals among samples of interactions assumed to be central in character, by reason of observed high-multiplicity of shower particles or high transverse energy flow. But the first thing to establish is the background to such signals for quark-gluon plasma states provided by the multitude of interactions which involve only ordinary, well known, nuclear processes.

One approach to these problems has been made by a team of European and Japanese emulsion laboratories working together with the Helios group. In this, for a small part of the experimental running time the usual heavy metal targets of the Helios apparatus have been replaced by small emulsion stacks. Since the lateral dimensions of the ion beam were small, it was necessary to move the emulsions during their exposure to ensure uniform irradiation. This was achieved with an 'emulsion target mover' whose position was continuously monitored so that ion interactions of interest within the emulsion could be located accurately (to 15 microns in directions transverse to the beam), having tracked the primary ion through a silicon microstrip beam hodoscope.

Emulsions, with their inherent high spatial resolution of one micron or better, present unique advantages in the search for evidence of quark-gluon plasma formation. They provide a fine-grain detector in which short-lived particles or hypernuclei can be detected. They also enable studies to be made of the fragmentation of both the target and the projectile nuclei, and of the multiplicities and complete angular distributions of secondary particles.

Scrutiny

Samples of central interactions of both oxygen and sulphur ions have been specifically selected for scrutiny in the emulsion and the distributions of various quantities have been determined. For example, measurements have been made of the multiplicities of charged shower particles for various values of the transverse energy flow, E_T, as observed in the Helios caloremeters. The results, depicted in figure 2, show that a strong correlation exists between these two quantities. The distribution of the pseudorapidity variable of shower particles, η, defined as $-1n \tan \theta/2$ where θ is the angle made with respect to the incident beam particle, is shown in figure 3 for samples of sulphur interactions exhibiting both high and low values of E_T. It is seen here that there is a shift towards lower values of η as E_T increases. Although the results are striking, they do not show any strong departures from the features expected from the superposition of many nucleon-nucleon interactions, except possibly at

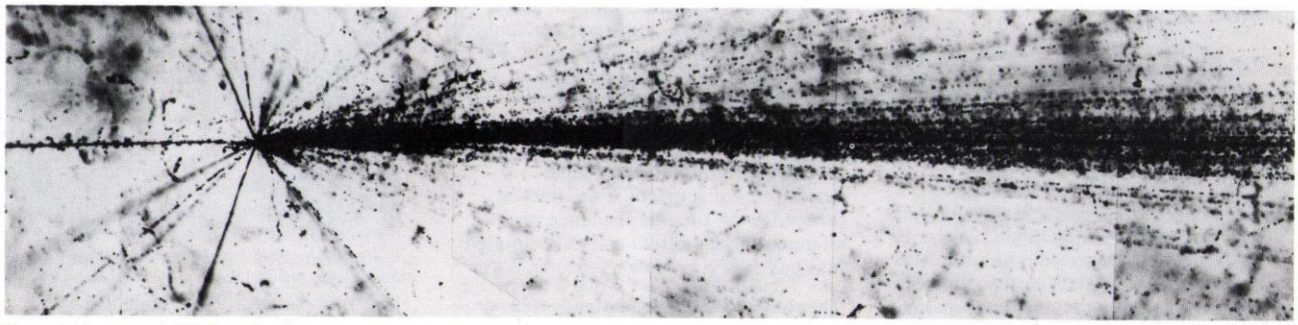


Figure 1: A central 6.4 TeV sulphur-heavy nucleus interaction.

the higher values of E_T, and hence show no conclusive evidence for the onset of quark-gluon plasma states.

Complementary exercise

As a complementary exercise, the characteristics of random samples of oxygen and sulphur interactions with emulsion nuclei have been determined, adopting along-the-track scanning procedures to locate the interactions in an unbiased way. The mean free paths for inelastic nuclear interaction in emulsion have been determined for 200 GeV A oxygen and sulphur ions as 117 mm and 87 mm respectively and these agree well with simple theoretical calculations.

It is found that a significant fraction of events (25% for oxygen, 13% for sulphur) contain no residual nuclear fragment with charge greater than one of the incident ion projectile, indicating its complete disruption. However, the majority of interactions show less, often considerably less, involvement of the projectile nucleus. Indeed, both the mean numbers of low energy fragments ejected from the target nucleus and shower particles both increase significantly the greater the number of projectile nucleons involved in the interactions, as expected.

A striking feature of the results is the significant fraction of interactions (11% in the case of oxygen, 20% for sulphur) in which all that is observed is the low energy break-up of the projectile nucleus, the fragments of which proceed in directions confined to within about one milliradian of that of the original beam particle. Such interactions are ascribed to the electromagnetic dissociation of the projectile nuclei brought about by their interaction with the electric fields of nuclei within the emulsion. Since the effect is proportional to the square of the nuclear charge of the target nucleus, the main contributors to this process in emulsion are silver (Z = 47) and bromine (Z = 35). The majority of such events in both the oxygen and sulphur experiments involve the stripping of a hydrogen nucleus which, from the measured angle

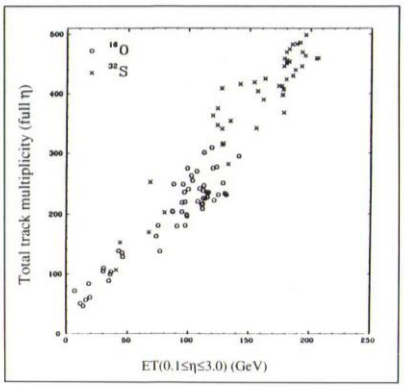


Figure 2: Shower track multiplicity as a function of E_T.

of the break-up, may usually be ascribed to single photon absorption in the giant resonance region (21< Eγ < 27 MeV). However, there exists a sizeable number of events in which the projectile undergoes multiparticle break-up.

A photomicrograph of such an event is shown in figure 4. The break-up process observed here is:

$S \rightarrow C + 3He + 4H + (neutrons)$.

Initially the process is indicated only by the sharp reduction of the delta-ray intensity occurring on the incident track, as seen in the first photomicrograph. However, the second photomicrograph, taken 50 mm from the origin, shows the secondary particles well resolved, the spatial spread of 50 microns here indicating an overall angular spread of about 1 mrad.

Multiphoton absorption?

Such events are difficult to ascribe to single photon absorption processes and suggest the possibility of multiphoton absorption — the ultra-relativistic ion's passage through the electromagnetic field of a heavy nucleus subjects it to a pulse of radiation equivalent to very many low energy gamma-rays — a new sphere of physics difficult to realise by more

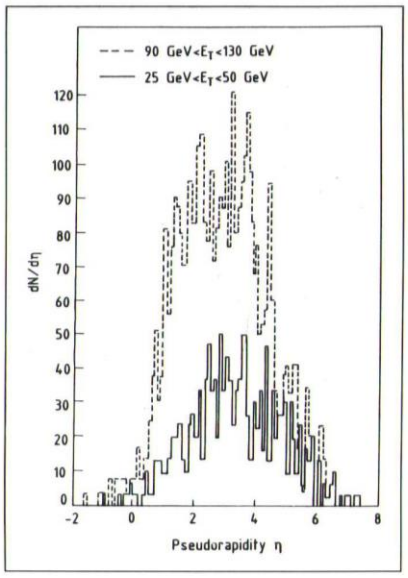


Figure 3: Pseudorapidity distributions for differing E_T intervals.

conventional means. In fact, multiphoton absorption may get to states single photons cannot reach.

To summarise, no clear-cut signal for a new phase of matter has yet emerged although many avenues — particle correlations, J/ψ, charm suppression and so on — remain to be fully explored. The discovery of quark-gluon plasma states may of course yet await experiments with the contemplated relativistic lead beam at CERN or even nucleus-nucleus colliders. On the other hand, in an entirely different energy regime, much work remains to be done to understand the mechanisms responsible for the production of the diversity of final states observed in the photodissociation processes.

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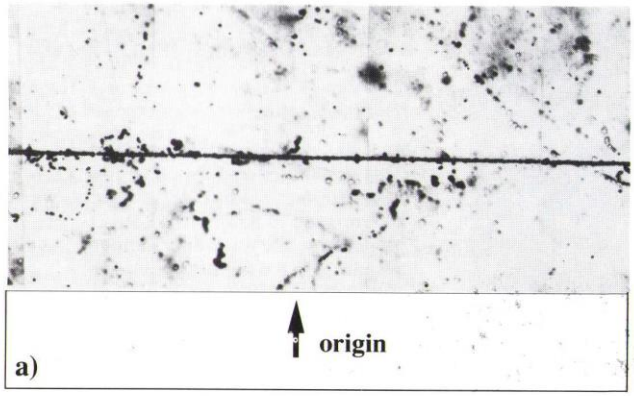

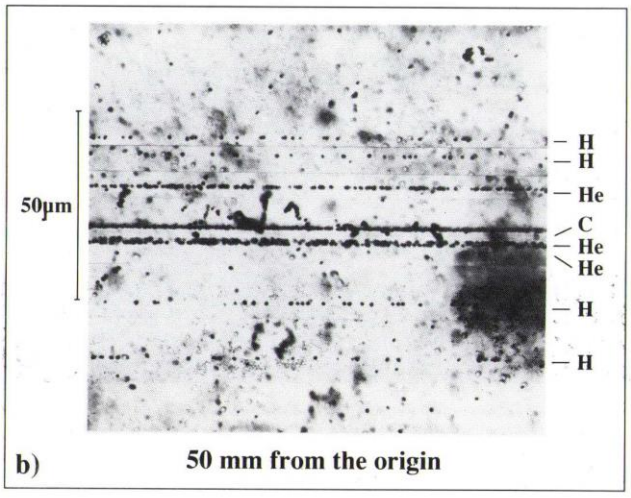

Figure 4: Electromagnetic splitting of a 6.4 TeV $_{32}S$ ion via the process $^{32}S \rightarrow C + 3He + 4H$ (+neutrons): a) The origin; b) 50 mm downstream of the origin.

CCDs for vertex detection in particle physics

Two-dimensional imaging charge-coupled devices (CCDs) are becoming familiar with the general public through their use in video cameras. They have for many years been used by astronomers because of their superb performance for sensing extremely faint signals. During the past eight years a UK group (a collaboration between Brunel University and Rutherford Appleton Laboratory) has proved that CCDs have excellent performance (about 5 microns precision) as tracking detectors for high energy particles. Chris Damerell of RAL and Steve Watts of Brunel here describe their work.

The reason why particle physicists need detectors with such high precision has arisen from the discovery of 'heavy flavours', or particles that contain one or more heavy quarks (charm, bottom, and so on). Such particles decay to ordinary matter with lifetimes around 10^{-13} seconds. In an experiment where they emerge from the production point at almost the speed of light, they may travel far enough before decaying for a 'vertex microscope' made of CCDs to recognise which particles came from the production point and which from the subsequent decay of the heavy-flavour parent particles.

The vertex microscope

The UK group is engaged in an experiment at the new Stanford Linear Collider (SLC) in which electrons and positrons collide with a total energy of 100 GeV (proton mass = 1 GeV). The overall detector (called SLD) consists of 4000 tonnes of equipment surrounding the interaction region. The vertex microscope will be located in the centre, immediately outside the vacuum pipe in which the collisions take place. The basic detector elements will be two-dimensional CCDs, each of about a square centimetre and containing about 250,000 pixels. The UK group has already successfully operated a CCD-based vertex microscope at the CERN Super Proton Synchrotron, but this consisted of only two CCDs, and there are many new problems associated with the SLC detector requirements. Some of these are:

- The detector must have large solid angle coverage, and this means many CCDs. The SLD vertex detector will use 250 CCDs arranged in four barrels, each barrel being made up of some ten ladders (see figure 1). A ladder is a two-sided multi-layer ceramic board with four CCDs mounted each side, with overlaps to give continuous coverage along the length.
- Access is limited to annual shutdowns, so extreme reliability is required.
- Material within the detection volume must be minimised to avoid disturbing the particle trajectories by multiple coulomb scattering, and yet the spatial stability must be excellent.

The RAL/Brunel collaboration has been working closely with industry to find solutions to these problems since SLD (including the vertex detector) was approved for fabrication in 1984. There are now several companies (including EEV and Thomson) which produce CCDs suitable for specialised scientific applications. Based partly on the work of these companies and partly on our own results, we believe that after a suitable burn-in procedure, CCD failure rates of 0.1% or less a year can be achieved, which will be entirely adequate for SLD.

CCDs are conventionally fabricated on silicon wafers about 0.5 mm thick, and are mounted in standard dual-in-line chip carriers. These would present far too much material, and a completely new form of chip carrier (a ceramic window frame 1 mm wide and 0.25 mm thick) has been developed in conjunction with GEC's Hirst Research Centre in the UK. The CCDs are thinned to 0.2 mm and mounted in the chip carriers by tape-automated bonding. The packaged devices can be tested, and those selected are then mounted on the ceramic mother cards to build up the ladders. The development of these mother cards has also been carried out at Hirst Research Centre.

The first ladder

At RAL, the first ladder has recently been assembled and tested (figure 2). Apart from the ladder development, we are engaged in an intensive R&D programme for the ladder support system, and we are now reasonably confident of achieving an overall stability of 5 microns. The most delicate areas are the centres of the ladders, which are susceptible to significant bowing if there are any compressive loads on the ladders (eg due to thermal variations). For example, a compression of 4 microns in length would induce a sagitta (the length

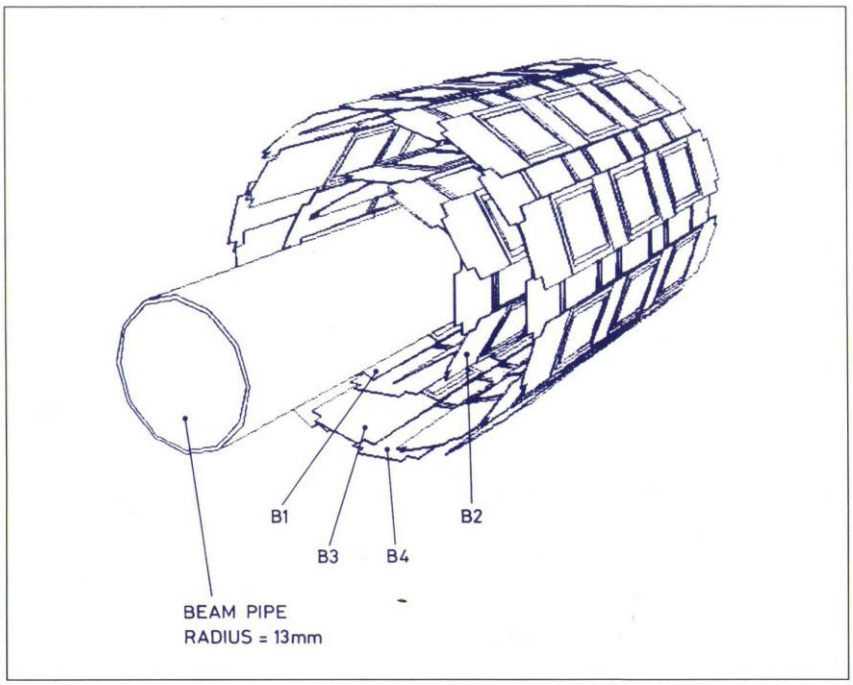

Figure 1: The four-barrel arrangement of CCDs which will be assembled around the SLD beam-pipe. This provides coverage with at least two hits per outgoing track down to a polar angle of 29°.

of the 'arrow' where it crosses the bow) of 70 microns in a ladder. By a suitable combination of fixed and sliding ends, such effects can be avoided while still achieving a precise and stable geometry.

The detector contains 70 million pixels. Using a simple pixel threshold for selecting the data would lead to 1 Mbyte per event of data from the detector, a factor 30 more than could be tolerated by the SLD data acquisition. We have devised a system for real-time cluster selection, using an application-specific integrated circuit designed by us, again in close liaison with industry. This should reduce the data level to a modest 20 kbytes per event.

Important benefits

Apart from the mutual advantages to particle physics and to industry of the cooperation which has characterised this project, there are important benefits to other areas of science. Close-packed arrays of CCDs in these newly developed miniature chip carriers will allow mosaics of CCDs to be assembled for large area imaging. This possibility has been received with great interest in a number of fields, such as electrophoresis, astronomy and X-ray diffraction: anywhere in fact where the centimetre-square area of typical CCDs is much too small.

The success of pixel-based detectors for vertex microscopes has triggered a major R&D activity internationally for the development of yet more sophisticated pixel devices capable of particle tracking under tera electron volt conditions. Such detectors will also be useful in other areas, such as X-ray imaging where the demands are growing for high-rate capability. Still at the conceptual design stage, these detectors will take advantage of the increasing miniaturisation of very large-scale integrated circuits, which will allow small pixels each incorporating a considerable amount of parallel processing capability. This will enable hit pixels to inform the off-chip electronics of their addresses and contents, instead of needing a serial readout of all pixels as in current CCDs. Such 'smart pixel' devices clearly point the way to the future and will be applicable in a wide variety of disciplines including robotics and other industrially important areas.

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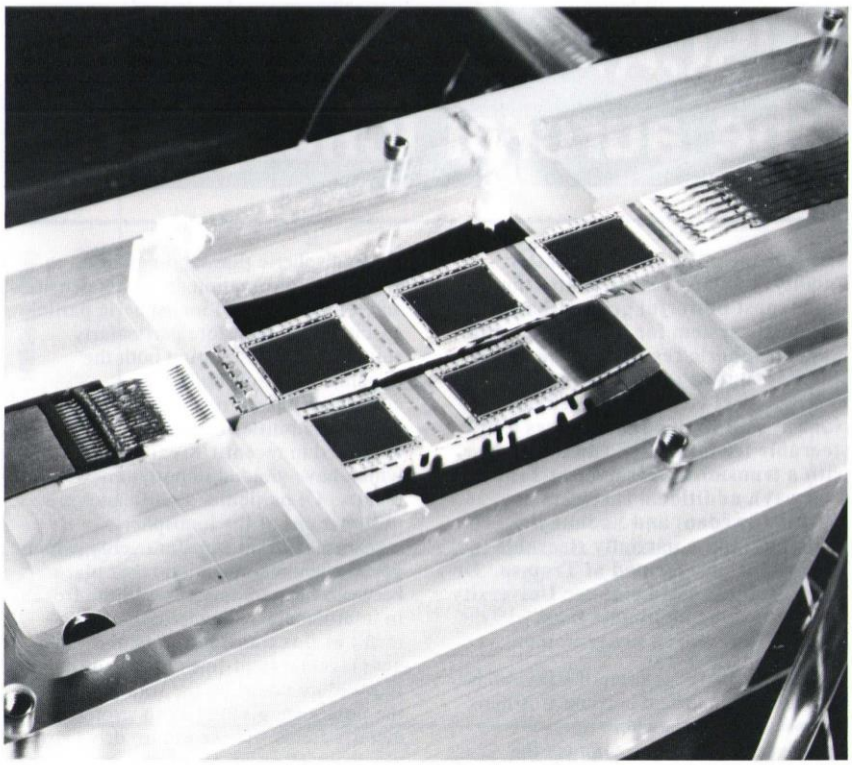

Figure 2: The first two-sided ladder under test at RAL. This consists of three CCDs above and two below (seen reflected in a curved sheet of aluminised mylar). Note the micro-connectors each end which bring in the drive signals from the right, and the analogue biases (and CCD output signals) at the left.

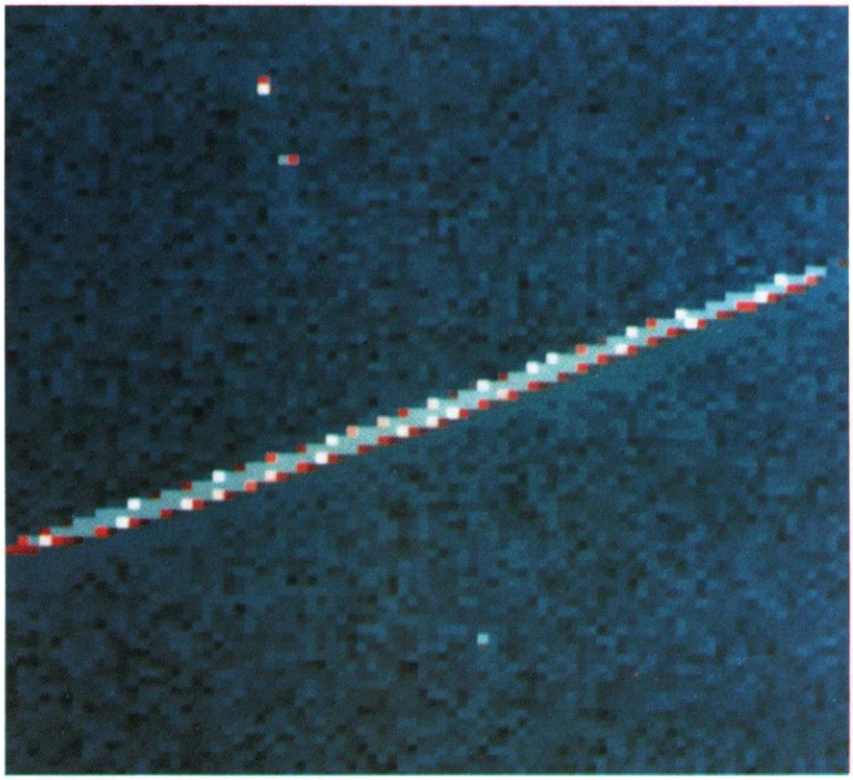

Figure 3: The track of an ionising particle as it travels a couple of millimetres within a CCD detector. The pixel area is 22 x 22 microns and the effective thickness about 20 microns. The three small clusters were produced by high energy particles traversing the detector normal to its surface.

EISCAT — probing the physics of the auroral ionosphere

The European Incoherent Scatter Facility (EISCAT) is currently the single most powerful ground-based diagnostic system for ionospheric and magnetospheric research. The facility, which is funded jointly by the UK, France, West Germany, Sweden, Norway and Finland, comprises a fully steerable tristatic UHF radar system with a transmitter/receiver at Tromsø (Norway), additional receivers at Kiruna (Sweden) and Sodankylä (Finland), and a partially steerable VHF radar also located at Tromsø. Dr Terry Robinson of Leicester University describes some highlights from EISCAT's research programme.

The high latitude location of EISCAT is particularly important because it is here, in the auroral zone, where open geomagnetic field-lines connect the terrestrial ionosphere directly to the interplanetary medium, that dynamic features of the auroral atmosphere can be driven by activity on the Sun. An understanding of the complicated processes by which energy from the Sun is ultimately deposited in the Earth's upper atmosphere remains a major goal of solar terrestrial physics.

Auroral geophysics

The EISCAT UHF system has now been operating reliably for more than five years. Being tristatic, it is capable of measuring the full vector drift velocity of the ionospheric plasma, in addition to providing information about the densities and temperatures of ionospheric particle species. It is therefore particularly suitable for investigating both the dynamic and morphological characteristics of the auroral ionosphere. These capabilities have been fully exploited in recent UK experiments which have yielded important new results. Of particular significance are observations of the ionospheric signatures of flux transfer events, which occur when reconnection takes place between the geomagnetic and the frozen-in interplanetary magnetic field. As a result of flux transfer events, the geomagnetic field-lines in the auroral regions are swept by the solar wind over the polar cap, giving rise to strong electric fields. These in turn drive strong plasma convection flows and currents which the EISCAT radar can detect. Recently, EISCAT observations have been coordinated with *in situ* measurements from the AMPTE satellite which was situated in the solar wind. Comparisons of the two sets of observations have revealed that the ionosphere responds to changes in the interplanetary magnetic field after a delay of less than five minutes.

Observations have been made by UK EISCAT scientists of a number of other important phenomena associated with enhanced plasma convection in the auroral and polar regions, such as ion upwelling which constitutes the so-called polar wind; joule heating associated with the generation of large atmospheric gravity waves; and field-aligned currents in the vicinity of auroral arcs. Most of these investigations form part of major international collaborative studies. In addition, EISCAT has recently provided strong evidence to support the theory that hydromagnetic cavity modes, which are associated with oscillations of the whole magnetosphere, constitute a continuous source of energy for geomagnetic pulsations. These pulsations correspond to resonant standing waves along closed geomagnetic field-lines.

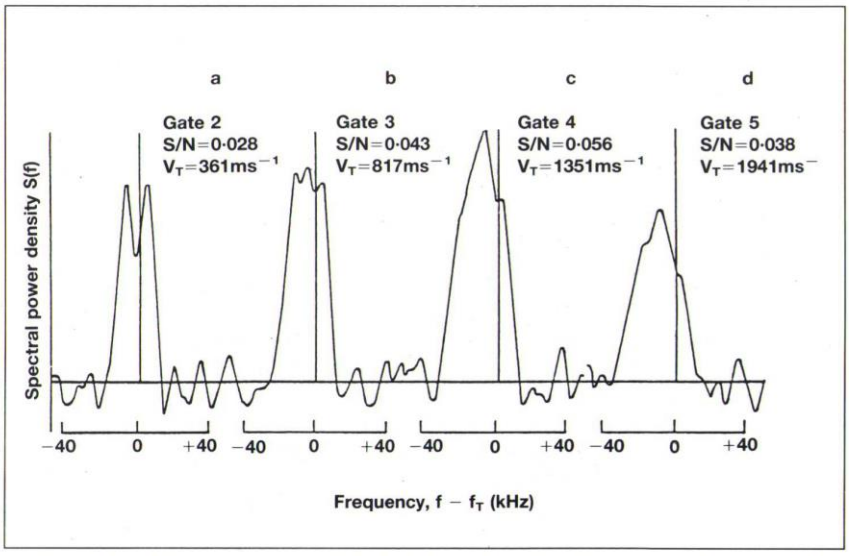

Figure 1 : EISCAT incoherent scatter spectra illustrating (a) a Maxwellian ion velocity distribution and (b—d) various non-Maxwellian distributions.

Mesosphere observations

The VHF radar came into operation in 1987, when its new fields of research became accessible to EISCAT scientists interested in the high latitude mesosphere. Because of its longer wavelength (130 cm as opposed to only 30 cm for the UHF radars), the VHF radar can probe altitudes in the range 75 - 90 km which lie in the mesosphere and which are inaccessible to the UHF radars. Even though the VHF radar is, as yet, not fully operational and only limited periods of observation are available, two major discoveries have already been made during joint campaigns involving UK experimenters. First, dawn observations during 1987 revealed, for the first time, the presence at mesospheric heights of an acoustic gravity wave moving with exactly the velocity of the solar terminator. Waves generated by differential heating associated with the terminator have long been predicted theoretically but no convincing evidence for their existence has previously been forthcoming. It is only at high latitudes that the terminator moves at subsonic speeds characteristic of acoustic gravity waves.

The second discovery was made during the summer of 1987 when unusually strong radar echoes from a narrow layer at about 88 km were observed. These echoes have since been attributed to quasi-coherent backscatter from turbulent structures in the neutral atmosphere. Normally these turbulent features have spatial scales which are far too large to give rise to the coherent echoes at VHF wavelengths. However, the inertial subrange of atmospheric turbulence can become accessible to VHF radars during periods of low temperatures in the summer mesopause.

Plasma physics

Some of the most exciting new science to come out of EISCAT research so far is in the field of basic plasma physics. The ionosphere is a relatively homogeneous and quiescent plasma, effectively without boundaries (unlike most plasmas which can be created in the laboratory). It thus serves as the ideal medium in which to study complex microscopic plasma processes such as nonequilibrium phenomena, plasma instabilities, turbulence and nonlinear effects.

EISCAT observations during recent UK experiments have yielded the first evidence of toroidal distributions of ion velocities in the ionospheric F-region (200 - 300 km altitude). Under undisturbed, low-drift conditions, the velocities have the usual isotropic Maxwellian distribution. This gives rise to a typical double-humped incoherent scatter spectrum (see figure 1). However, during disturbed periods, when ions are accelerated to high drift-speeds by enhanced auroral electric fields, large velocity differences arise between the drifting ions and the slower neutrals. Weak scattering by the neutrals, whose distribution remains Maxwellian, then causes the ion distribution to become anisotropic. At differential velocities which exceed the neutral sound speed, the ion distribution takes on a bi-Maxwellian form with different temperatures parallel and perpendicular to the geomagnetic field. At higher differential velocities, the ion distribution becomes toroidal, with the axis of the toroid along the geomagnetic field.

Under these conditions, with the EISCAT radar beam pointing in a direction which is more than a few tens of degrees to the geomagnetic field, the usual 'two-hump' incoherent scatter spectrum is replaced by a somewhat enhanced single hump or even three-hump spectrum, characteristic of the toroidal distribution (figure 1). EISCAT observations of this phenomenon have had a significant impact on our understanding both of the microscopic plasma mechanisms involved, and of the implications for large-scale plasma transport in the ionosphere.

The first EISCAT observations of non-Maxwellian spectra occurred earlier, during experiments in which high-power, high-frequency radio waves from the high-power facility (heater) at the Max-Planck-Institut (MPI, at Lindau, West Germany) were used to heat the ionosphere. The high-power radio waves are of sufficient intensity to trigger a variety of plasma instabilities in the vicinity of their reflection region. EISCAT observations in this region have revealed a number of new effects, including non-Maxwellian spectra, wave-wave interactions and nonlinear thermal effects. Among the most exciting results to come from recent UK EISCAT

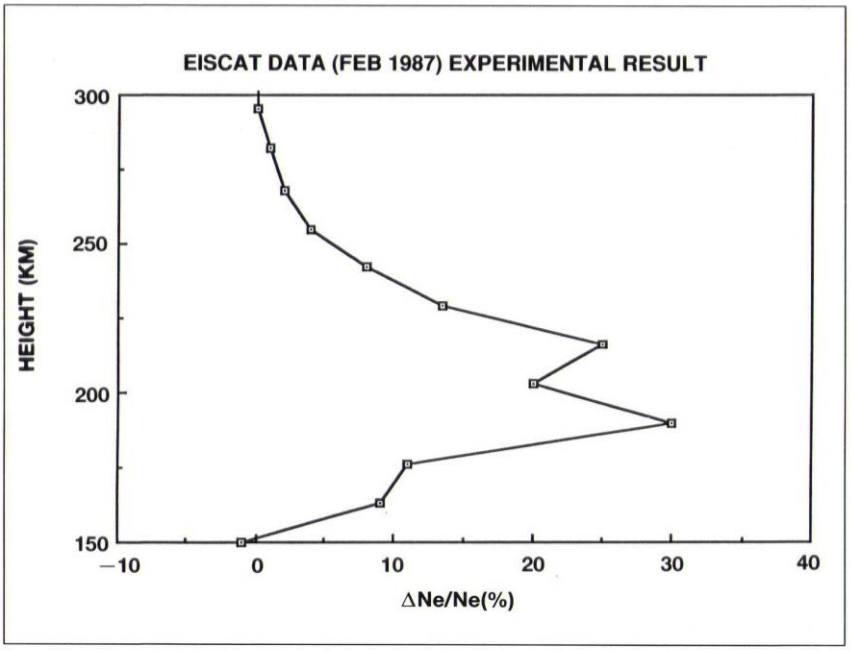

Figure 2 : Vertical profile of the relative change in electron density during heating by intense radio waves. Cavitation is occurring at 200 km.

experiments, carried out in collaboration with MPI, have been the first observations at high latitudes of a thermal cavitation effect. Instabilities in the heater wave reflection region give rise to plasma turbulence and strong anomalous absorption. The electron temperature rises quickly and within a few seconds reaches values up to 50% above its background value. Plasma is pushed out of the high temperature region causing a density depletion of a few tens of percent. The resulting 'hole' or caviton is illustrated in the electron density profile obtained by EISCAT in figure 2.

The EISCAT radars and the MPI heater have proved a powerful combination for studying important basic plasma phenomena such as turbulence. EISCAT observations of electron transport phenomena in the E-region (100 - 130 km) of the ionosphere have also yielded improved understanding of natural plasma turbulence which arises when the plasma drift is enhanced by intensification of the high-latitude electric field. Figure 3 illustrates the increases in electron temperature as a function of electric field strength observed by EISCAT in a recent Anglo-Soviet experiment. Classical frictional heating due to collisions between electrons and ions or electrons and neutral gas particles would predict no temperature change at all due to the low frequency of the particle collisions. However, anomalous heating calculations, based on a new nonlinear theory in which plasma turbulence is treated as gas of quasi-particles (plasmons), predict enhanced electron

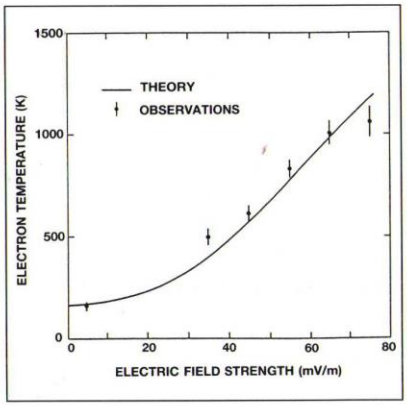

Figure 3 : EISCAT measurements of electron temperature enhancements as a function of electric field strength compared with a theoretical curve calculated on the basis of electron-plasmon collision rates.

temperatures which are in excellent agreement with the EISCAT observations.

The results described here illustrate how EISCAT is making a significant contribution to the research effort into solar-terrestrial physics both in the UK and at an international level. Although EISCAT was envisaged as a tool for geophysical research, it has also proved to be invaluable for research into fundamental plasma physics.

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Ignition in lean-burn engines

The lean-burn engine holds great promise as a practical solution to the pollution problems associated with passenger vehicles. Unfortunately, its widespread use has so far been inhibited by technical difficulties associated not only with combustion initiation but also with low and highly variable mass burning rates.

It is known that these difficulties have their origin in the complex interactions between the ignition source, the flow field and the fuel chemistry during the critical early stages of flame kernel formation. This area is currently the subject of research at Exeter University, funded by the Electro Mechanical Engineering Committee.

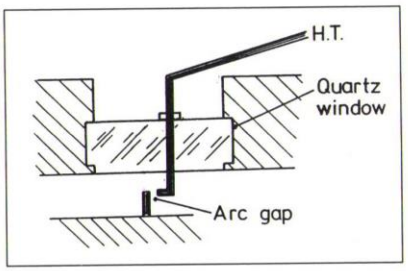


Figure 1: Schematic view of optical access to chamber.

In support of this study, the research team has recently had access to a Hadland Photonics Imacon camera and the Oxford Framestore Image Analysis System from the Engineering Board Instrument Pool at Rutherford Appleton Laboratory (see *SERC Bulletin* Volume 3 No 8, Summer 1987). In this article, Dr Martin Hancock of Exeter describes the use of this apparatus in the study of early flame growth in a test engine.

The engine which has been used in these studies was chosen with the aim of providing the best possible view of the arc channel and its immediate vicinity, in a chamber as near two-dimensional as was practicable. This aim was achieved by the modification of a small side-valve engine in the manner illustrated schematically in figure 1.

The Engines Group at Exeter has previously employed an Imacon camera for combustion studies but the early flame is a tenuous self-luminous event and no external illumination can be employed. Under the lean, low-load conditions of interest, it proved impossible to detect the first stages of combustion using standard polaroid film. However, the images captured on ultra-high-speed film (20,000 ASA) suggested that only a modest improvement in the overall sensitivity of the system would be required in order to produce useful information at this early stage of the combustion process.

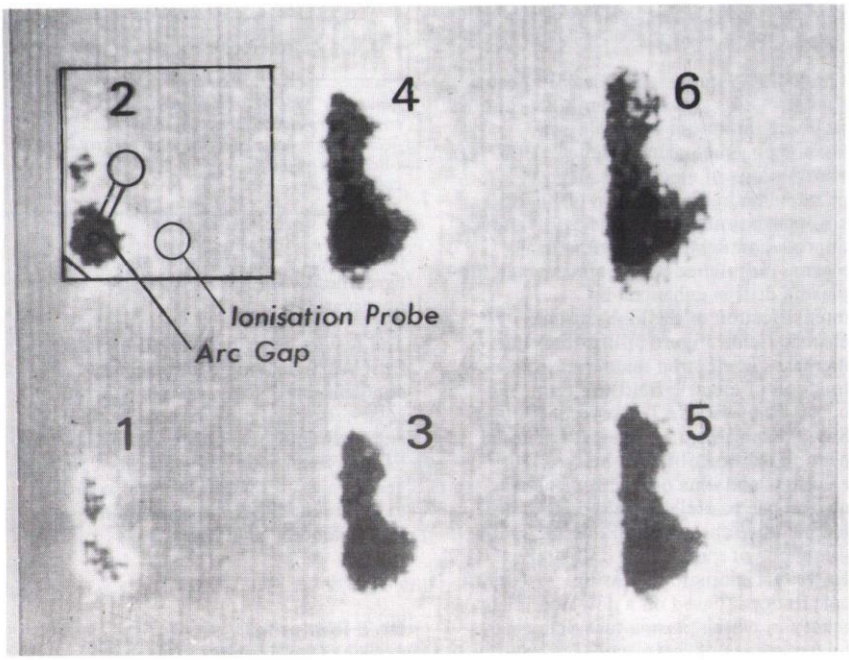


Figure 2: An example of combustion development.

The sensitivity and ease of use of the Imacon has been greatly enhanced by the Oxford Framestore Image Analysis System, which incorporates an image-intensifier, CCD camera and framestore with associated software for data manipulation. This combination is claimed to provide an effective ASA rating of 1 million and it did indeed prove possible for the first time to record images of the earliest events. The other great improvement is provided by the use of a framestore to grab the image.

These additional features allow image enhancement techniques (for example, artificial colouring and smoothing) to be employed to great advantage, and open up the possibility of applying powerful image-processing algorithms to the data. The flame development and heat release under the operating conditions of interest are extremely variable, even with the engine nominally under steady-state conditions. Statistical treatment of the images is therefore essential to show detailed variations in kernel formation as a function of operating parameters; such processing is also made possible with this equipment.

The camera was used at its lowest possible framing rate of 10,000 fps to produce images such as those illustrated in figure 2. This image has been reproduced in monochrome from a colour slide and, inevitably, less detail can be resolved than was possible from the original images. Frame 1 in this figure corresponds to 0.5 seconds after arc extinction and, to give some idea of scale, there is 15 mm between the arc gap and the ionisation probe. It has proved practicable to detect illumination due to combustion immediately after arc extinction and long before any measurable rise in the pressure trace.

This present study of combustion development during the first two milliseconds following ignition has led to some general observations which can be briefly summarised as follows:

- ☐ The faint illumination that represents the start of combustion spreads quite rapidly into the chamber.
- ☐ It is soon followed by a much brighter event which often starts in several isolated sites around the arc gap.
- ☐ Initially, this second event spreads relatively slowly but soon accelerates until eventually it becomes the dominant source of light emission.
- ☐ Those few cycles that exhibited combustion knock (as indicated by the pressure trace) appeared to behave in a different manner from 'normal combustion'. (The appearance of knock under these conditions may be attributed to the use of hexane as the fuel).

The most pronounced feature of a knocking combustion was the virtual absence of any separation between the two events described above.

The analysis equipment was able to produce luminosity plots through the image and an example of this is shown in figure 3. Several intriguing aspects of this luminosity variation have become apparent and will be the subject of investigation during the next period of access to the equipment. Statistical studies of flame propagation will be made possible by the implementation of automated experimental control and data collection, together with the application of image processing techniques to large numbers of images, with the aim of enhancing regions of particularly rapid luminosity change.

In this context it is worth mentioning a practical problem that has arisen with the equipment: successive images are not reliably placed on the same screen location by the Imacon. This has complicated the comparison of like with like in subsequent processing. To circumvent this problem, it is proposed to modify the hardware so as to place register marks in the image field. Automatic search routines are being developed to use the registers for image location and orientation.

In summary, the equipment described above has proved extremely useful, allowing the study of combustion initiation to a degree of detail that was previously unattainable. Several very interesting observations have already been made and a statistical study of kernel growth has been made possible. This will allow a systematic investigation of the influence of engine parameters on early flame growth in a way that would not otherwise be practicable.

Dr M S Hancock
Department of Engineering Science
Exeter University

Engineering Board Instrument Pool

For further information and advice on the equipment available, contact:

Peter Goodyer
Rutherford Appleton Laboratory,
ext 6272

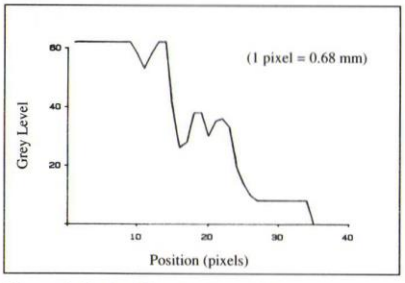


Figure 3: Typical luminosity profile.

Radiometer for upper atmosphere research

The Physics Department of Heriot-Watt University, in collaboration with the Millimetre Wave Technology group at Rutherford Appleton Laboratory, have recently completed construction and testing of a 183 GHz radiometer which will form part of the Microwave Limb Sounder (MLS) instrument due for launch on NASA's Upper Atmosphere Research Satellite (UARS) in October 1991. The MLS project is a joint undertaking with the Jet Propulsion Laboratory in California and the UK sub-assembly was delivered to JPL on 15 March 1988. It successfully passed a hardware review and has now been integrated with the US instrument, writes Brian Kerridge of RAL.

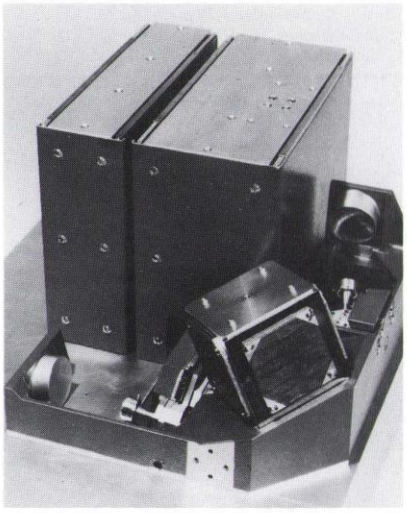
The 183 GHz radiometer has been designed to detect thermal emission from ozone and water vapour and will provide new information about the distributions of these important atmospheric constituents, particularly in the upper stratosphere and mesophere where previous observations are sparse. These measurements form part of the large suite of UARS measurements which, as a whole, should revolutionise middle atmosphere science in the early 1990s. They will complement the ozone and chlorine monoxide measurements to be made by the MLS 205 GHz radiometer and will allow global distributions of ozone and water vapour to be mapped on a daily basis from the tropopause (roughly 10 kilometres) right through to the mesopause (about 80 kilometres).

These observations will be of great value to a wide variety of studies concerning middle atmosphere photochemistry and dynamics. Perhaps most important will be the ability to investigate the recent development of a springtime hole in the Antarctic ozone layer. Chlorine monoxide is believed to play a central role in the development of the hole and so the simultaneous ozone and chlorine monoxide measurements to be made by MLS will provide a unique set of data with which to investigate this phenomenon.

The algorithms for processing data from the UK (183 GHz) radiometer are currently being developed and tested by JPL in consultation with the Department of Meteorology at Edinburgh University. The Edinburgh group also intend to participate in scientific interpretation of the data when it comes on stream from UARS in 1991.

The radiometer is the first space-borne instrument and the first atmospheric sounding project to benefit from the expertise developed by the RAL group for the James Clerk Maxwell Telescope and is evidence of the mutual benefit to be derived from the complementary space and ground-based programmes. The radiometer required two millimetre-wave components to be constructed: a frequency tripler and a low-noise mixer, both of which are whisker-contacted Schottky diodes. This is the first time that such delicate devices have been subjected to the rigorous testing required for space qualification. The tripler converts the 61.59 GHz output from a Gunn oscillator to 184.8 GHz which is then optically coupled to the incoming beam of atmospheric radiation by a Fabry-Perot cavity. The mixer generates electrical side-band signals from radiation within several GHz of 184.8 GHz, and these are amplified, spectrally analysed and integrated using conventional radio-frequency methods. The Heriot-Watt group undertook the system design and development of the electronics and quasi-optical coupler. In addition to the two millimetre devices, RAL also provided flight electronics, project management and facilities for environmental testing.

B J Kerridge
Rutherford Appleton Laboratory



The 183 GHz radiometer due for launch on the Upper Atmosphere Research Satellite as part of the Microwave Limb Sounder.

ACME research conference highlights results

ACME's third Research Conference, held from 19 to 21 September 1988 at Nottingham University, was attended by 200 delegates from the academic and industrial communities. This significant event in the ACME calendar gives grantholders and their industrial collaborators the chance to exchange ideas and experiences with their counterparts from other academic institutions and companies. In addition, discussions between delegates and members of the ACME Directorate staff make an important contribution to ACME's medium and long-term strategy for industry-related research, including a perception of where existing and potential research projects might best fit into that strategy and an indication of hitherto unresearched areas of industrial interest.

ACME Director Bill Hillier introducing AMTC Chairman Len Weaver (centre) at the conference dinner. On the right of the picture is Professor Maurice Bonney, the host at Nottingham University.

The successful format of the 1987 conference — parallel sessions over three days — was again followed, enhanced on the first evening by a tour of the Nottingham University mechanical and production engineering laboratories, organised by Professor Maurice Bonney. An innovation was the inclusion of an initial session containing papers on various aspects of manufacturing technology management, one of them describing how an ACME collaborative research project was itself effectively managed. Other papers among the 48 presented concentrated on the results achieved from ACME-sponsored projects in the fields of production management and control, manufacturing processes, advanced production machines, and computer-aided engineering.

Many papers and a great deal of post-presentation discussion strove to provide all-embracing answers to problems thrown up by industrial research projects. Mr Len Weaver, Chairman of the Directorate's management body — the joint SERC-Department of Trade and Industry Advanced Manufacturing Technology Committee — picked up this point in his keynote address at the conference dinner. "There is still a lot of research going on to find the Eldorado of integration and the perfect algorithm," he said. "Yet some degree of sub-optimisation must be accepted by academics — companies can't always wait for the perfect solution." Mr Weaver, who is chairman of a number of engineering companies, and a Vice-President of the Institution of Production Engineers, also pointed out that some 143,000 manufacturing sites in the UK employed less than 100 people. Few of these sites yet had contact with the academic world; advanced manufacturing techniques applicable to all areas of manufacturing, both high tech and traditional, were therefore essential if Britain was to maintain its position in the face of increased international competition. Clearly many opportunities for high quality, industrially relevant projects still existed.

At the plenary session on the last day of the conference, ACME Director Bill Hillier responded to a number of questions and comments that had arisen over the preceding three days. The main points covered were:

- After a period of severe restraint, the Directorate has funds available to support new research but, as ever, only proposals of the highest quality with real industrial relevance will be considered.
- Guidelines have been developed to assist researchers in making applications.
- The Directorate is currently reviewing the spread of grants across its portfolio and will be expecting to fund work in important areas so far neglected. Once such areas have been identified, researchers may well be invited to tender for funds to carry out this work.

Copies of the full proceedings of the conference can be obtained from the ACME Directorate, SERC Swindon Office (telephone 0793 411106).

A J Parsons
SERC Swindon Office

Professor George Russell of Heriot-Watt University talks about effective collaboration.

Conference delegates at a demonstration of filament winding, an on-going research project at Nottingham University.

Another Nottingham project on display: ultrasonic sensors of flexible manufacturing.

Automotive Design Programme

The Automotive Design Programme has recently been launched as a joint initiative between SERC's Electro Mechanical Engineering Committee and ACME Directorate. In this article, Carol Dent of SERC's Engineering Division describes the scope of the programme.

The automotive industry in the UK makes a substantial contribution to the national economy and spends significant sums on research and development. Increasing international competition is, however, placing heavy demands on this sector, and highlighting the need to integrate activities between automotive component suppliers and assemblers.

The automotive industry is increasingly turning to computer technology for implementation, employing such methods as the use of computer databases for holding information on geometrically modelled shapes and on materials, tooling, spare parts, performance, and so on. These techniques are continually developing, and much research is needed on many aspects of geometric modelling, ways of accessing databases and integration of computer-aided engineering packages with computer-aided design/computer-aided manufacture. New methodologies such as design for manufacture and assembly, failure modes and effects analysis, and Taguchi quality methods are also continually advancing with the promise of considerable improvement through integrated design processes.

The Automotive Design Programme will provide a focus for research in universities and polytechnics on all these aspects of automotive design. The main aim of the programme is to promote excellence in design of automotive products for both function and manufacture through:

- stimulating new industrially relevant research and development including the generation of integrated design methods, design codes and databases;
- providing a focus for collaborative research between the automotive and academic sectors, initiating strategic research and disseminating results through a 'club' of companies and universities/polytechnics;
- providing a mechanism to coordinate research and establish integrated computer-based design tools;
- providing an academic centre supporting industry-quality software and integrated design tools for use by academic departments engaged in collaborative research with automotive sector companies;
- providing an enhanced flow of trained manpower to the industry sector.

The programme will consist of a coordinated portfolio of individual projects, each of which will be carried out as a collaboration between one or more academic departments and one or more companies. Each project will have, as a major element, development of the use of modern computer-based tools to support the generation of design codes, design methods and design databases. The programme will cover projects in nine main technical areas as shown in the box, with application to all product sectors within the automotive industry.

All projects will use common Apollo-based hardware and, wherever possible, common software, and will be linked together through the Joint Academic Network (JANET). A Central Support Unit (CSU) is being established at Birmingham University to provide technical coordination of the programme, to provide general support to remote site users for the software packages mounted on the ADP, and to facilitate the development of engineering databases accessible to the community. In particular the CSU, by pulling together information and experience from each project, will encourage the growth of a community of academic research workers with a common interest in design engineering for the automotive sector, and will provide a central resource of data, expertise and information on generic design research, methodologies and techniques for use by universities/polytechnics and industry.

We seek to encourage further well conceived applications with clearly defined objectives and well designed programmes, leading to the generation of knowledge of design and computer-aided design methodologies for the automotive sector.

For further information on the programme contact Louise Johnson, Electro Mechanical Engineering Committee (0793 411117) or Adrian Dent, ACME Directorate (0793 411270), both at SERC Swindon Office.

Carol Dent
SERC Swindon Office

Technical areas to be covered by the Automotive Design Programme

- Experimental engineering science leading to generation of design rules.
- Design-driven materials selection.
- Modelling.
- Design codes.
- Design analysis.
- Integrated knowledge-based systems.
- Engineering database development.
- Design for manufacture.
- Manufacturing processes

Staff at Birmingham University working on development of a coupled acoustic structural vibration model for use in design of vehicles with reduced passenger noise: an example of the type of project to be carried out within the Automotive Design Programme.

SERC Graduate Schools 1989

The Graduate Schools were set up by SERC to give PhD students some idea of what it might be like to work in industry, commerce and the public sector. They demonstrate to the students that there are opportunities for people with their ability outside the academic world which are both interesting and challenging. This year there will be 11 schools held between March and September in some very pleasant locations around the country — but there is not much spare time for sightseeing! They run for five very busy days, and during those five days students have a go at a wide range of occupations, such as marketing; personnel and industrial relations; finance; product management; production; research and development, and so on. By the end of the school, students will know a lot more about the career opportunities that are open to them, and will be able to make a more informed decision about whether to seek a career outside the academic world.

Each Graduate School is different, with its own individual programme, but all have the same objectives and all are lively and informal. The directors and their teams of tutors are drawn from industry, government and academic life and are chosen for their variety of experience and skills.

The 90 students are divided into groups of eight to ten; each group contains an 'executive' and is allocated a tutor. The tutor is not there to teach the group how to solve the problems, but rather to help members make the most of the opportunities available during the School. The 'executives' are graduates and PhDs who have experienced a few years' employment in industry or the public sector. They take part on equal terms with the students and bring their own experience to bear on the problems posed. What is probably more important is that students can talk to the tutors and the executives informally about what their jobs are like and how they got them.

Students are plunged in the school straightaway with a game which helps them get to know the other members of their group. It might be based on building a paper tower, or surviving in the desert, or selecting staff for an oil company.

In the following days students tackle a variety of business games and role-playing exercises including, for example, developing a marketing strategy for a personal computer, settling a strike at an airline, negotiating over the closure of schools in a local authority or helping an ailing margarine company. On top of that, throughout the week there is a chance to play at managing a company.

The Schools are not business management courses — they do not set out to teach people how to run a business or how to do marketing. The experience gives a taste of the sorts of problems, challenges and issues that can occur in a non-academic career.

Students also have the opportunity to work as a member of a team, and to reassess their own strengths and weaknesses, and likes and dislikes, in the light of the experience of that team. The tutors and the executives are there to help in this process.

SERC contacts all students with SERC research studentships in their second year. Priority is given to students in their second postgraduate year but students in their third year can apply if they missed going before. If students have had more than three years' full time experience in industry, commerce or the public service the course is not likely to be of great benefit and we recommend that they do not apply. There is no charge for tuition, accommodation or food at the school but students are expected to meet their travelling expenses within the UK. Students not holding SERC studentships are welcome to apply and will be offered a place if there is room. However these students will be charged the full cost of £330 (including VAT) but other organisations sponsoring the PhD student may be prepared to contribute.

This year's schools are listed below.

For further information, please contact:
Julie Hutchinson
Graduate Schools Secretariat
SERC Swindon Office
Telephone Swindon (0793) 411427

Choose your School

Durham University
Hatfield College
16-21 March
Director: Tony Boardman
Regional Marketing Director
Ministry of Defence

Brunel University
Uxbridge: The Lecturers' Centre Building
22-27 May
Director: Larry Roberts
Head of Applied Science
Kingston Polytechnic

Stirling University
Pathfoot Building
22-27 June
Director: Brian Briscoe
County Planning Officer
Kent County Council

Brunel University
Uxbridge: The Lecturers' Centre Building
3-8 July
Director: Ian Elson
Business Development Manager
ICI Chemicals & Polymers Limited

York University
Alcuin College
13-18 July
Director: Norman Price
Managing Director
Seamless Tubes Limited

Sheffield University
Earnshaw Hall
20-25 July
Director: David Hulbert
Director of Ravensbeck Ventures Limited

Cardiff University
Dyffryn House
31 August-5 September
Director: Mark Atkins
Social Director
Proctor & Gamble Limited

York University
Alcuin College
7-12 September
Director: Jeremy Monroe
Management Consultant
Seer Management

Sheffield University
Earnshaw Hall
14-19 September
Director: John Mogg
Under Secretary
Department of Trade and Industry

Exeter University
St. Luke's College
21-26 September
Director: Nigel Brown
Schools and Development Manager
IBM (UK) Limited

Durham University
Hatfield College
25-30 September
Director: Mike Cleare
Director of Planning and Development
Johnson Matthey

Alvey Vision Club

The prize for the best paper of the Alvey Vision Club 1988 (AVC 88) were awarded to G P Otto, T K W Chau, T Day and J P Muller of University College London for their joint presentation on stereo matching methods for extracting elevation data from SPOT satellite images. They described a novel approach to an important practical problem, giving quantitative results which included an objective comparison with previously published methods.

The Alvey Vision Club Committee also commended D Charnley and R Blisset of Plessey Research Roke Manor who described the application of previously reported 'structure-from-motion' methods to outdoor image sequences acquired by a vehicle-mounted TV camera.

All 45 papers presented were published in the *AVC88 Proceedings* (302 pages) available from Margaret Matthews, AVC88 Proceedings Secretary, Department of Medical Biophysics, Manchester University, Stopford Building, Oxford Road, Manchester M13 9PT, telephone 061 - 275 5131, price £27.50 inclusive of postage and packing.

Selected papers appear in a special issue of *Image and Vision Computing* published by Butterworth Press.

Vision Club activities will continue under the auspices of the Department of Trade and Industry/Information Engineering Directorate. We look forward to the next conference, to be held in the Reading University, 25 to 28 September 1989.

Further details can be obtained from the Secretary, K M Crennell, Rutherford Appleton Laboratory; telephone (0235) 446397; electronic mail KMC@UK. AC. RL. VJ.

Microelectronics at ITEX 88

Brian Nuttall (left), the National Director of Devices of the new joint SERC-Department of Trade and Industry information technology programme (see* SERC Bulletin *Vol 3 No 12, Autumn 1988), visits the SERC Microelectonics Facilities stand at ITEX 88, held at the Barbican in London in November 1988. Seen here discussing the facilities with him is Eddie Jones from the coordinating team at the Rutherford Appleton Laboratory.

Some new publications from SERC

SERC annual report

Report of the Science and Engineering Research Council for the year 1987-88 was laid before Parliament in December 1988. Copies are available from the Public Relations Unit, SERC Swindon Office (0793 4011256) or from HM Stationery Office bookshop in Manchester, price £6.00; or through institution libraries (ISSN 0261-7005; ISBN 1 870669 20 7).

SERC corporate plan

The second *Science and Engineering Research Council Corporate Plan* was published in January. It gives current objectives and a discussion of the mechanisms for their attainment, as well as a review of progress since the first corporate plan was published in 1985. Copies are available from Alan Brittain, Swindon Office (0793 411174).

Research summaries

Copies of *Summaries of research reports, November/December 1988* for each of the Environment Committee's Subcommittees — Building, Civil Engineering and Transport — are available from James Fraser, Swindon Office (0793 411060).

Process engineering

Copies of *Grants current at July 1987* and *Specially Promoted Programme in Particulate Technology Newsletter, October 1988 (No 5)* are available from Brenda Fallows, Swindon Office (0793 411449).

Separation processes

Copies of *Separation Processes: Highly selective separations* are available from Sue Cooper, Biotechnology Directorate, Swindon Office (0793 411495).

Biotechnology

Copies of the *Report of the 1988 Biotechnology Review Panel*, chaired by Professor T Blundell, are available from Sue Cooper (see above).

Science-based archaeology

Copies of the *Science-based Archaeology Committee report 1985-88* are available from Janet Niven, Swindon Office (0793 411215).

Physics

Copies of the *Physics Committee report 1985-88* are also available from Janet Niven (see above).

Ceramics

Copies of the *UK technical ceramics register*, produced jointly by SERC and the Department of Trade and Industry, are available from Joe McIlherron, Swindon Office (0793 411021).

Particle physics

Copies of the *Particle Physics Committee annual report 1987-88* are available from Tracey Gilliland, Swindon Office (0793 411325).

Research funds from Europe

Have you ever thought about applying for research funding from the European Community? There may be more opportunities than you realised.

There are numerous schemes to support research and development under the EC Framework Programme, and further programmes may develop as a result of the mid-term review next year. SERC has an interest in several programmes and hence provides information and advice on them, primarily through the International Section at Swindon Office and the recently established UK Research Councils' European Office in Brussels (see box).

The SCIENCE Plan (a continuation of the Stimulation Plan)

If you have plans to collaborate with colleagues in a university or industry in another EC country, then you can apply for a grant under this Plan. It is open to all fields of science and provides the chance to identify and assist promising new areas or techniques of research in a rapid and flexible way. Grants for exploratory visits to define collaborative programmes are available from the British Council, 10 Spring Gardens, London SW1A 2BN. Application forms for proposals under the SCIENCE Plan can be obtained from Charles White, DGX11/H, Commission of the European Communities, Rue Montoyer 75, B 1040 Brussels, Belgium, and can be submitted at any time. There are no closing dates and applications are considered by the most appropriate meeting of the EC Committee for the European Development of Science and Technology (CODEST) which meets four times a year.

Three forms of support are available which can provide 100% funding:

☐ Research grants for personal mobility (so that individual researchers may go from one Member State to join a team in another, contributing their own expertise or developing a specialisation).
☐ Twinnings between research teams from at least two different Member States and from the academic or public or private sectors, for meeting costs, travel and accommodation expenses and extra staff and equipment needs.
☐ Operations with a specific result in view, where a contribution to the costs of existing staff and equipment can be made in addition to help given under twinnings.

If your application is unsuccessful and your institution is a member of the Brussels Office 'Club', Wendy Light, our European Liaison Officer in Brussels may be able to advise you on whether it is worth re-submitting a revised proposal.

UK European Liaison Officer in Brussels, Wendy Light.

BRITE/EURAM (Manufacturing Technologies and Advanced Materials)

Research will be supported on a shared-cost basis (50%) in a framework of European cooperation. It will promote collaboration in strategic industrial research between industrial firms and complementary centres of expertise in industry, universities and research institutes.

Two main types of shared-cost activities will be supported:

Type 1 projects of industrial applied research and

Type 2 projects in focused fundamental research. Type 2 support is intended for universities and similar organisations which may be funded up to 100% of marginal costs by the Commission.

Calls for proposals will be issued on an annual basis.

ESPRIT (European Strategic Programme for Research in Information Technology)

Support will be provided through shared-cost projects (50%). On present plans, the first focused calls for proposals will be in microelectronics, with other specific areas for fundamental research being earmarked later in the programme. The programme is designed to help provide the European information technology industry with the key components of technology it needs to be competitive in world markets. It aims to foster European collaboration and pave the way to standards of European origin, while boosting pre-competitive R&D in key areas of information technology.

Other programmes which are of interest to SERC's community include:

BRIDGE (Biotechnology Research for Innovation Development and Growth in Europe)

SPRINT (Strategic Programme for Innovation and Technology Transfer) and

RACE (Research in Advanced Communications Technologies for Europe).

Further information can be obtained from:

General — Alison Bowen, SERC Swindon Office (0793 411036);

SCIENCE Plan — Charles White, EC, Belgium (010-322-235-5369);

BRITE/EURAM — Graham Gadge, Department of Trade and Industry, London (01-215 6617);

ESPRIT — Dave Worsnip, SERC Swindon Office (0793 411104); and

Brussels Office Club — Wendy Light, Brussels (010-322-230-5275).

Diana Herbert
SERC Swindon Office

UK Research Councils' European Office

We have now celebrated the first anniversary of the launch of the Brussels Office. (see *SERC Bulletin* Volume 3 No 11, Summer 1988).

The 'Brussels Club' services, which are available to all universities and polytechnics through the Office for a fee of £1500 a year, are now well subscribed and are being enhanced all the time. Of course we would like to see even more institutions becoming part of the Club and so making use of the services that Wendy Light and Gaynor Whyles of the Brussels Office can provide. The Office can act as an advisory service to researchers on EC matters and as an early warning system on calls for proposals, closing dates or changes in the nature or priorities of a programme.

SERC enquiry points: new telephone numbers

As announced in *SERC Bulletin* Volume 3 No 12 (Autumn 1988), SERC has a new telephone system at Swindon Office. As a result, all staff can now be contacted through Direct Dialling In. The new general switchboard number is Swindon (0793) 411000. To contact individual extensions, dial Swindon (0793) 41+ extension number. The central fax number is Swindon (0793) 411400.

ASTRONOMY AND PLANETARY SCIENCE DIVISION

Studentships and fellowships	N R Mayl ext 1267

Ground-based Programme Committee

International activities	Dr A Game ext 1417
UK activities	Dr P W H Fletcher ext 1319
Research grants	C G Brooks ext 1359
PATT awards	Miss T Kerrigan ext 1198

BRITISH NATIONAL SPACE CENTRE

(SO: Swindon Office; MT: Millbank Tower, London SW1 4QU; 01-211 3000 or extension)

Space Science Programme Board

UK activities	Dr R L T Street SO ext 1265
Research grants	C G Brooks SO ext 1359
International activities	Dr P C L Smith MT ext 7290
Microgravity	Mrs Y Windsor MT ext 8111
ESA fellowship scheme, Young Graduate Trainee scheme	D Peters SO ext 1007

Earth Observation Programme Board

UK activities; International activities	Dr G Thomas MT ext 3957
Research grants	C G Brooks SO ext 1359

ENGINEERING DIVISION

Building	Miss S Charlesworth ext 1487
Civil engineering	V M Osgood ext 1155
Transport	Miss J Sykes ext 1353
Electrical and power industries	Mrs S R Hehir ext 1350
Aerospace	C P Whitlock ext 1350
Machinery, plant and vehicle	Mrs L Johnson ext 1117
Particulate and coal technology	Dr C Little ext 1476
Chemical engineering	Mrs D Warren ext 1492
Separation processes	Dr C Lines ext 1484
Joint ESRC-SERC; Studentships & fellowships	Dr A M Wilson ext 1238
Information dissemination	I Maxwell ext 1429
Design	A H Spurway ext 1102

DIRECTORATES

ACME (including manufacturing processes)	T J Keaney ext 1106
Biotechnology	Mrs A Williams ext 1310

Information Technology

Systems engineering	Miss R L Sirey ext 1260
Control and instrumentation	P O Hicks ext 1401
Communications and distributed systems	R Bond ext 1436
Devices technology	P N Burnell ext 1061
VLSI design and optoelectronics	Dr H Aldridge ext 1479
Systems architecture, speech and vision	N Williams ext 1478
Education and training	ext 1428
Teaching Company	Miss K Enifer
Faringdon (0367) 22822	ext 208

NUCLEAR PHYSICS DIVISION

Nuclear structure; studentships and fellowships	Miss C Armstrong ext 1331
Particle physics	Dr A E A Rose ext 1278
CERN	M Bowthorpe ext 1271

SCIENCE DIVISION

Biological sciences	Dr S J Milsom ext 1136
Mathematics	F Hemmings ext 1312
Neutron facilities; laser facility	M J Hotchkiss ext 1222
Physics; science-based archaeology	Miss F E Smith ext 1261
Chemistry	Dr P B Sharma ext 1496
Synchrotron radiation facility	Dr G C Stirling ext 1212
Pharmacy	Dr G Ll Richards ext 1323
Cooperative grants (Science); Secretariat	J R Peabody ext 1314
Science Board Computing Committee	Ms A Blanchflower ext 1113

MATERIALS SCIENCE AND ENGINEERING COMMISSION

Ceramic and inorganic materials	Dr S J Chambers ext 1110
Metals and magnetic materials	Miss R Wilson ext 1110
Polymers and composites	D R Mullins ext 1338
Medical engineering and sensors	Dr A Thomas ext 1338
Semiconductors	Ms J S Williams ext 1435
Molecular electronics	A G Buckley ext 1166
Superconductivity	Ms E Peacock ext 1361
Compound semiconductor technology	P N Burnell ext 1061

FINANCE

Account queries	P Bussey ext 1434

RESEARCH GRANTS

Most enquiries should be addressed to the appropriate subject committee.

Terms and conditions; supply of forms	ext 1405

STUDENTSHIPS

Applications

Advanced course studentships.	ext 1414
Research studentships; Studentships tenable abroad, including NATO.	ext 1316
CASE	ext 1082
General enquiries.	ext 1137

Current awards

For current studentships, give the switchboard the name of your institution.

FELLOWSHIPS

Postdoctoral (home, overseas and NATO); and advanced and senior fellowships.	ext 1172/1403
Royal Society/SERC Industrial.	ext 1206/1352

Anglo-Australian fellowships:
Ms K B Maunders, Royal Observatory, Edinburgh 031-667 3321 ext 249

CERN	ext 1325
ESA	ext 1007

Visiting fellowships on grants: Enquiries should be made to the appropriate subject committee.

INTERNATIONAL COLLABORATION

(except NATO and SERC studentships and fellowships tenable overseas) ext 1121/1404/i253

CENTRAL COMPUTING

Dr B W Davies, Rutherford Appleton Laboratory, Didcot (0235) 21900 ext 5547

LINK	S D Ward ext 1173
SERC BULLETIN	ext 1120
PRESS ENQUIRIES	ext 1257/1256

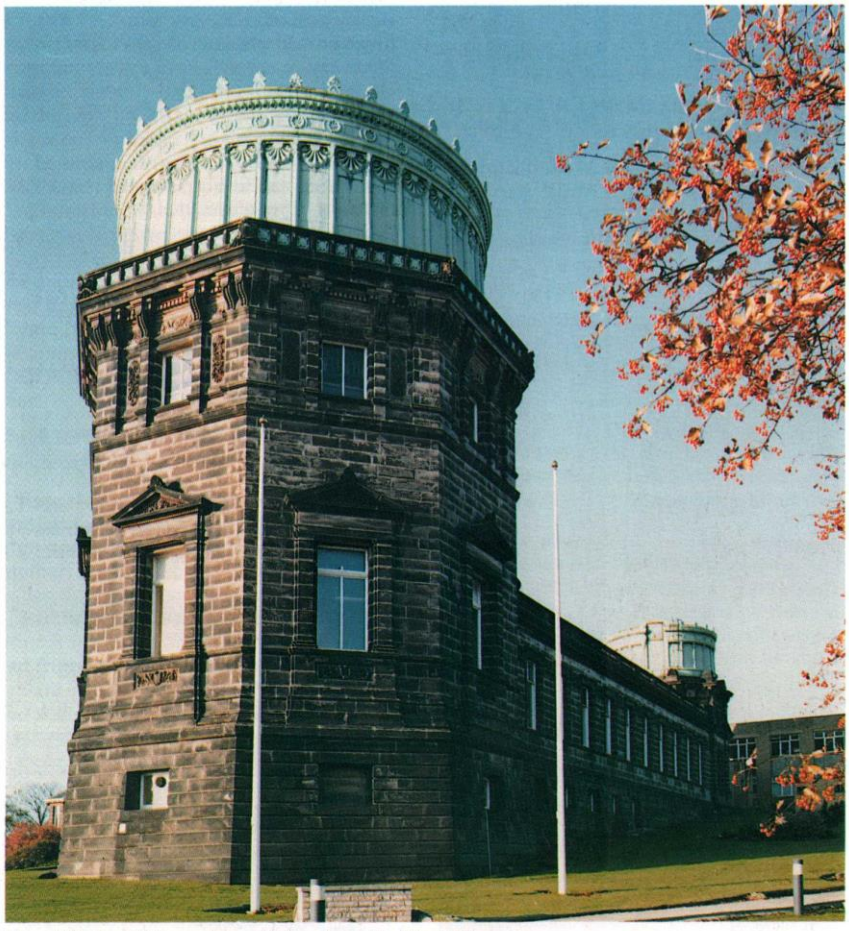
Centenary celebrations at ROE

Upwards of 100 staff and distinguished guests celebrated three linked events at the Royal Observatory, Edinburgh on 23 September 1988.

The first and most important was the centenary of the transformation in the fortunes of the Observatory that occurred in 1888 thanks to the generosity of Lord Lindsay, the 26th Earl of Crawford and Balcarres. In 1888, when the Astronomer Royal Charles Piazzi Smyth retired, the Royal Observatory was in a very run-down condition: it consisted of poor instruments housed in inadequate buildings and, because of the Observatory's situation then on Calton Hill in the middle of Edinburgh, it was no longer an appropriate place to make astronomical observations. A Royal Commission recommended the closure of the Observatory and a bill to this effect was brought before Parliament. On hearing this Lord Lindsay proposed, and the Government accepted, that he should present as a gift to the Observatory and the nation the instruments of his own well equipped Observatory (at Dunecht near Aberdeen) and also his unique astronomical library of 15,000 books, pamphlets and manuscripts, on the condition that the Government should build and maintain a new Royal Observatory. Construction on the Blackford Hill site began in 1893 and the new Observatory was formally opened in April 1896.

The nucleus of the superb collection of astronomical books and manuscripts given to the Observatory, now called the 'Crawford Collection', is housed in the 'Crawford Room' at the Royal Observatory in conditions of security and of controlled temperature and humidity. The room was formally opened in November 1972 by the 28th Earl of Crawford on the occasion of the 150th Anniversary of the title 'Royal' being conferred on the Observatory during the visit of George IV to Scotland in 1822. The Crawford Room has recently been extended so that more of the collection can be made accessible to research workers in the history of science. The official opening ceremony of the extension was performed by the present Earl of Crawford on 23 September.

The 26th Earl of Crawford and Balcarres, the Blackford Hill benefactor.



View of the Royal Observatory, Edinburgh, on Blackford Hill.

The final part of the celebrations was associated with the Astronomer Royal, Charles Piazzi Smyth, who retired from the Royal Observatory 100 years ago after a very colourful career. He was not only an accomplished astronomer but was also active in many other fields, including geodesy, spectroscopy, meteorology, photography and pyradmidology. He was also a talented artist and inveterate traveller and writer. The Piazzi Smyth archives, which were housed partly at the Royal Society of Edinburgh and partly at the Royal Observatory, have recently been consolidated at the Observatory. To celebrate this event, an exhibition illustrating the various facets of Piazzi Smyth's life was mounted.

The evening began with a welcome and introduction by Professor Malcolm Longair, Astronomer Royal for Scotland and Director of the Royal Observatory, followed by witty and entertaining speeches by Professor H A Brück, a former Astronomer Royal for Scotland and an authority on the life and work of Piazzi Smyth, and by the Earl of Crawford. The Observatory plans to commemorate the occasion by the production of a small publication, the core of which would be the speeches made in the course of the evening.