SERC bulletin

Science & Engineering Research Council
Volume 4 Number 8
Autumn 1991

Research and industry

This issue highlights some of SERC's many schemes for helping industry to benefit from academic research

SERC

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

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

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Reorganisation of Engineering Board

SERC's Engineering Board administration has been restructured, with the introduction of the Engineering Research Commission. Dr Barry Martin, Head of Engineering Division, explains the reorganisation.

The Engineering Research Commission brings together the present main discipline committees of the Engineering Board (the Electro Mechanical Engineering, Construction, Environmental Civil Engineering and Process Engineering Committees) together with the Engineering Design Committee, Marine Technology, and the joint ESRC-SERC Committee. It will report to the Board alongside the Information Technology Advisory Board, Education and Training, the ACME Directorate, Clean Technology and the joint bodies which administer Biotechnology and Materials research. The Commission is essentially a mini-Board and will advise the main Board on the distribution of funds between the discipline committees and smaller initiatives, leaving the Board to decide on policies between the large activities and the whole of Education and Training. From time to time (as was recently the case with Clean Technology) a major new initiative may arise from the Commission and be thrust forward to the Board and perhaps Council to compete for funds. The combination of Board and Commission will thus inject a considerable dynamism into engineering policy. Mrs Carol Dent takes charge of the Commission, at the same time retaining her responsibility for Biotechnology within SERC.

The Commission has a strong industrial flavour with six LINK programmes and a number of industrially relevant initiatives. A further feature of the new management arrangement is that Dr Roger Burdett will be bringing SERC's Industrial Affairs Unit into the Commission. This will not change the IAU's Council-wide role, but it should strengthen industrial input into the Commission's activities. He will also take responsibility for the Design Initiative.

IN THIS ISSUE

Front cover picture

CRISP, the neutron reflectometer on RAL's neutron scattering facility Isis, is much used in studies of direct interest to industry, such as the life of magnetic films, the drying of paint and the nature of plastic blends. See page 14.

Congratulations to . . .

Recently elected Fellows of the Royal Society:
Professor J E Baldwin (Cambridge University), Astronomy and Planetary Sciences Board member;
Professor K J Packer (British Petroleum plc), Science Board member.

Recently elected to the Fellowship of Engineering:
Professor J L Douce (Warwick University), Engineering Board member;
Dr G R Higginson (Southampton University), Council member and Chairman of Engineering Board;
Professor J L Knill, Chairman of Natural Environment Research Council;
Professor R E Smallman (Birmingham University), Materials Commission member;
Professor M J H Stirling (Durham University), Engineering Board member.

Senior staff moves

Dr R W Newport has been promoted to a new post of Associate Director, Programmes.

Dr M A Wilkins has succeeded Dr Newport as Head of Science Division. He was formerly Head of the Information Technology Directorate.

Council Commentary, March — July 1991

Closure of Daresbury's Nuclear Structure Facility

The eventual closure of the SERC Nuclear Structure Facility (NSF) at Daresbury Laboratory, foreshadowed as one of its measures to combat a shortfall in funding, was confirmed at the Council meeting in March.

Commenting on the decision, Sir Mark Richmond, Chairman of Council said:

"This was a very sad day for the SERC — we have been forced by shortage of funds to shut down a world-class facility for nuclear structure science. I greatly regret that the extra money needed for running beyond 1992 cannot be made available from within SERC's financial provisions. The Council will look urgently for ways to run the Nuclear Structure Facility up to closure both for the benefit of the UK community, and to honour the first stage of the EUROGAM agreement between SERC and CNRS, the relevant French Authority.

"Council will do its utmost to minimise the need for redundancies at the Daresbury Laboratory. Much excellent work will continue there, particularly through the use of the Synchrotron Radiation Source."

SERC support for nuclear structure physics

A panel, under the chairmanship of Professor Brian Fender, Vice-Chancellor of Keele University and a former chairman of SERC's Science Board, was convened in March to review SERC's future support for nuclear structure physics following the Council's decision to close the NSF. The Panel included overseas scientists nominated by the Institute of Physics.

At its July meeting, the Council asked the Nuclear Physics Board to look at the detailed scientific priorities for nuclear structure physics and to consider how expenditure on this topic could be accommodated within future programmes.

Council staffing

In the light of its financial situation, SERC has had to reduce several of its programmes, not only the NSF. In consequence it will need about 300 fewer posts across the whole of the Council by 1993. In July, the Council concluded that the measures it has so far introduced — for example, restrictions on recruitment and the promotion of early retirement schemes — will be insufficient, given the unusually low rate of resignations, to achieve this target. Accordingly volunteers have been invited to apply for early departure on redundancy terms.

Review of neutron facilities

As a result of recommendations by the Neutron Facilities Review Panel (chaired by Dr M Lomer), the Council decided to try to renegotiate the terms of UK membership of the Institut Laue-Langevin in Grenoble from 1994. It also decided to make a firm commitment to Isis, the spallation neutron source at RAL, until at least 1997.

The Royal Observatories

A panel set up in December 1990 and chaired by Dr Tony Hughes, Deputy Chairman of SERC, studied a number of options for redistributing responsibilities between the two Royal Observatories. It decided that no worthwhile financial advantage would result from such moves. The Council accepted this conclusion. The Royal Greenwich Observatory and the Royal Observatory, Edinburgh, will therefore continue to operate broadly as at present.

Global environment satellite support agreed

In April the Council agreed that SERC will take part in the first NASA satellite programme to enable long-term monitoring of key factors in global environmental change. SERC is to support the design of instrumentation (the High Resolution Dynamics Limb Sounder — HIRDLS) for the NASA Polar Platform Satellite (EOS — A1) due for launch in the late 1990s. HIRDLS will monitor the upper troposphere, stratosphere and mesosphere, determining the temperature and concentrations of a number of chemicals to provide valuable data on global warming and the size of ozone holes over the Earth's poles.

The design of HIRDLS will be carried out by a team led by Oxford University and the US University Corporation for Atmospheric Research, with the UK's half of the hardware being provided through Oxford and Reading Universities, RAL and British industry.

Council funding, of £13 million over 10 years, falls within the budgetary level agreed in the SERC financial review, announced in February 1991, which cut Council's planned spending.

Supercomputing steering group

A new SERC Supercomputing Management Committee was approved in April to oversee the Council's role as executive agent for managing supercomputing services on behalf of the Research Councils. This follows the transfer of responsibility for national supercomputing from the Computer Board to the Advisory Board for the Research Councils on 1 April 1991. The new committee will report annually through the Council to the ABRC on procurement of supercomputing services and technical options.

Superconductivity review

The National Committee for Superconductivity has prepared a review of progress in superconductivity for SERC and the Department of Trade and Industry. It concluded that the UK had made a significant contribution to an understanding of the new ceramic superconductors, but had been less successful to date in exploiting the applications of these new materials. It recommended that the academic scientific programme relating to both low and high temperature superconductivity should be continued.

Major grants in semiconductor materials

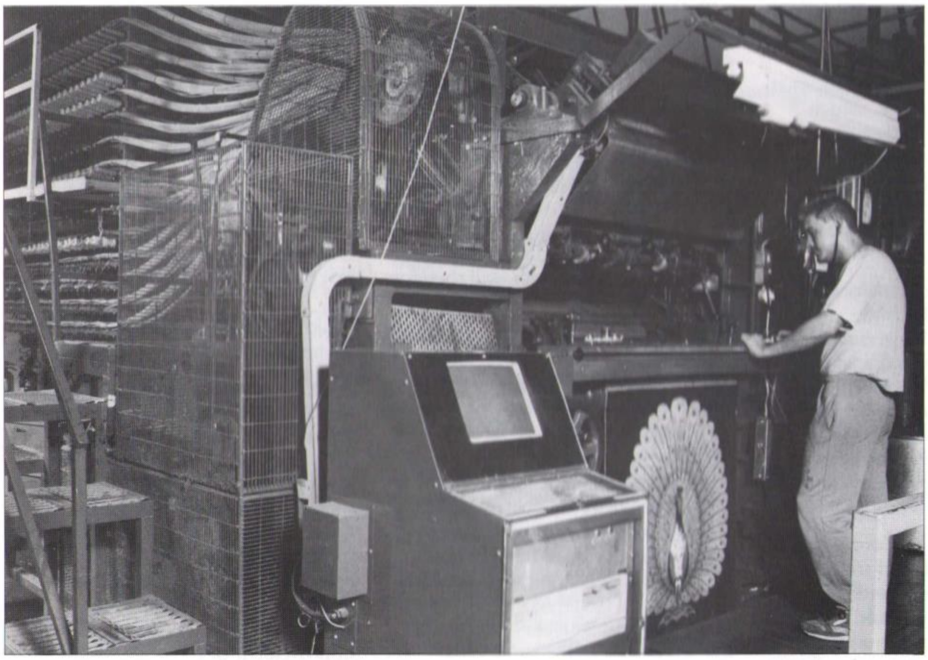
Two major grants were approved by the Council in April. A £1.7 million award was made to Nottingham University for phonon interactions in low dimensional structures grown by molecular beam epitaxy. A team at Cambridge University was granted up to £2 million to continue investigations into the physics of transport in low dimensional semiconductor structures and improvement of molecular beam epitaxy, growth and processing facilities. The main work involved at Cambridge was rated as 'world-class science which should be pursued vigorously' by the subcommittee which reviewed the grant application.

Industrial Affairs Unit — our second year

The Industrial Affairs Unit has now been in existence since February 1990. Dr Roger Burdett, Head of the Unit, reviews its progress.

The Unit was originally set up with three main aims:

- to encourage (and where necessary fund) collaboration between industry and higher education institutes on training, research and problem solving;
- to coordinate SERC's wide variety of schemes designed to bring together British industry and higher education to work for their mutual benefit. Some of these schemes are joint with other bodies such as the Department of Trade and Industry (DTI) and the Royal Society;
- to act as an interface and first point of contact between industry and SERC.



Computer-controlled loom on which carpet designs can be programmed at will; developed under a Teaching Company programme.

The first year has largely consisted of telling people of our existence and trying to discover those networks that already exist and which we can use.

The Unit has been received enthusiastically by large companies, especially those with a high-tech base such as pharmaceuticals and electronics. It is, however, still proving difficult to find ways of dealing with the thousands of small and medium-sized enterprises in the UK. Obviously it is not possible to speak to all of them individually. The academic institutions have, in general, also welcomed the setting up of the Unit.

Much of the year has been spent in giving presentations to industry, academics, trade associations and other influential groups, such as the National Economic Development Organisation, University Directors of Industrial Liaison, Association of Industrial Liaison Officers, Electronic Business Equipment Manufacturers Association, Inter-company Academic Relations Group of the chemical industries, the Society for Research into Higher Education, and the Confederation of British Industry. Individual companies such as ICI, Glaxo, GEC, Plessey and Babcocks have received presentations as have several academic institutions such as Liverpool University, Humberside Polytechnic and Aston University. European aspects of industrial collaboration and technology transfer have been approached through Technology Innovation Information and their technology transfer seminars. The Unit has made use of existing networks such as the DTI's regional offices, the Teaching Company's network of consultants, the technology transfer centres and of course the industrial liaison officers in the universities and polytechnics.

Publicity has been carried out through numerous mailshots as well as articles in many technical journals and the house journals of professional institutes.

Achievements

The Unit has also been influential in improving interactions between the research councils. Irregular meetings are now held between the industrial representatives of all the councils, although their roles are very different in each council.

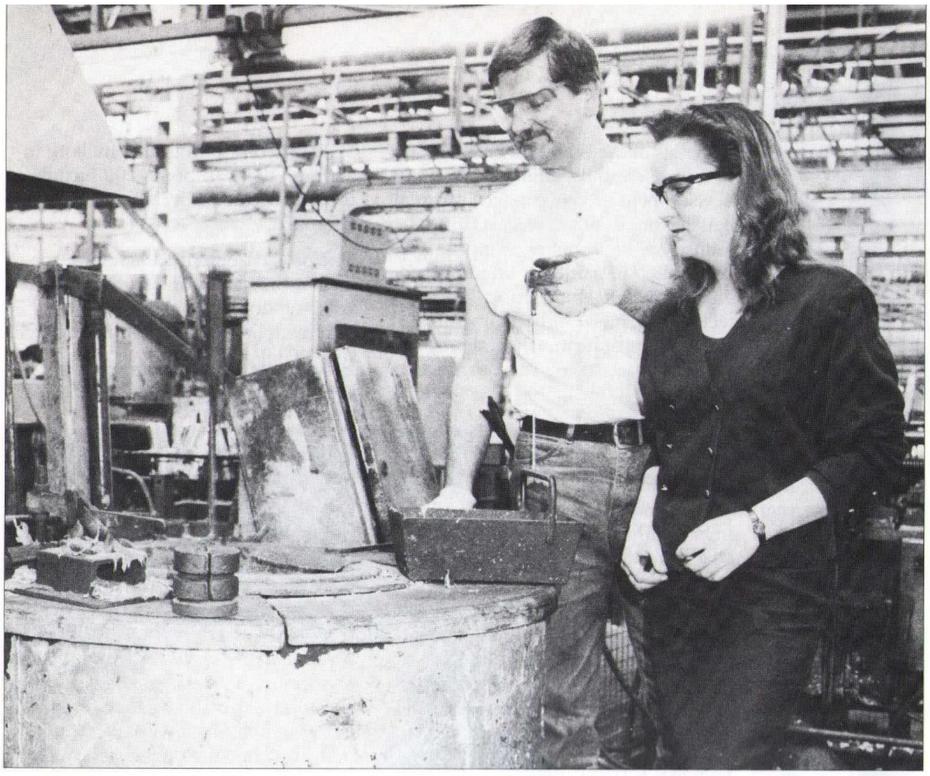
An important part of the Unit's role is overseeing of the LINK scheme for SERC. The IAU is the coordinating body for all matters LINK, and has built a strong rapport with the LINK secretariat based in the DTI. An important part of the role here has been in streamlining and coordinating SERC's methods with respect to LINK and in trying to influence DTI to take due notice of the SERC and academic points of view when making decisions on LINK (for more on LINK, see page 6).

While it would be unreasonable to say that the Industrial Affairs Unit was the main cause of the significantly increased take-up of Cooperative Awards in Science and Engineering in 1990, at least we may have been a contributory factor.

Several collaborations between higher education institutes and industry are known to have started with a phone-call to the Industrial Affairs Unit or a discussion over lunch at a meeting. These include one of the Industrial Fellows, at least one Teaching Company Scheme, a cooperative research grant or two and an Industrial Student.

The smaller company

It is not difficult to convince high-tech and research-oriented industries of the importance of academic/industrial interaction, but many of the older, more traditional industries such as machine tools and civil engineering are more conservative, especially as many of these industries consist largely of small companies.



Teaching Company Associate Eileen Feehan evaluates improved die-casting techniques in a programme between AE Piston Products and Birmingham University.

The IAU has developed agreements, within the chemistry/chemical engineering and electronic equipment industries, by which appropriate trade associations attempt to interest their member companies in considering SERC's 'unfunded alpha' awards for contract funding or cooperative research grant applications.

The Unit has been responsible for a new pilot scheme at Thames Valley Technology Centre aimed at short-term placements of students (both undergraduate and postgraduate) in small or smallish companies. It is hoped in this way to convince these companies of the importance of the latest research information and the employment of high-quality brain power. It is also important to improve the links between the smaller company and the student's polytechnic or university. It is too early to say how successful this scheme is going to be but, if as successful as we hope, it is intended to make it nationwide and self-supporting.

The Industrial Affairs Unit is also developing, with expertise in the Informatics Division of Rutherford Appleton Laboratory, a database of companies in the UK interested in research and academic collaborations. The database is intended to be user-friendly and interactive and available over a range of networks such as JANET.

The Industrial Affairs Unit has as its advisory body the Industrial Affairs Panel, directly responsible to the Council. This body meets two or three times a year to consider the work of the Unit and makes suggestions on its future policy and work programme.

Industrial affairs panel membership

Dr A E Hughes *Chairman*
(SERC Director Programmes)
Dr G H Fairtlough
C A P Foxell CBE, FEng (British Telecom)
Professor R E Hester (York University)
Dr A Ledwith (Pilkington Bros plc)
Professor J S Mason (Glasgow Polytechnic)
Dr D A Melford FEng

Who's who in the Industrial Affairs Unit
at SERC Swindon Office

Dr Roger Burdett
Head of the Unit
Telephone (0793) 411173

Tony Medland
LINK Coordinator
Mainly responsible for the LINK Programmes and for building our technology database
Telephone (0793) 411162

Fred Hemmings
Industrial Coordinator
Particularly responsible for interactions with other government departments and the DTI regional networks
Telephone (0793) 411162

Andy McKinna
Administrative Officer
The man who keeps the wheels turning
Telephone (0793) 411091

SERC schemes

Cooperative Awards in Science and Engineering
Research students (normally graduates) receive a standard SERC studentship, topped up with extra funds from industry and SERC, to carry out a research programme defined by the industrial partner in collaboration with the academic investigator.

The Teaching Company Scheme
Develops active partnerships between higher education institutions and industry in order to transfer technology and train able graduates for careers in industry.

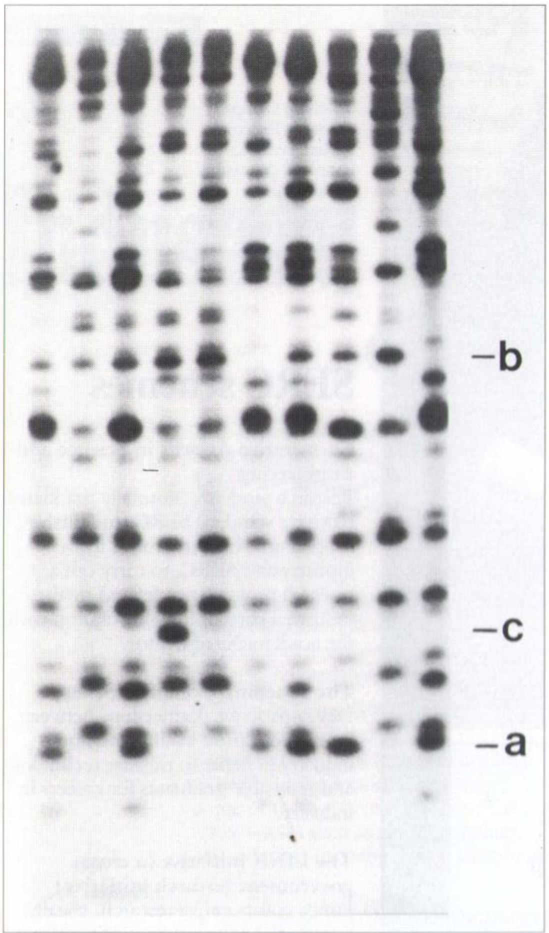
The LINK initiative (a cross-government research initiative)
Funds collaborative research, usually interdisciplinary and precompetitive, within specific targeted programmes of significant national importance. More than 20 programmes now exist, ranging from molecular electronics to crops for industrial use, and from nanotechnology to selective drug delivery and targeting. Each programme is funded 50:50 by industry and government (see page 6).

Industrial studentships
Give postgraduates in industry the opportunity to get a higher degree, without loss of salary, by working on a project of significance to both the company and academic department.

Industrial fellowships
Enable the more senior researcher in either industry or an academic institution to carry through a research programme significant to both.

Integrated Graduate Development
Provides an industrially oriented training programme in the first years of a postgraduate student's work with a company. The schemes are tailored to the needs of a particular group of companies.

Total technology
Provides a fully rounded engineering PhD with skills in all functions of engineering together with management skills. The scheme is currently being piloted in five universities.



"Possibly the best lager in the world": a genetic fingerprint.

LINK news round-up

New programmes

Four new programmes have recently been announced under the Government's LINK scheme for collaborative research with industry although only one, Medical Implants, involves SERC. This brings the total number of programmes within the scheme to 28. The new programmes are:

Medical implants

The use of materials for implanting in the human body is rapidly increasing, but a significant fraction of implant surgery today is to replace existing, worn out implants. This £10 million programme, jointly supported by government (SERC, Department of Trade and Industry, Department of Health and Medical Research Council) and industry, aims to provide second-generation medical implants with increased lifetimes. The use of novel materials in the body will be a key area of research leading ultimately to the development of new products that will benefit the patient as well as British industry as the supplier. Support will be targeted in particular on improved implant materials and fixing techniques; repair of bone fractures; vascular grafts; heart valves; dental implants; pacemakers and other active implants.

For further information contact Dr Alan Thomas, SERC Swindon Office, telephone (0793) 411108; or Brian Kent, Programme Manager, Laboratory of the Government Chemist, Teddington, Middlesex TW11 0LY; telephone 081-943 7464.

Enabling technologies for advanced rotorcraft: tackling the problems of safety, noise and efficiency in rotorcraft. SERC is not a sponsor for this programme but will maintain an awareness of its progress.

Contact: P Wilby, Materials and Structures Department, Royal Aircraft Establishment, Farnborough, Hants GU14 6TD; telephone (0252) 24461 ext 5108; or B Glenister, Department of Trade and Industry, 151 Buckingham Palace Road, London SW1W 9SS; telephone 071-215 6248.

Agro-food quality: stimulating improvements in consistency of food raw materials.

Contact: Dr Christiana Goodacre, Programme Coordinator, Laboratory of the Government Chemist, Teddington, Middlesex TW11 0LY; telephone 081-943 7346.

Hydrocarbon reservoirs: exploration, appraised and exploitation of oil and gas reservoirs.

Contact: K White, Offshore Supplies Office, Alhambra House, 45 Waterloo Street, Glasgow G2 6AS; telephone 041-242 5780 or Dr A T Huntingdon, NERC, Polaris House, North Star Avenue, Swindon SN2 1EU; telephone (0793) 411684.

Projects under way

SERC has agreed joint support for 23 of the 28 LINK Programmes to date, each lasting from three to six years (see box). SERC has made available funding up to some £52 million. Programme subject areas include topics in electronics and communications, measurement and sensors, materials, food and biosciences, and a range of engineering disciplines. There are now 150 active collaborative projects involving industry and higher education institutions, spread across these different programme areas to which SERC is contributing £14 million; in addition there are some 100 further projects that have been technically approved.

The projects described here give an idea of the quality and extent of the collaborations, and the interdisciplinary nature of the research.

Eukaryotic genetic engineering

This four-year SERC/DTI programme was announced in February 1988 to increase the understanding and control of the genetics of eukaryotic organisms.

At UMIST, Dr Richard Walmsley and Dr Barrie Wilkinson, in collaboration with Allied Breweries and Distillers (Yeast) Ltd, are applying the techniques of ***DNA fingerprinting for the identification of yeasts***. Species and strains of yeasts are notoriously difficult to identify with any certainty. Current methods involve the use of many physiological and biochemical techniques. For those industries using yeasts like the brewers or bakers, knowing which strain of yeast is being used is important for a variety of reasons including quality assurance, standardisation of production, and so on, particularly where production is licensed to other companies. Using a probe DNA sequence which is found at several places in every chromosome, Dr Walmsley is able to generate 'genetic fingerprints' which are unique for a particular strain. These appear as 'bar codes' as shown in the picture.

Dr Walmsley has been able to demonstrate the success of this technique for more than 40 strains of test yeasts and has found for example that while lager yeasts are all similar, ale yeasts are varied. He has shown that these fingerprints can be analysed by commercial machine vision and pattern comparison systems, so demonstrating the potential automation of identification and quality control procedures. He is now extending the work to other yeasts, including *Candida*, a pathogenic species that causes thrush in many individuals and death for some AIDS victims and transplant patients. Here automation will speed diagnosis and epidemiology. He is also refining the technique with the brewing strains to map and identify the genes involved in giving these yeasts their attractive characteristics.

Industrial measurement systems

Launched in April 1988, this six-year SERC/DTI programme now has 23 projects under way. The programme's coverage is broad both in technologies employed and application areas, concentrating on instrumentation and measurement technologies where there is an emphasis on systems integration.

Acoustic signal processing technology can now be considered for industrial process monitoring in a wide range of applications. Such technology has particular significance in process monitoring in the hostile conditions found in chemical and nuclear plant.

Mechanical noise can be generated as a result of fluid/wall friction or viscosity changes in moving liquids and is also influenced by solid material content. ICI, AEA Technology Sonomatics Ltd and UMIST are collaborating in a £351,000 project to further this technology. It is hoped this will result in its eventual application to a wide variety of process plant.

Current LINK programmes

Programme	Sponsors	£M*
Molecular Electronics	DTI/SERC	3.0
Advanced Semiconductor Materials	DTI/SERC	12.2
Industrial Measurement Systems	DTI/SERC	10.8
Eukaryotic Genetic Engineering	DTI/SERC	2.8
Nanotechnology	DTI/SERC	7.8
Biotransformations	DTI/SERC	5.0
Personal Communications	DTI/SERC	6.3
Selective Drug Delivery and Targeting	DTI/SERC/MRC	1.5
Construction Maintenance and Refurbishment	SERC/DOE	1.5
Food Processing Sciences	DTI/MAFF	7.0
Ventilation, Air Conditioning and Refrigeration	DTI/SERC	2.0
Optoelectronic Systems	DTI/SERC	15.0
Design of High Speed Machinery	DTI/SERC/AFRC	10.5
Structural Composites	DTI/SERC	21.0
Protein Engineering	DTI/SERC/MOD/AFRC/MRC	4.9
Biochemical Engineering	DTI/SERC	7.5
New Catalysts and Catalytic Processes	DTI/SERC	2.5
Power Electronic Devices and Derived Systems	DTI/SERC	7.0
Control of Plant Metabolism	DTI/SERC/AFRC	1.5
Molecular Sensors	DTI/SERC/DH/AFRC	5.5
Technology for Analytical and Physical Measurement	DTI/SERC	8.2
Transport Infrastructure and Operations	DTp/SERC	6.0
Asymetric Synthesis	DTI/SERC	3.5
Crops for Industrial Use	AFRC/MAFF/DAFS/SERC/DTI	3.0
Enabling Technologies for Advanced Rotorcraft	DTI/MOD	2.4
Medical Implants	DTI/SERC/DH/MRC	5.0
Agro-Food Quality	MAFF/DTI/AFRC	8.0
Hydrocarbon Reservoirs	NERC/DEn (OSO)	6.0

Key

* Government funding available (to be matched by industry)

AFRC — Agricultural and Food Research Council; DAFS — Department of Agriculture and Fisheries for Scotland; DEn(OSO) — Department of Energy, Offshore Supplies Office; DH — Department of Health; DOE — Department of the Environment; DTI — Department of Trade and Industry; DTp — Department of Transport; MAFF — Ministry of Agriculture, Fisheries and Food; MOD — Ministry of Defence; MRC — Medical Research Council; NERC — Natural Environment Research Council; SERC — Science and Engineering Research Council.

Optoelectronics

This five-year SERC/DTI programme, announced in April 1989, focuses on research into the integration of optoelectronic devices and techniques within optical communication and information processing systems, including work on devices and enabling technologies.

One recent project was on the development of high power ***optical pumps*** to improve the performance of optical fibre amplifiers radically and so permit more efficient and cheaper transmission of information through optical communication networks. Optical fibre amplifiers boost the light signal within the fibre without the requirement to convert the light into electrical signals, amplify it and reconvert it to light. They are much less complex than conventional electrical amplifiers, having only four components (the optical pump being one) and can be spliced directly into the fibre. Fibre amplifiers are seen by many as the key to future optical communication systems for both long distance transmission through underwater cables, for example, and for short distance systems, such as local area networks.

This £2 million project aims to use novel techniques to develop high power semiconductor laser pumps operating at the relevant wavelengths of 980 and 1490 nm. At present practical laser sources are not available at these wavelengths. Such pump lasers need to be reliable at very high output powers, with a 25-year life for use in underwater systems. Six partners are collaborating in this project: St Andrews, Glasgow and Southampton Universities, BNR Europe (formerly STC Technology), Plessey Casswell and MCP Wafer Technology.

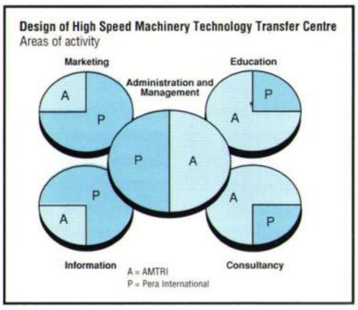
Design of high speed machinery

This five-year SERC/DTI/AFRC programme was announced in May 1989 to support research into the basic technologies underlying the successful design and construction of high speed, high performance machinery in a range of industrial sectors.

Loughborough University, together with Simon Container Machinery Ltd and UK Corrugated Ltd, are collaborating on a £714,000 project in ***mechatronics research for a new generation of corrugated board casemaking machines*** which, in simple terms, make boxes for the packaging and transport industries. A casemaking machine consists of up to 13 synchronised units, functioning as a continuous operation, which print and load the corrugated board, slot and crease, die cut, glue, fold, square, count, collect and palletise boxes. However, the dynamic relationships between the machine processes are not fully understood and the research will investigate these operations and develop ways to improve quality and productivity by reducing down-time caused by machine blockages and jamming.

There is no sensory instrumentation on the current generation of machines, and a novel sensory system will need to be developed to sense the distributions of both thickness and consistency and monitor these through each stage of the machine. The medium-term benefits are a potential increase in machine speed from 18,000 to 30,000 cases an hour, as the technology is incorporated in machine design. In the longer term, significant generic results could be applied to the paper, card, textile and packaging industries and the computer-controlled guide system will be relevant to a wide range of machinery currently using manual adaptation.

For further information on LINK and SERC's own collaborative schemes for research and training contact: Tony Medland, Industrial Affairs Unit, SERC Swindon Office; telephone (0793) 411162.



DESIGN OF HIGH SPEED MACHINERY TECHNOLOGY TRANSFER

The Design of High Speed Machinery Technology Transfer Centre aims to help in the developmental application and exploitation of technology relevant to the design, manufacture, and use of high-speed and high-performance machinery. It is an initiative supported by both SERC and the Department of Trade and Industry, but operated on a commercial basis jointly by the Advanced Manufacturing Technology Research Institute (AMTRI) and Pera International.

The initial idea of such a Centre arose out of the SERC Specially Promoted Programme (SPP) in the Design of High Speed Machinery which had, as one of its major goals, the effective transfer of technology to British industry.

The idea of a Technology Transfer Centre to assist with the broader goals of the initiative was investigated by Dr George Sweeney, the SPP Coordinator, early in 1988. Such a Centre was to include not only companies involved in current projects, but also those with a general interest in the technology, but without specific initiatives in mind.

At the inaugural meeting of the new LINK programme for the Design of High Speed Machinery, the concept of a Centre, already well advanced within the SPP, was endorsed. At later meetings, it was decided to invite proposals for the establishment and operation of a long-term, commercially funded Centre.

After consideration of a number of proposals, those from Pera International and AMTRI were considered the most attractive. The two organisations had submitted quite different approaches, with the AMTRI proposal stressing the role of education, design methodology and the data gathering in technology transfer, and the Pera International proposal making more use of information retrieval sources and commercial experience within the organisation. It was realised that the two proposals were complementary and that there could be considerable advantage in combining the strengths of both. However, perhaps the greatest advantage would be the creation of a role model which would demonstrate how organisations could work effectively together to achieve successful technology transfer, both for their own benefit, and for the greater benefit of the British economy.

In February 1991, AMTRI and Pera International agreed to establish and operate a joint Technology Transfer Centre which would combine the strengths of each organisation.

The Centre's activities will:

- support research organisations, especially those which are or have been involved in either SPP or LINK Design of High Speed Machinery projects, and will seek to encourage interaction between project participants and other relevant parties;
- support machinery users, designers in industry, machinery manufacturers, system developers and integrators, component and related equipment suppliers who have a research or manufacturing base in the UK;
- achieve effective technology transfer rather than merely promote it;
- seek to adapt available technology to requirements as well as influence requirements through educational activities;
- provide a reputable source of independent advice.

The Centre will not only play a vital role in increasing the competitiveness of British industry through the transfer of technology from the SPP and LINK Programmes, but will also provide a proven mechanism which can be utilised in other areas of technology development.

For further information on the Centre contact Hugh Thurbon at SERC Swindon Office, telephone (0793) 411117.

Industrial materials for the future?

A study identifying what structural materials will be needed by British industry into the next century has been jointly funded by SERC and the Department of Trade and Industry.*

The Institute of Metals, the Plastics and Rubber Institute and the Institute of Ceramics carried out the study under contract and interviewed top executives from a wide range of British companies. Both suppliers and consumers of materials took part in identifying what new materials they will require.

The results of the study will be used by SERC to assist in the selection of strategic areas of generic materials research. This will underpin industry's programme of applied research and development.

Two main issues have been considered: what influences the selection of materials and what developments in materials would most enhance a company's competitiveness?

The industrial sectors covered by the study are: consumer packaging, offshore and ocean resources, automotive, biomedical materials, construction and aerospace.

By way of an example, an examination has been made of the requirements of the British packaging industry where there is fierce competition between different materials, and environmental considerations are paramount. One wish was for a polymer which can be repeatedly remelted without degradation, especially of properties like transparency.

Further information can be obtained from:

Michael King
Materials Commission, SERC
Swindon Office; telephone (0793) 411022.
or
Roger Robinson
Department of Trade and Industry,
1/052 Red Core, 151 Buckingham Palace Road, London SW1W 9SS;
telephone 071-215 1476.

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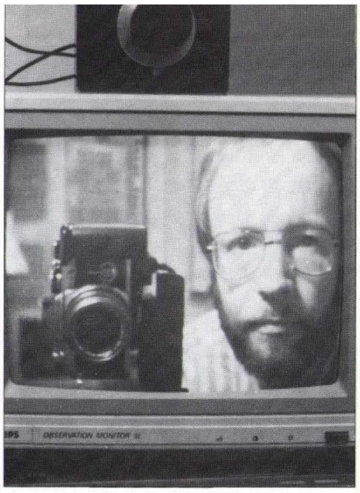


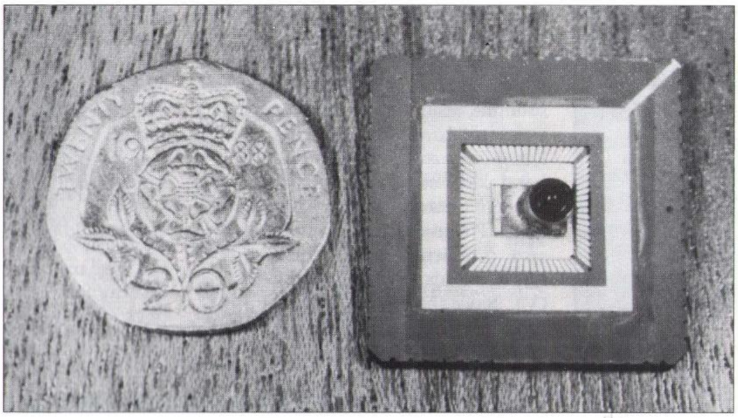
Image from video camera chip displayed on TV monitor.

Image sensing technology

Researchers at Edinburgh University have recently demonstrated the first integration of high quality analogue image sensors with digital image processing circuitry. This enables the manufacture of a single very large-scale integrated (VLSI) silicon chip with both these functions combined. The Edinburgh group, under Professor Peter Denyer and Dr David Renshaw of the Electrical Engineering Department, have produced several demonstration chips of this nature, including a miniature closed-circuit television camera integrated on one silicon substrate and incorporating a microlens bonded to the chip, as shown in the picture. This complete CCIR-compatible TV camera has automatic exposure control.

The market for electronic vision systems has, to date, been restricted by the technical limitations and capabilities of charge-coupled device cameras. The new capability for vision integration is not achievable by existing image sensing technologies and enables the production of image sensors at a substantially lower cost, size and power consumption than has previously been possible. The sensors are fabricated in standard CMOS VLSI technology and are powered from a single supply of 5V.

There is the potential to develop sensors for specific applications and so this flexibility is expected to allow the development of innovative products. Immediate applications are low cost 'micro' video and still camera products, and domestic and commercial security systems (low bandwidth remote video systems using combined image sensor and image compression devices interfaced to telephone lines via modems). The team at Edinburgh are already working on customised products for facial and fingerprint verification, and car number plate recognition. Further opportunities to be investigated include industrial inspection systems, computer vision, robotics and videophones. The University has established a company, VLSI Vision Ltd, to manage the development and commercialisation of this novel imaging technology.



Prototype video camera chip measuring 4mm x 6mm with lens attached and packaged in LCC for test and characterisation.

Support was provided for this work by SERC through the SERC/ Department of Trade and Industry Information Engineering Advanced Technology Programme. This programme was launched in 1988 with funding of £34 million from DTI and £27 million from SERC and has concentrated on selected topics where research is considered to contribute significantly to industrial competitiveness. There have been three calls for proposals and the funds are now fully committed.

Dr J Seed
Information Technology Directorate
SERC Swindon Office

Optoelectronics IRC opened at Southampton

The Interdisciplinary Research Centre (IRC) in Optoelectronics funded by SERC was formally opened on 5 July at Southampton University by Sir John Fairclough, former Chief Scientific Advisor to the Cabinet.

SERC has provided £11.13 million over six years to a consortium of higher education institutions led by Southampton University and University College London. Collaborations with Sussex, Oxford, Kent and Liverpool Universities have also been established as integral parts of the research programme. The director of the IRC is Professor Alec Gambling FRS.

The main themes within the IRC are optical physics, optical fibre technology and optical systems; with major aims being to develop miniature lasers, amplifiers and tunable sources based on optical fibres, crystals and planar waveguides. These would have a wide range of applications including sensors and biosensors.

Quantum jump in solar cell efficiency?

The direct conversion of sunlight to electricity in semiconductor solar cells has great potential as a sustainable, non-polluting source of energy. Two factors currently limit the widespread use of such cells: their relatively low efficiency and their cost. Quantum well structures, made possible by new semiconductor growth technologies, have recently led to important developments in lasers and other optoelectronic devices. Could quantum wells improve solar cell efficiency and costs? The first tests made by a group at Imperial College, London, look promising, as Keith Barnham reports.

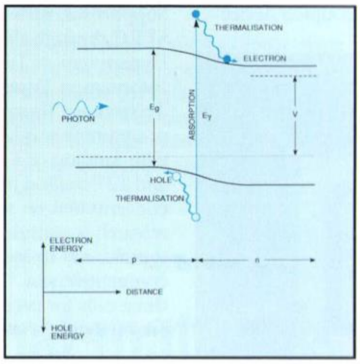


Figure 1: A conventional solar cell of bandgap E_g. A photon of energy E_γ is absorbed and creates an electron and hole with total energy greater than E_g. The carriers tumble down ('thermalise') to the lowest energy states and are swept apart by the electric field between the p and n regions.

Even in the UK, solar cells could make a major contribution to energy supply. All the average household's non-space heating electricity needs could be provided by just over 2 m^2 of collector if 50% efficient solar cells and suitable storage were available. Conventional solar cells have efficiencies in the 5-25% range but the absolute limit is 95% according to thermodynamics. Hence there is considerable potential for development and a need for basic research. Our group at Imperial College is investigating whether quantum wells (see box) could help bridge this efficiency gap. The work is funded by SERC's Low Dimensional Structures and Devices Initiative and the Greenpeace Trust and benefits from collaboration with the new Interdisciplinary Research Centre in Semiconductor Materials.

The first results are encouraging. We have doubled the efficiency of some test devices by incorporating a quantum well system. Conventional GaAs solar cells are already produced by MOVPE (see box) so in principle quantum wells could be added during growth with little additional expense. Quantum well solar cells should also have properties that will make them particularly suitable for use in concentrated sunlight, so reducing costs.

A conventional solar cell consists of a p-n junction in a semiconductor of band-gap E_g (figure 1). Electron-hole pairs are produced when light with energy E_γ greater than E_g is absorbed. If the electron and hole are produced close to the p-n junction they are separated by the electric field and move in opposite directions, producing a *current*. Semiconductors with smaller band-gap absorb more sunlight, resulting in higher output current. However, the carriers rapidly lose energy and 'thermalise' to the band-edges and so much of the incident photon energy ends up as heat. The use of larger band-gap semi-conductors reduces this energy loss and leads to higher output *voltage* (V). Since the output *power* is the product of current and voltage, the choice of band-gap is a compromise.

This trade-off between current and voltage produces a maximum theoretical power conversion efficiency for a conventional cell of about 30% at a band-gap close to that of GaAs (1.4 eV).

In principle, higher efficiencies could be achieved by stacking together several solar cells with different band-gaps. In practice connecting them together optically and electrically has proved difficult. The quantum well solar cell (figure 2) is an alternative approach which works on a different principle. The region over which the electric field of the p-n junction operates is larger. It contains a layer of undoped (intrinsic) material and includes a number of quantum wells (in practice 50 or more). For light with energy E_γ greater than E_g the new cell behaves like a conventional solar cell. However, many photons with energy less than E_g and greater than E_a will be absorbed in the quantum wells. The electrons and holes which are created in the well can either escape from the well (by tunnelling or absorbing heat energy) or they will be lost by recombination. Our results show that in good material at room temperature the escape processes dominate. The escaping electrons and holes are separated by the electric field and collected as current.

Note that the opposite process is occurring to that in the conventional cell in figure 1. These carriers are 'thermalising' up to the bulk band-edge. The cell generates extra current from the photons absorbed with energy less than E_g and the output voltage should be similar to that in a conventional cell of band-gap E_g. This is the principle of the quantum well solar cell. Efficiencies of more than 40% should be achievable.

We have tested the principle of the quantum well solar cell by studying photodiodes produced by MOVPE at the SERC III-V Semiconductor Facility at Sheffield University. In recent years

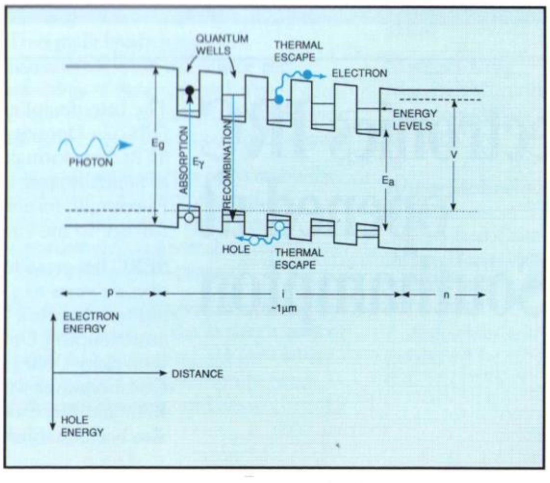


Figure 2: A quantum well solar cell absorbing a photon of energy E_γ which creates an electron and hole in the quantum well. These can then recombine (emitting photons) or absorb thermal energy and escape from the well where they are separated by the electric field in the undoped (intrinsic) region. Note that the output voltage is similar to that of a conventional cell with bandgap E_g (figure 1), while the current has increased.

extensive studies have been made of these devices as detectors and modulators for optical communications. In such applications a large external field is applied across the wells and the devices have a high *internal* 'quantum efficiency' (the probability for collecting the electron and hole once a photon has been absorbed in the well). Little is known about how they work using only the electric field of the p-n junction as happens in a solar cell. In fact we find that, if the material quality is good, the quantum efficiency remains high in this situation.

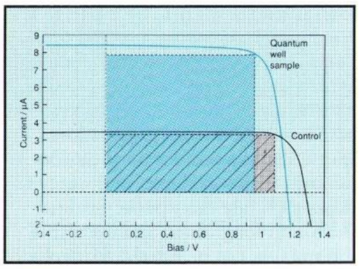


Figure 3: Current-voltage (I-V) characteristic under white light illumination (a tungsten bulb) for a test device with 30 quantum wells. The output power is given by the area of the coloured rectangle. Also shown is the I-V characteristic of the control device which contains no wells but has an equivalent thickness.

We have compared pairs of test devices which were grown in identical conditions except that one had 30 quantum wells and the other (the control) had no wells. Figure 3 shows the current-voltage characteristics of one such pair under white light illumination (a tungsten bulb). The output power is given by the area of the rectangle. It can be seen that the device with the 30 quantum wells has more than twice the power conversion efficiency of its control.

These test devices are not yet solar cells, having been designed to resemble successful photodiodes. However, similar efficiency enhancements should be carried over to practical solar cells. This is suggested by the similarity of the

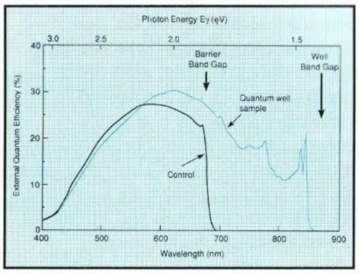
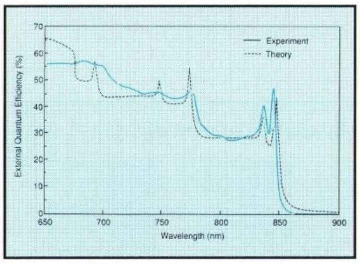


Figure 4: External quantum efficiency for a test device with 30 quantum wells and its control device. Note that the effect of the wells is to absorb light with energies less than the bandgap of the barrier.



response of quantum well and control devices to photons of energy greater than E_g. The *external* quantum efficiency (the probability for collecting the electron and hole per photon incident on the cell) for one test device is compared with the control in figure 4. For wavelengths less than 600 nm the curves are similar.

Our most recent results confirm that further efficiency enhancements are possible. The characteristics of the devices are being improved. For example, a 50-well sample grown recently by molecular beam epitaxy at Philips Research Laboratories, Redhill, has a power conversion efficiency more than double that of the test devices in figure 3. The 'external' quantum efficiency of this new sample is compared with our theoretical predictions for the wells in figure 5.

One important advantage of a quantum well solar cell is that, as temperature rises, the probability of the carriers escaping from the well increases while the probability of the carriers being lost by recombination falls. The use of concentrated sunlight is one way to reduce dramatically the cost of solar cell systems. However a major problem is that the cells get hot. Conventional solar cells lose efficiency as temperature rises because the band-gap falls but a quantum well solar cell could be designed so that the efficiency increases as its temperature rises.

To date our tests have been made with GaAs wells and the alloy AlGaAs as the barrier. Some other materials, of the many which are being studied as part of the LDSD Initiative, may prove to be even more suitable for quantum well solar cells. Furthermore, understanding how carriers escape from quantum wells at room temperature is important for any LDSD device which involves fast switching speeds or high absorption. Hence this project has relevance for materials, device and physics aspects of the LDSD programme as well as the potential to make an important impact on solving some of our environmental problems.

Dr Keith Barnham
Physics Department,
Imperial College of Science Technology and Medicine, London

Figure 5: External quantum efficiency for a recently grown 50 well sample. The theoretical curve assumes that once the photon has been absorbed there is a more than 90% probability that the electron and hole pair will escape from the well and be collected (internal quantum efficiency above 0.9).

QUANTUM WELLS

Most physics and chemistry undergraduates will have encountered the potential well as their first problem in undergraduate quantum mechanics. New crystal growth techniques such as metalorganic vapour phase epitaxy (MOVPE) and molecular beam epitaxy (MBE) have made it possible to produce quantum wells in practice.

A quantum well is formed, as in figure 6, when a very thin layer (around 10-50 times the inter-atomic spacing) of a narrower band-gap semiconductor (the well) is grown in between regions of a wider band-gap semiconductor (the barrier). In good quantum wells the edges are extremely sharp. The change is over one or two atomic spacings.

Electrons and holes show their full quantum properties in these wells. They can only occupy certain energy levels with the wave functions shown in figure 6. They can tunnel or be excited thermally out of the wells.

Quantum wells have not, until now, been considered as the active elements in solar cells. However, they are already in use in lasers (many of the latest compact disc players use quantum well lasers) and in ultra-fast electronics (the fast transistors used in satellite TV dishes have electrons moving along similar wells). In the future they will form the basis of the elements used in computers which use light to transmit information rather than electric currents. The SERC Low Dimensional Structures and Devices (LDSD) programme has enabled the UK to be at the forefront of these important developments.

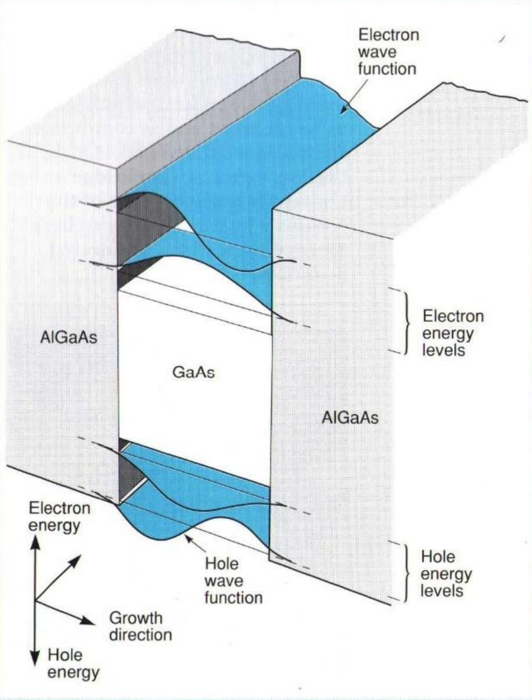
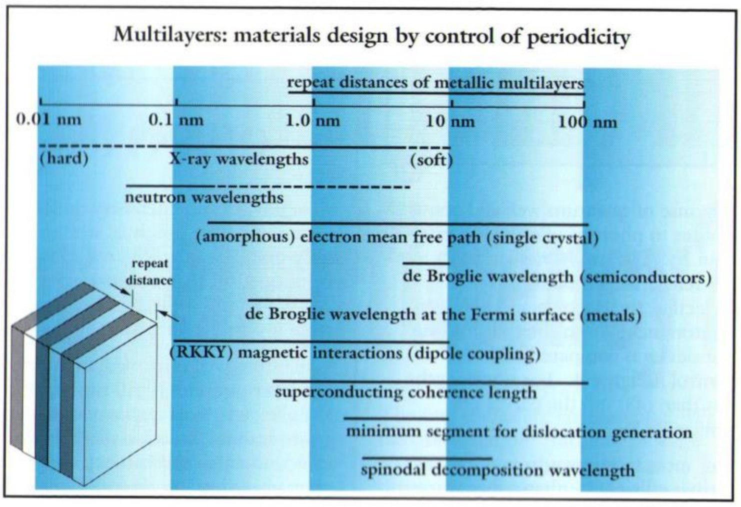


Figure 6: Schematic representation of a quantum well showing allowed energy levels and wave functions of the confined electrons and holes.



As can be seen from this rough guide, the repeat distances in metallic multilayers can now be reduced to be comparable with important length-scales underlying physical properties. Novel effects can be expected and have been observed, for example: increased X-ray reflectivity, various types of coupling between alternating magnetic layers, increased yield stress.

Metallic multilayers

Research on semiconductor multilayers over the past 20 years or so has created the new field of band-structure engineering and has been of considerable commercial importance in revolutionising semiconductor device design. In comparison, metallic multilayers, though a subject of research for some 60 years, have languished in some obscurity. Now, however, they are attracting increasing attention as improved fabrication techniques permit new phenomena to be observed and as commercial applications are realised. Dr Lindsay Greer of Cambridge University outlines some of the reasons why we are likely to hear more of these novel engineered materials.

A multilayer is made by the alternating deposition of two different materials. Repeat distances (the thickness of two adjacent layers) typically fall in the range of about 1 to 100 nm, much finer than laminated composites. Indeed, the design and fabrication of multilayers are virtually materials engineering on an atomic scale, with individual layers as little as 2 or 3 monolayers thick. Most physical properties have an associated length-scale (see box above). The repeat distance in metallic multilayers can now be made comparable to many of these, and when it is, novel properties can be expected. While all of these length-scale effects are of scientific interest, some novel properties of metallic multilayers have already found commercial application.

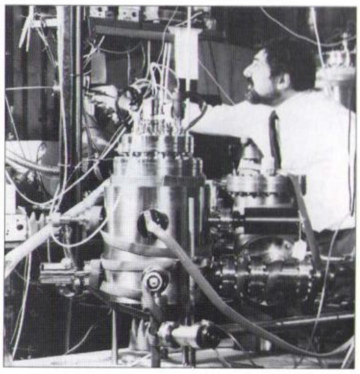


Figure 1(a): One of the dc magnetron sputtering systems at Cambridge. The outer can filled with liquid nitrogen ensures very low outgassing rates from the chamber walls and consequently high purity.

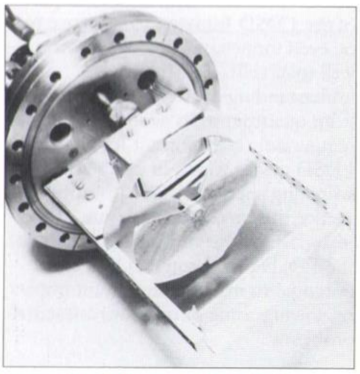


Figure 1(b): A close-up of a simple flange, showing a magnetron target (rectangular), shield, rotating shutter and substrate table.

Production

The range and reproducibility of the novel properties of metallic multilayers are limited by the quality of the materials available. Improvements in the control of layer thickness (constancy during deposition and uniformity across the substrate), in the smoothness of the layers and in the purity obtainable at higher vacuum, together with the wider range of epitaxial multilayers available through the use of graded buffer layers, have enabled the current growth of research on the properties of metallic multilayers. At the heart of the multilayers research programme at Cambridge are the facilities for dc magnetron ultra-high vacuum getter-sputtering built up by Jan Evetts and Rob Somekh (figure 1). A major part of the work is the development of sputtering as a process for precision deposition; for example, uniformity of deposition rate can now be held to 0.1% over long times, and interfacial intermixing can be limited to involve only two monolayers. While most metallic multilayers have been deposited by sputtering or by conventional evaporation, they are increasingly being grown by molecular beam epitaxy (MBE), which is the standard technique for semiconductor multilayers.

Structure and characterisation

There are multilayers in which each layer is a single crystal, epitaxial with the layer below. Such materials could be represented by the imposition of a composition modulation on a single crystal, and have been termed superlattices. This type of structure is the only one of importance for semiconductor multilayers, but their metallic counterparts show a much wider range of types. The structure in the layers may also be polycrystalline (of widely ranging grain size), or amorphous, and various combinations are possible. General characterisation of multilayer structure is mostly by X-ray diffraction. Among the special effects of the layering is the appearance of satellites about the Bragg peaks. For compositionally modulated amorphous materials these satellites appear only about the zero-order beam (figure 2). Transmission electron microscopy is a complementary technique, providing local information; at Cambridge, Mike Stobbs and his group have examined local defects (figure 3) and interfacial composition profiles (figure 4).

Interdiffusion studies

Diffusional mixing between the different materials in a multilayer may

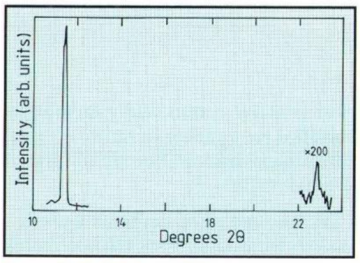


Figure 2: CuKα X-ray diffractometer trace from an amorphous $Ni_{65}Zr_{35}/Ni_{65}Hf_{35}$ (atomic) multilayer with 400 periods and repeat distance of only 0.78 nm. The second order satellite peak is just visible.

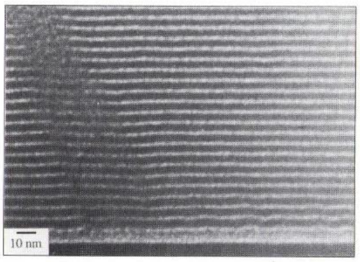


Figure 3: Cross-sectional bright-field transmission electron micrograph of a W/Si X-ray mirror (repeat distance 6.5 nm), showing levelling out of substrate-derived unevenness in the layers.

be important during deposition, or may limit the lifetime of the multilayer. It is also an interesting subject of study in its own right, as shown by the work of John Hilliard and his colleagues some 20 years ago at Northwestern University, Illinois. In the steep concentration gradients achievable, the interdiffusion coefficient shows a dependence on the repeat distance and on coherency strain. Also, the short diffusion distances in multilayers permit the determination of exceptionally low interdiffusivities ($\geq 10^{-27}$ $m^2 s^{-1}$). This allows the measurement of interdiffusion in metastable and unrelaxed structures. At Cambridge attention has focused on amorphous alloys of the type exemplified by Ni-Zr. It has been shown that mobility of the larger species (Zr) in such a glass is only about one millionth that of the smaller, a disparity believed to be of importance in solid state amorphising reactions. The multilayer technique was vital in enabling determination of the mobility of the slow species without crystallisation of the alloy.

X-ray and neutron mirrors

Metallic multilayers are now commercially available to replace and improve upon the capabilities of conventional long-period crystals in spectrometers. Multilayers can also be used as elements in larger structures to achieve greater efficiency in wavelength dispersion. The multilayers can be separated by a deposited spacer to give a Fabry-Pérot étalon or can be lithographically patterned. By extending to smaller repeat distances the principles of multilayer design well developed for visible light, Eberhard Spiller at IBM's T J Watson Laboratory has demonstrated that reflectivity can be controlled for a range of wavelengths at normal incidence. Of use mainly with soft X-rays ($\lambda \sim 5$ nm), normal-incidence mirrors can be applied in telescopes and microscopes. Reflectivities of about 20% have been achieved, indicating a possible application in X-ray lasers. Multilayers are also of interest for the reflection of neutrons (λ = 0.05 to 5 nm), where they can be used as monochromators and as polarising mirrors. Whatever the details of the application, it is clear that achieving design properties rests on control of layer thickness and interface quality. These processing issues are the focus of current work at Cambridge in this area.

Magnetic properties

As recognised within SERC's Magnetism and Magnetic Materials Initiative, metallic multilayers, with the degree of control that is at present possible in their deposition, offer an exciting range of opportunities for fundamental studies of magnetism. The decay length of the interaction between magnetic spins is within reach of multilayer repeat distances. Layers of magnetic spins well separated by non-ferromagnetic layers do not couple from one layer to another and show two-dimensional ferromagnetism. When the ferromagnetic layers are closer, however, examples of parallel, antiparallel and helical coupling have been demonstrated. There has also been interest in multilayers (such as Fe/V) which unusually permit the co-existence of magnetism and superconductivity.

In addition to the longer term potential for application of novel magnetic properties in devices, there is much immediate interest in polycrystalline multilayers as alternatives to rare earth-transition metal thin films for magneto-optic recording. The multilayers require some care in deposition, consisting of Co layers only about 0.4 nm thick, with Pt or Pd layers around 1 nm thick. Work at Cambridge is on the influence of deposition conditions on structure and properties. The desirable properties of coercivity and squareness of hysteresis loop are improved at higher sputtering pressure (figure 5), corresponding to lower bombardment during deposition. Interestingly, the better properties are found for less perfect structures, in particular, rougher interfaces.

While X-ray and neutron reflectivities are already used commercially, and magneto-optic recording may soon be, there are many other properties of metallic multilayers awaiting exploitation such as elasticity, plasticity and superconductivity. De Broglie wavelength effects on normal-state electron transport, while readily observable in semiconductor multilayers, are because of the shorter length just becoming observable in metallic multilayers. Yet further possibilities are opened up by the as yet little explored area of metal/ceramic multilayers. In all, a great deal remains to be done, not only in fundamental studies, but in exploiting the remarkable capabilities for tailoring the properties which metallic multilayers offer. In every case, however, progress will rely on tackling the processing issues in multilayer fabrication.

Dr A L Greer
Department of Materials Science and Metallurgy
Cambridge University

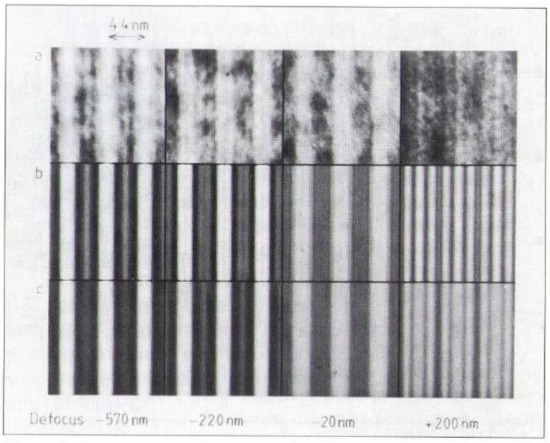


Figure 4: Fresnel contrast in transmission electron micrographs used to estimate interface sharpness by comparison with simulated images. The images (a) of a Cu/Ni-Pd multilayer at different defoci most closely resemble the calculated images (b) assuming intermixing over two atomic planes at the interface. (Calculated images (c) correspond to four mixed layers.)

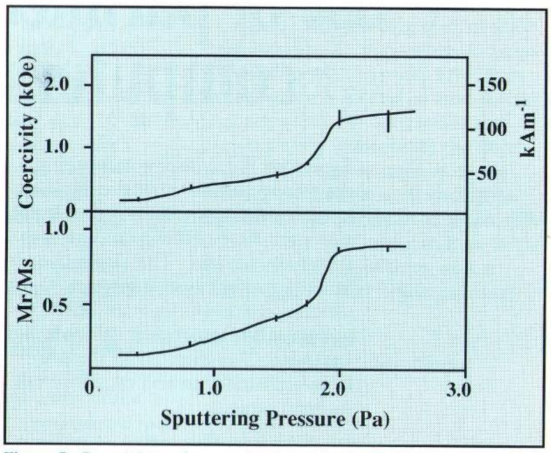
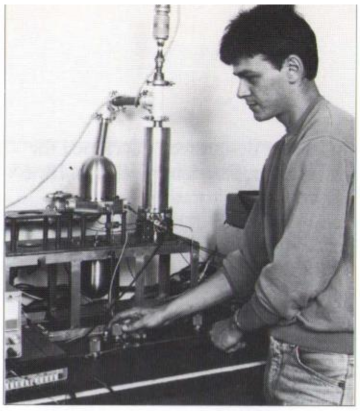


Figure 5: Coercivity and magnetisation ratio (indicating squareness of hysteresis loop) as a function of sputtering pressure for Co/Pd multilayers (0.3 nm Co/1.2 nm Pd).



Jamie Hieatt working on the two-stage cooler at RAL.

RAL's two-stage cooler available to industry

RAL Research Services (RRS) is the small but significant commercial part of the Rutherford Appleton Laboratory's activities. While support for the British academic community will always take priority, access to the special facilities at RAL (microelectronics, Isis and supercomputing), plus the expertise of the scientific staff, can be used for the benefit of industry. Typical of this activity is the work described here by Dr Tom Bradshaw of RAL's Applied Science Division.

Many space instruments require cooling to low temperatures to increase the sensitivity of infrared detectors. Missions relying on cooling from liquid helium could have their lifetimes greatly extended by using active shield cooling for the cryostats. RAL has been involved in the development of a range of closed cycle coolers suitable for long-life operation in space.

The original single-stage coolers were developed by RAL and Oxford University for the Improved Stratospheric and Mesopheric Sounder, an Oxford University instrument. This instrument will be launched later this year as part of NASA's Upper Atmosphere Research Satellite. A similar cooler was developed and built at RAL for the Along Track Scanning Radiometer on ERS-1. These coolers produce more than ½ watt of cooling at 80 K. The technology has been transferred to industry by way of the British Technology Group and such coolers, now available commercially, have been specified for a variety of future instruments both in Europe and the United States.

RAL has continued development of coolers to produce lower temperatures with internal funding and through contracts awarded by the European Space Agency (ESA).

A recent major development is a cooler that will produce liquid helium temperatures — around 4 K (-269°C). The cooler consists of a two-stage Stirling cycle refrigerator developed from the original machines which is used to pre-cool a Joule-Thomson system. It is this stage which allows temperatures of around 4 K to be reached.

First results on this system are encouraging. Useful cooling powers at 4 K have been obtained with input powers that are comparable to the power available on a typical spacecraft. The cool-down time from the pre-cooler temperature of around 30 K is quick, around three hours. This technique may eventually replace bulky helium dewars on long-life space instruments and will reduce the volume, mass and cost.

Once again the technology has been transferred to industry through the British Technology Group.

Further details of the full range of RSS facilities can be obtained by contacting the RRS Coordinator, Geoff Lambert, at RAL, telephone 0235-44-5663 or e-mail GAL@UK. AC. RL. IB.

Boost for industrial use of parallel computers

Exploiting the immense computing power provided by parallel computers for industrial applications is the aim of a programme based at four centres in British universities. The £34 million funding package over four years includes contributions from SERC (£4 million) and Department of Trade and Industry (£9 million), with the rest from industrial partners taking part in research projects.

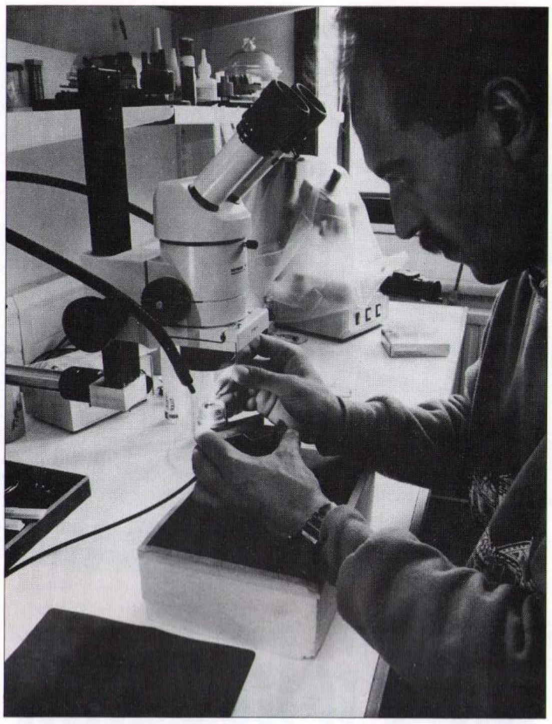
Parallel computing, which provides vast amounts of power compared to conventional computing, has been taken up slowly by industry mainly because of the difficulty of developing versatile, efficient software. The programme will bring together interdisciplinary teams at each centre to demonstrate effective solutions for industrial applications developed from research in parallel computing, and ensure that they are exploited by companies.

The four research centres, due to open from Autumn 1991, are at Edinburgh University, London University (Queen Mary and Westfield College, Imperial College of Science and Technology and Medicine and University College), Oxford University in association with SERC's Rutherford Appleton Laboratory, and Southampton University.

Commenting on the initiative, Sir Mark Richmond, Chairman of SERC, said: "This is a perfect example of how SERC-supported fundamental research in leading-edge computing can become the catalyst for the next generation of industrial products."

Some of the key projects are:

- Developing systems which can comprehend and process human speech.
- Real-time visualisation enabling users to 'walk through' images on screen, based on interaction with large datasets.
- Developing parallel processing telecommunications networks for application to high-bandwidth connections, integration of local and wide area networks and transmission of large files.
- Implementing solution algorithms using the multigrid technique on parallel computers, for flow calculations in aircraft design.
- Applications of neural computing in such diverse areas as medical imaging and marketing.



Nick Ferneyhough of RGO inspecting the male coupling that joins lengths of optical fibre from the prime focus of the William Herschel Telescope.

RGO's work on optical fibres

The use of optical fibres to take light from the focus of an astronomical telescope to an instrument requires significantly different techniques from those used in the communication industry to convey digital signals, writes Dr Peter Andrews of the Royal Greenwich Observatory (RGO). In industry the ratio of signal to noise is very high and significant losses in signal strength can be made up by amplifying the signal without decreasing its information content whereas in the astronomical application any loss is serious.

The problems that are being solved at RGO concern the reduction of losses at the ends and junctions of these fibres. From the feed from the automatic fibre location instrument — Autofib, being developed at Durham University — about 150 fibres emerge. These all have to feed into the WYFFOS spectrograph being designed at RGO. The overall design is that spectra of up to 150 objects in a one-degree diameter field can be obtained simultaneously, thus vastly improving the efficiency of the William Herschel Telescope on La Palma.

At RGO, because of the requirement to keep the pass-band of the fibres to as much as possible of the range from the ultraviolet to the near-infrared, fused silica fibres coated with doped silica and protected by a polyimide buffer are used. For applications such as the feed from the prime focus of the William Herschel to its Nasmyth focus, fibre lengths of up to 20 metres are needed. Losses in the fibres vary with wavelength and the type of fibre adopted. Typically a throughput of 50% at 350 nm rising to 91% at 500 nm and 95% at 600 nm can be achieved with a 20-metre length if radii of curvature greater than 10 cm are maintained. The losses in the infrared are dominated by OH-bands; at 1 micron, for example, the throughput is down to 40%. The balance between the efficiencies at the blue and red ends of the spectrum depends on the OH content of the silica.

The fibres have a diameter of 100 microns, corresponding to two arcseconds at the prime focus of the WHT, and special techniques have had to be developed to reduce losses at the ends of the fibres and at fibre junctions. Removal of the instrumentation from the telescope would obviously be impractical if the fibres were continuous from prime to Nasmyth foci. Special connectors have been designed so that the ends of two fibres can be accurately aligned, using a special jig, to within a micron before they are joined. The keyed junction of 10 fibres is then cemented together and when solid is halved using a diamond saw. Each end is then optically polished and the union reassembled using optical gel. Losses at such junctions are less than 2.5%.

The remaining source of light loss is at the ends of the fibres. At the prime focus end attachment is made to small prisms which accept the light at the telescope focus. The attachment can be made with the same small light loss as the fibre junction and the loss at this end is due solely to the air/glass interface of the prism, which can be reduced by coating.

Technical challenge

The main technical challenge in using fibres to feed a highly efficient spectrograph is that the normal exit beam of the light from the fibres is at f/2.5 whereas the spectrograph requires a beam at f/8. To overcome this problem special micro-lenses have been designed to be attached at the instrument end of the fibres. These take the form of 2 mm-diameter sapphire balls which in their turn can be coated to reduce the losses at the air/sapphire interface. Many technical problems of matching these lenses to the fibres have been overcome and lens-matched fibre lengths exceeding 20 meters can now be reliably made.

The total bundle of 150 fibres is split up into smaller bundles of 10 so that the connectors are manageable and also so that in the event of damage to the fibres, which with the passage of time will occur, they are quite simple to replace. Engineering tests of these small bundles are in progress to assess how they perform as they flex when the telescope is moved around the sky. It appears that the light losses are dominated by those inside the fibre and at the air/glass surfaces of the prism and micro-lens. It should be possible to reduce these to about 10% at 600 nm, a small price to have to pay for the advantage of being able to obtain data on 150 objects at once.

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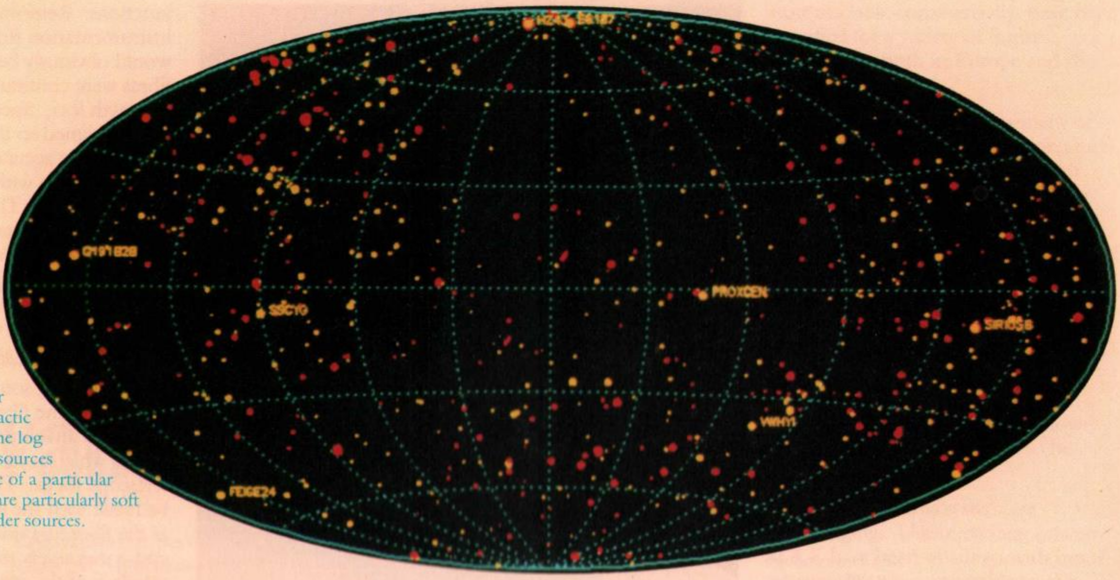

Figure 1: A map of EUV sources detected in the ROSAT WFC all sky survey. The Milky Way is along the equator of the map, with the galactic centre in the middle. The log brightness of individual sources is represented by the size of a particular dot, whilst those in red are particularly soft and those in yellow, harder sources.

ROSAT Wide Field Camera in orbit

The primary scientific aim of the UK Wide Field Camera, launched into orbit on ROSAT on 1 June 1990, was successfully accomplished earlier this year. The 'survey phase', during which the whole celestial sphere was scanned for the first time in the extreme ultraviolet (EUV) waveband, ran from 30 July to 25 January, by which time more than 96% of the sky had been observed in depth. It is described here by its originator, Professor Ken Pounds of Leicester University.

The ROSAT Wide Field Camera (WFC) is an imaging EUV telescope that has been developed by a consortium of five British institutions led by Leicester University, in collaboration with the Mullard Space Science Laboratory of University College London, Birmingham University and Imperial College of Science, Technology and Medicine, London and SERC's Rutherford Appleton Laboratory. The WFC complements the main (German) X-ray telescope on ROSAT by extending the wavelength range of the sky survey from about 6 nm to 20 nm, reaching well into the EUV band. This is a region of the spectrum largely unexplored to date — and one that until a few years ago was believed to be inaccessible due to absorption by the interstellar gas.

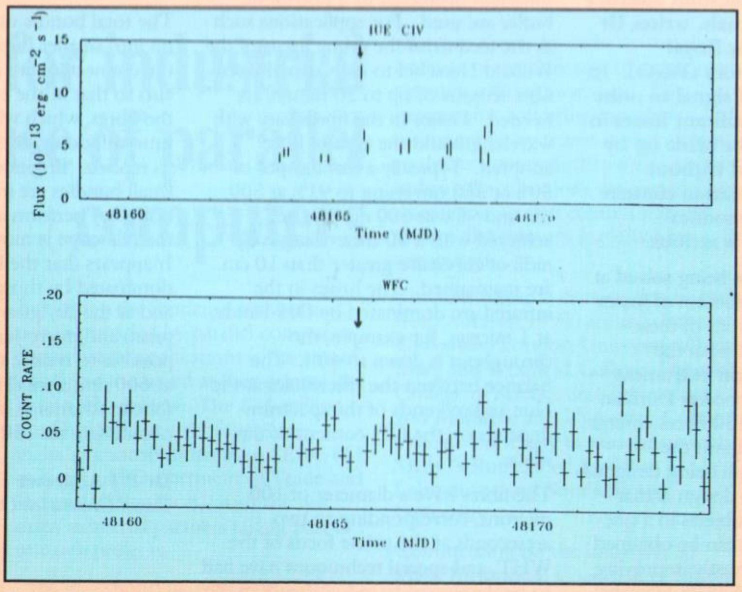

Figure 2: Variable EUV flux from the binary flare star BY Draconis. Modulation is seen at the rotation period of the spotty stellar component, in addition to several flares, one of which was also detected (upper panel) by IUE.

The first analysis of the EUV sky survey data has now been completed, as a joint effort of the WFC consortium groups. Figure 1 shows a map of the brightest 732 EUV sources produced by the UK Survey Centre at Leicester. This represents a 'conservative' list, including only those sources detected in a computer search of the WFC data and confirmed by visual examination of EUV sky images. One measure of the productivity of this phase of the ROSAT mission is provided by noting that this number already represents a hundred-fold increase on the known cosmic EUV source population pre-launch.

What are these luminous sources of EUV radiation? An idea is given by recalling the link, well established in astronomy, between the wavelength at which an object radiates most brightly (its 'colour') and the temperature of that object. Thus, EUV sources, radiating strongly in the 5-50 nm band, are likely to have characteristic temperatures in the range 100,000 to 1,000,000 Kelvin. Examples found in the first lists of ROSAT WFC sources illustrate the rich variety of astrophysical locations where such high temperature plasmas exist.

An apparently common class of EUV emitter is the 'active star' , such as in the binary system BY Draconis (figure 2). Here, the gravitational interaction between two red dwarf stars, separated by only 0.07 AU is apparently stimulating intense activity in the chromosphere (or upper atmosphere) of one, possibly both component stars. The EUV flux from BY Draconis was monitored by the WFC for 15 days, during which time a large flare was seen (with an energy output ten times that of major flares on the Sun), as well as a flux modulation at the 3.5 day spin period of the more active of the two component stars. Further study of such systems will be valuable in obtaining a better understanding of the non-thermal heating processes in the outer atmospheres of late-type stars, including the Sun.

A second type of object to feature often in the list of ROSAT EUV sources is the 'hot white dwarf'. These highly compact stars, little larger than the Earth, are the bare 'cores' of solar-type stars which have used up their nuclear fuel and shed their cool, outer atmospheres. The early ROSAT survey data is revealing many more white dwarfs than previously known, with some being previously 'hidden' from view (to optical telescopes) by nearby luminous main sequence companions. A fascinating prospect is to compare in more detail the properties of white dwarf stars in such binary associations with those of isolated white dwarfs.

Supernovae are among the most violent and energetic events known. Figure 3 shows the remarkable extended nebula in Vela detected by the WFC at the site of a massive stellar explosion some 15,000 years ago. The EUV image traces out the million degree gas, 150 light years in diameter and still expanding to enrich the interstellar medium with heavy elements (from carbon to iron) produced in the final days of the progenitor star.

Catalogue searches of a region within 1.5 arc minutes of each of the 732 brightest EUV sources have revealed probable optical counterparts of about a half. Included in this list is a 'who's who' of galactic stars, with a range of the nearest, brightest, most active or 'peculiar' objects showing up. Further study will show why these, rather than other (visibly similar) objects emit strongly in the EUV. Further surprises can be expected from the follow up studies of the many presently unidentified ROSAT WFC detections. Early work with the SERC optical telescopes on La Palma has now begun to yield fascinating new results from this list. Figure 4 contrasts the optical spectra of two such sources, one new hot white dwarf star, the second a previously unknown active galaxy.

It is already clear that the ROSAT catalogue of EUV sources, eventually expected to reach around 1500, will form the basis for an active new discipline, of 'EUV Astronomy', and many associated scientific studies in the years ahead.

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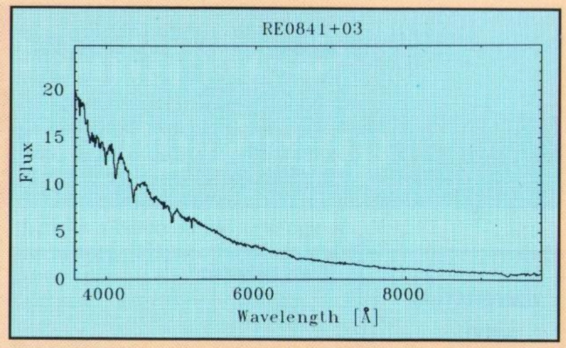
ROSAT WFC Project Scientist
Leicester University



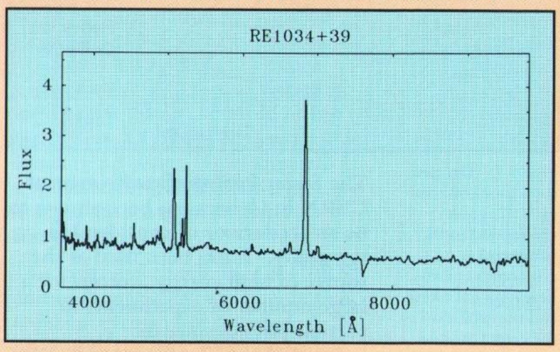


Figure 4: Optical spectra obtained with the INT on La Palma, identifying two new WFC sources with a) (pictured above) a previously unknown white dwarf star, having a characteristic blue continuum with hydrogen absorption lines, and b) (pictured below) the emission line spectrum of a previously uncatalogued active galaxy.

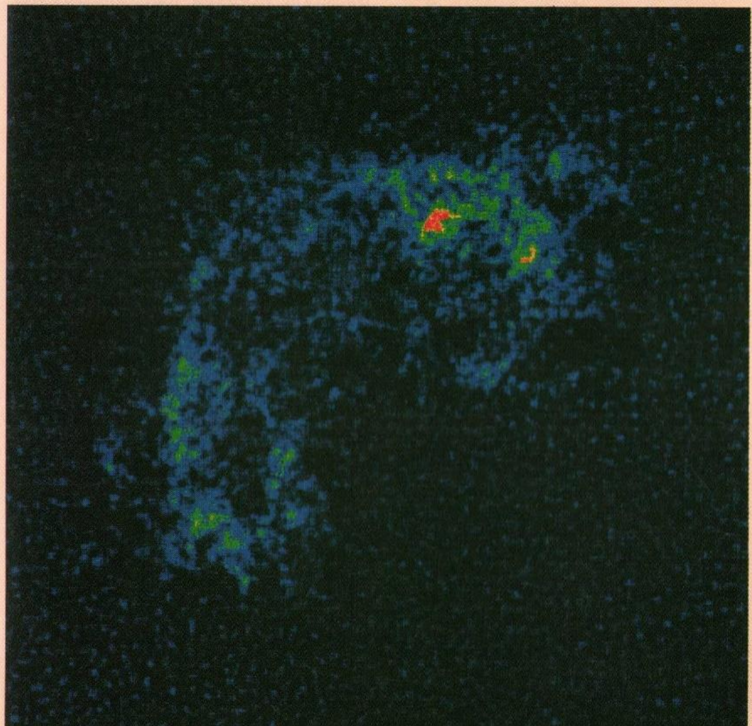


Figure 3: EUV image of the Vela Supernova Remnant, formed from a mosaic of many small WFC images. The remnant now extends over 5° of the sky and marks the position where a massive star exploded some 15,000 years ago.

Searching for the quark-gluon plasma

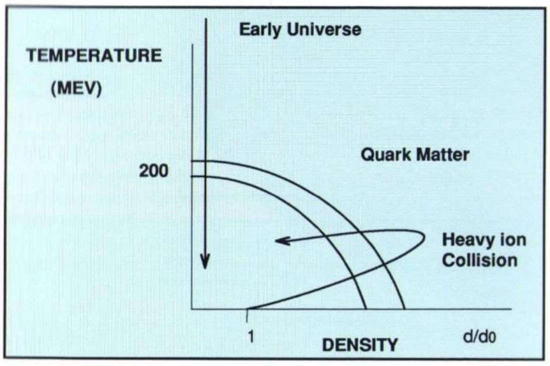


Figure 1: The two trajectories on this phase diagram correspond to the compression achieved by means of heavy ion collisions and the evolution of the early Universe.

The Super Protron Synchrotron at CERN in Geneva has been shown to be an accelerator of considerable versatility. It has been used as the source of high energy protons for a large number of experiments in particle physics since its inauguration. The pioneering developments which allowed the machine to accelerate and then store counter-rotating beams of protons and anti-protons led to the Nobel prize-winning discovery of the W and Z bosons. More recently, the successful operation of the Large Electron-Positron ring (LEP) has been another credit chalked up for the SPS. Now that the SPS has added heavy projectiles to its inventory, a large number of nuclear and particle physicists have been working on a search for a new state of matter — the quark-gluon plasma. In the course of this search, the experiments are probing nuclear matter under extreme conditions quite different from those normally investigated by nuclear reactions with excitations close to the ground state. This article, by Dr John Nelson and Dr Robert Zybert of Birmingham University, outlines one of the experiments in which participation is supported by SERC's Nuclear Structure Committee.

Present theories suggest that soon after the Big Bang, matter was mostly in the form — not of protons and neutrons — but of free quarks and gluons which are the basic constituents believed, like the electron, to be 'elementary'. After several tens of microseconds of cooling, this matter-state 'froze' into hadronic matter. These ideas are based on theories of Quantum Chromodynamics (QCD) which is the framework used to describe the strong interaction. The description of an extended system of quarks and gluons that might result from the 'melting' of nuclear matter constitutes a difficult technical problem since the quark interaction is weak at very small distances (perturbative QCD) and becomes stronger without limit as the distance increases.

For a quark gluon system extending over many fermis (10^{-15}m), statistical methods backed by lattice QCD calculations are required as the only known approach to tackle this problem. These calculations have been used to predict that a phase transition should take place at energy densities of 2 to 5 Gev/fm^3 and temperatures of 200 to 300 MeV. Collisions of two heavy nuclei are the only means of generating sufficient energy density over an extended volume. The CERN ^{32}S ion beam interacting with a heavy targets provides the necessary starting point for the experimental search.

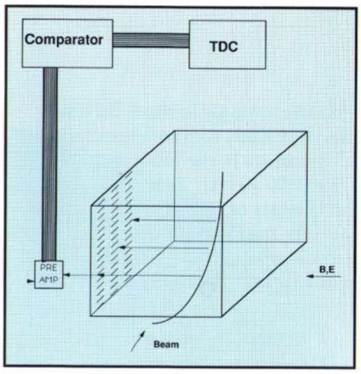


Figure 2: Schematic diagram of a time projection chamber showing part of the endcap containing 6400 sense wires. The signals, following amplification, are fed to LeCroy 1879 time digitisers.

Questions of considerable interest arise. At what temperature did this phase transition, from one state of matter to another, occur? What is the equation of state? What is the nature of this transition? If first-order, what might have been the result of the energy release when the Universe cooled? How does the process of hadronisation occur? What does the quark-gluon plasma teach us about the early Universe and, in particular, nuclear synthesis?

Of special interest to experimentalists is the possibility of detecting this phase transition in the laboratory. It is not possible to study the path taken by Nature in the early Universe as shown in figure 1, but rather a different trajectory in phase space, starting from nuclear matter at normal density which is then compressed, will pass through the phase transition boundary, and will then return on cooling to hot nuclear matter.

The energy density in normal nuclear matter is about 0.13 Gev/fm^3. A head-on collision between a ^{32}S ion, accelerated to 6.4 Tev in the SPS, and a lead nucleus will produce a considerable increase in energy density which may reach 2 to 3 Gev/fm^3 or more. This is a difficult quantity to estimate with certainty. It may be sufficiently high to bring about the transition from normal nuclear matter to a state of free quarks and gluons over the volume of impact — the quark-gluon plasma. This new state of matter will exist for only a brief instant of time

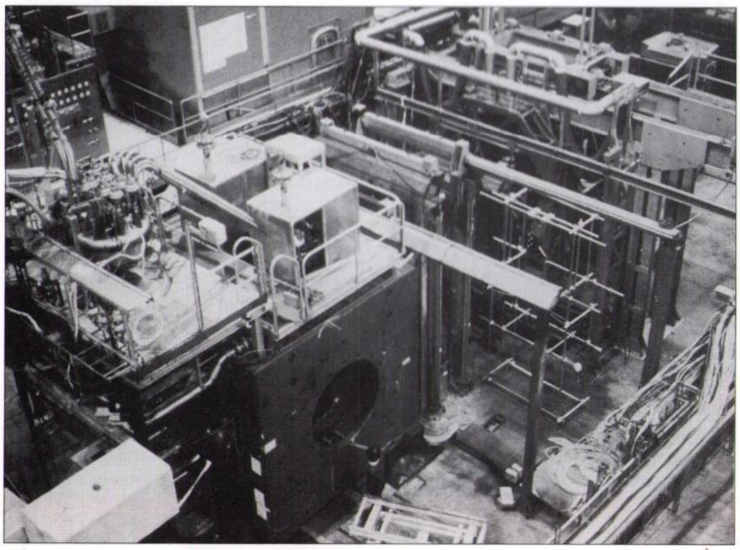


Figure 3: Layout of the NA36 experiment designed to detect neutral lamda particles.

and there are many suggestions concerning the signals that will remain to be observed as proof that it was ever created.

One result is certain: such a high energy impact will generate an enormous amount of debris. The signal to be detected will be buried in these residues. This signal from the plasma phase must be a quantity that is not affected by the subsequent transition from the plasma back to the hadronic phase. One of the signals that has been suggested, in particular by Koch, Müller and Rafelski, is an enhancement of the production of strange particles. A simple argument can be used to illustrate this idea. The colliding nuclei will consist in total of about 700 up and down quarks which, being fermions, are subject to the exclusion principle. If the quark-gluon plasma is created in a volume, it will be energetically favourable to create (new) strange quarks in previously empty quantum states. These strange quarks will combine with up and down quarks in the 'freeze-out' to produce K^0, lamda, as well as xi and even omega particles. These particles decay weakly and survive long enough to reach the detectors. The increased number of strange quarks produced will therefore be apparent in the increased production of these strange particles. The production cross-section of strange particles is known from proton-proton and proton-nucleus collisions which can therefore form the basis of a comparison.

The NA36 experiment has been designed to detect the neutral lamda particles by observing their decay products in a 'time projection chamber' or TPC. The NA36 collaboration consists of physicists from 11 institutions including Birmingham University. The TPC was designed by Dr CR Gruhn from the Lawrence Berkeley Laboratory in California. High energy physics has developed various techniques of measuring trajectories of charged particles produced in collisions. Photographing tracks produced in bubble chambers and streamer chambers, for example, produces high quality pictures but at a very low rate. Time-consuming scanning of the photographs can be aided by new computer-assisted methods. The data recorded by wire and drift chambers, on the other hand, can be read electronically, and therefore rapidly, but these detectors are not suitable for very complex events.

The time projection chamber attempts to resolve both of these problems. It is designed to provide three-dimensional information, in digital form, about tracks in very complex events. The principal idea is illustrated in figure 2. Charged particles pass through a gas-filled box generating ionisation clouds along their tracks. The detector is placed in a strong magnetic (3T) and electric (110V/cm) field. The curvature of the tracks in the magnetic field allows momentum measurements to be made. Under the influence of the electric field, the ionisation cloud drifts towards one end of the detector — the endcap — which is equipped with 6400 sense wires in 40 rows along the 1m length of the detector. The (x,y) coordinate of each ionisation cloud is given by the location of the sense wire on the endcap. The third coordinate is obtained by measuring the drift time of the charge cluster between point of generation on the track and the endcap. For this purpose a time digitiser is used. In this way, each track is represented by a series of well defined space points — up to 40 in the case of a particle that traverses the full length of the detector. The experimental layout is shown in figure 3. The beam enters from lower left into the target area which is inside the yoke of a large superconducting magnet. The TPC itself is situated at the centre of the magnet and about 1 cm above the beam axis. Beam fragments following the collision continue their path towards the upper right where they are detected in a large lead-glass array which is not shown.

The aim of the pattern recognition program is to reconstruct individual tracks from space points. The complexity of the problem is a function of the number of tracks, but for the NA36 detector, even very complicated events consisting of up to 300 tracks can be reconstructed with more than 85% efficiency. That is, more than 85% of the tracks are correctly reconstructed as determined by software experiments with Monte Carlo data. The detection of strange particles is based on the topology of their decay. The neutral lamda and K^0 particles decay into two particles of opposite charge thus producing characteristic V-shaped pairs of tracks. An example of a reconstructed event is shown in figure 4 with the tracks extended forwards to the target area on the left. The decay of an anti-lamda is clearly seen as a V-shaped pair of tracks with no track to the left of the vertex. An algorithm has been developed to locate such 'Vs' and kinematic calculations are performed which allow tests to be made on the hypothseis that a pair is the result of a lamda or K^0 decay. Approximately 7 seconds of IBM3090 computing time is required to process an event completely.

This experiment took place at CERN during August 1990 when more than 6 million events were recorded. Analysis of the data is well under way. It is a pleasure to acknowledge the support of the Nuclear Structure Committee of SERC in this experiment.

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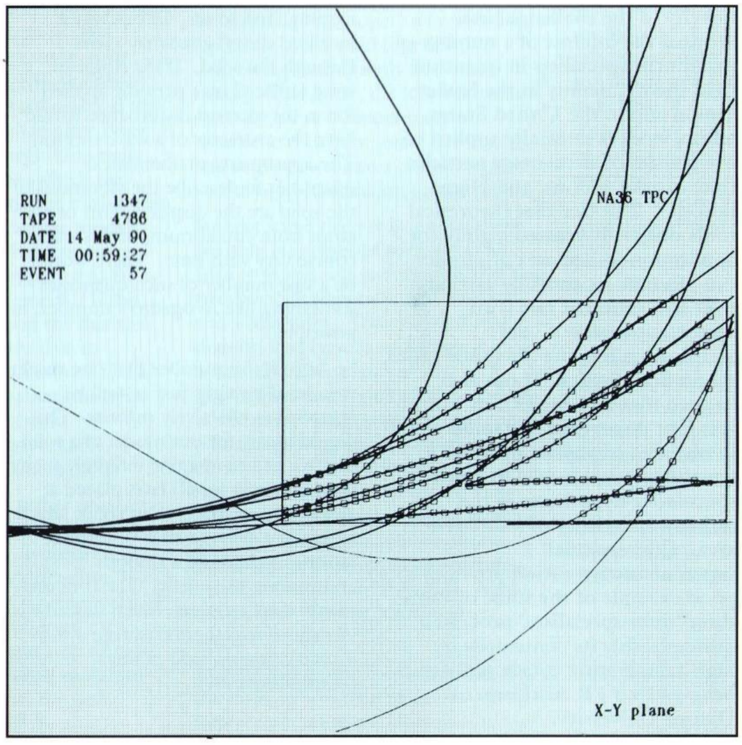


Figure 4: Reconstructed event showing tracks extended forward to the target area. The decay of a neutral anti-lamda into a p and pi⁺ can be seen in the centre-bottom of the diagram as a V with no track leading into the vertex.

Field theory and high temperature superconductivity

The phenomenon of 'high temperature' superconductivity, which in view of its possible technological significance created a considerable sensation when it was discovered a few years ago, continues to defy clear theoretical understanding. While it is still just possible that the accepted explanation of ordinary 'low temperature' superconductivity could be extended to provide the answer, most researchers believe that new ideas are needed. Many condensed matter theorists are working on the problem, but the excitement of the subject and the novelty of the challenge have aroused the interest of a number of prominent specialists in quantum field theory, mainly in the Soviet Union and in the United States, whose work is normally applied to the physics of elementary particles (like quarks, gluons, and Higgs bosons). The fact that theoretical tools originally created mainly for application in one area of physics can often be successfully carried over to a different one is an important aspect of, and justification for, the discipline called theoretical physics. It can also happen that a phenomenon which was first discovered and understood in one area of physics provides a fruitful physical model to guide speculative hypotheses in the unknown territory of a different area. Conventional superconductivity itself provides a good example of the value of both these 'inter-specialism' processes; quite possibly its contemporary high-temperature cousin will also, believes Dr I J R Aitchison of Oxford University.

Most people have a fair idea of what condensed matter theory is about (crystalline solids and liquids, for example); field theory however may be less familiar. Yet from some points of view the two areas are not so different. Imagine a simple and standard model of a solid, consisting of regularly spaced balls (atoms) connected by springs (interatomic forces), and suppose that we want to study the way in which the solid can vibrate — in response, say, to being hit at one end. The struck atoms will start to oscillate on their springs, and will set the neighbouring atoms in motion, which will in turn set their neighbours jiggling, and so on. In this way a localised disturbance may travel through the solid. If the single hit were replaced by a periodic applied force, the internal disturbance would have the character of a wave motion. The appropriate mathematical quantities to describe the vibrations of the solid are the displacements of each atom from equilibrium, which will of course vary with time. There would be a vast number of such quantities — something like Avogadro's number, in principle.

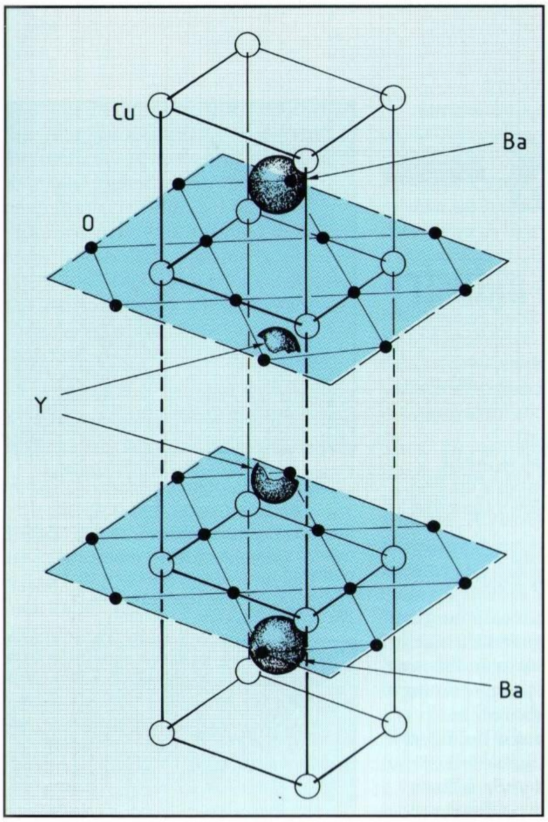
So large is this number that one might wonder if it might just as well be regarded as effectively *infinite*. This would mean, for our model of a solid, that we had to imagine infinitely many (and infinitely small) balls placed at *every* point of space. Our solid, which began as a discrete array of distinct atoms, has become a smooth continuum, like a jelly. The (infinitely many) displacements which describe its vibrations together constitute a *field* — the vibration field of the (continuous) solid.

In general, then, a field is any quantity which has a definite value at every point in space and time. Examples are the electromagnetic field introduced by Faraday and Maxwell, and its modern descendants, the 'strong' and 'weak' subnuclear force fields. It is typical of such fields that they are associated with wavelike phenomena — electromagnetic waves, for example. In developing his famous mathematical theory of the electromagnetic field, Maxwell made much use of mechanical and hydrodynamical models for the medium (called the aether) which, it was then thought, transmitted electromagnetic forces. The known physics of mechanics and fluids provided fruitful concepts with which to create an understanding of the new area of electromagnetism — which led, in fact, to the *prediction* of electromagnetic waves.

Eventually, however, Maxwell himself decided that physical aether models had outlived their usefulness, and that the field itself, without any underlying 'particulate' or fluid substance associated with it, should be regarded as an independently existing physical entity. This is a very fundamental point. Nevertheless, it remains true that actual material systems can provide very illuminating models for the behaviour of systems of fields. This is especially relevant when quantum (rather than classical) mechanics is introduced — leading to the subject of quantum field theory.

Quantum phenomena most commonly occur at the tiny length-scales of atomic and subatomic phenomena, far below our everyday experience. However, macroscopic materials can directly exhibit the effects of quantum mechanics at sufficiently low temperature. This is essentially because, as Einstein realised right at the start of quantum theory, the internal energy of the material has to be parcelled out into packets of energy (quanta), and at low temperatures there is not much energy to be distributed so that the 'lumpiness' of the packets becomes evident. At high temperature, there are so many little packets that the energy seems continuous, as in the classical case. Thus the behaviour of material substances at low temperature may provide clues to that of quantum fields, and conversely the methods of quantum field theory may conceivably help in understanding novel phenomena at low temperature.

A crucial element in the extremely successful electroweak theory, which was created in the 1960s and 1970s as a generalisation of Maxwell's



Simplified structure of the cuprate superconductor $YBa_2Cu_3O_7$ (known as 'ybco' or '1-2-3'). The smallest repeating unit consists of three cubes, with copper atoms at the vertices. The cubes are shown here one above the other, with the middle one 'disconnected' to allow the top and bottom halves of the structure to be (artificially) pulled apart in a vertical direction, for greater clarity. A barium atom occupies the centre of the top and bottom cubes, and an yttrium atom (shown broken apart here) the centre of the middle cube. Most of the oxygen atoms lie in the two planes shown, which each contain four copper atoms belonging to the cubes.

electrodynamics to include the 'weak' force, was specifically motivated by the physics of superconductivity (the understanding of which, in its turn, had been aided by the efforts of field theorists). This aspect is known as the Higgs mechanism, named after Peter Higgs, now at Edinburgh University. In literal physical terms (which may conceivably be ultimately as misleading as nineteenth century aether models) the idea is essentially that free space behaves like a superconductor as far as the weak force is concerned. (If this seems crazy, reflect upon the fact that 'free space' is apparently able to support electromagnetic waves!). This idea and various generalisations of it have proved to be of central importance in creating workable theories of subatomic interactions.

It should therefore be rather obvious why quantum field theorists might be particularly excited by an apparently novel form of superconductivity. If indeed the physical mechanism behind it is radically new, the phenomenon itself may provide an unexpected new model for the behaviour of quantum fields. Or it may be that the field theorists themselves will be able to help in cracking the puzzle of what that mechanism is.

As far as the second possibility is concerned, there has certainly been a surge of theoretical activity recently, most of it focusing on a possible consequence of one particular aspect of the superconducting copper oxides — their pronounced *planar* structure. It seems that (in these particular compounds at least) the charge carriers are highly localised to the two-dimensional copper-oxide layers (see figure). This feature can be idealised into a model, in which the carriers are strictly confined to motion in two dimensions. Some remarkably exciting possibilities then emerge, of which undoubtedly the most exotic is that a completely new type of quantum particle may be involved.

Traditionally, all known particles are classified into exactly two types: bosons (which have intrinsic spin equal to an integer time $\hbar$) or fermions (which have spin equal to $1/2\,\hbar$, $3/2\,\hbar$, . . .). Examples of the first are photons and π mesons, and of the second are electrons and quarks. This distinction is fundamental, not least because of the profound differences exhibited by multiparticle assemblies of the two kinds of particle: fermions obey Pauli's exclusion principle, while bosons have no such tendencies, but instead are happy to occupy the same state (at low temperatures). The latter effect plays a crucial role in the classic Bardeen-Cooper-Schrieffer (BCS) theory of 'conventional' superconductivity. A mechanism was discovered (by Cooper) whereby two electrons could bind together, converting them jointly into one boson. This done, the way becomes open for these 'Cooper pairs' to overcome their fermionic exclusivity, and settle down into a common state — the superconducting ground state.

Is there some deep reason why there are only two types of particle? The answer to this was provided in 1977 by two Swedish physicists, J M Leinaas and J Myrheim. They showed that the division into bosons and fermions was a natural consequence of the geometrical and topological properties of the phase space available to identical particles moving in three spatial dimensions. They also noted, however, that things would be very different in *two* dimensions — in fact, particles of arbitrary spin would be possible, continuously interpolating between bosons and fermions. Such things have become known as 'anyons'.

This discovery was hardly noticed at the time, or was treated as an unphysical curiosity. However, nature has a way of making use of interesting mathematics. There is now good evidence to suggest that anyons can indeed occur in two-dimensional electron systems which exhibit the Fractional Quantum Hall Effect. This interpretation was based on the work of R B Laughlin (of Stanford University), who then went on to propose that anyons might also be at work in high temperature superconductivity. His idea was that two half-fermions would have a strong intrinsic tendency to bind together to form a boson (No: two half-fermions *don't* make a fermion). These bosons would then play the role of the Cooper pairs in the BCS theory. It must be emphasised, however, that there is as yet no clear understanding of how normally occurring electrons could be effectively converted into such curious 'quasi-particles'.

A convenient field-theoretic description of anyons has been provided by F Wilczek (Princeton) and others, which can be used to investigate the difficult problem of the behaviour of assemblies of anyons at finite temperature. Since Laughlin's original suggestion, a considerable theoretical effort has gone into exploring his idea, and variations on it. It certainly seems to be true that an assembly of charged anyons *is* superconducting at zero temperature, although the precise properties at $T \neq 0$ are still controversial. One remarkable empirical consequence of the 'anyonic' mechanism is that, in almost all models, the superconducting ground state violates the symmetries of time-reversal and parity. This can be tested experimentally — with results that are still inconclusive, though probably indicative of no such effect. But even if anyons are not behind high-temperature superconductivity, there are other peculiar mathematical features of two-dimensional physics which could well play a distinctive role.

However things may turn out, the understanding of high-temperature superconductivity is likely to constitute a fascinating chapter in theoretical physics, of importance to condensed matter and particle theorists alike. And without that theoretical understanding, the technological application of the phenomenon is unlikely to proceed very fast.

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Numerical analysis —

indispensable tool for science, engineering and industry

Numerical analysis has provided invaluable enabling tools for industrial research. But there is a danger that the current breed of numerical analysts will, and are, losing sight of the goals of the early pioneers — men like Wilkinson, Goodwin and Fox. This article by Professor Sean McKee of Strathclyde University, suggests cost effective ways of remedying the situation.

Numerical analysis is concerned with the derivation, implementation and analysis of algorithms. The name was coined around the time of the second world war and was strongly associated with the emergence of the digital computer. Although basically mathematical, numerical analysis remains interdisciplinary: it pervades and permeates much of science and engineering and is a fundamental tool for industrial research.

With the appearance of the digital computer, the subject both matured and broadened, rapidly providing robust algorithmic software. Software of this type now underpins most scientific and engineering programmes. Moreover, the subject still has considerable potential for applications in areas including computational fluid dynamics, finite element and stress analysis, computation of electromagnetic fields, large-scale computations involving sparse matrix technology, conformational analysis, accident consequent analysis and process and device modelling of semiconductors.

University Consortium for Industrial Numerical Analysis

In 1977 the Mathematics Committee of the then SRC recognised the need to stimulate greater activity in this area and agreed to provide pump-priming support for the formation of the University Consortium for Industrial Numerical Analysis (UCINA), a grouping of numerical analysts from universities in the south of England interested in providing solutions to industrial problems. Following the initial launch of UCINA a number of industries came forward, with the encouragement of the coordinator, with a variety of problems.

Semiconductor simulation, both process and device modelling, gave rise to a number of problems of a mathematical nature. A study of optimal power output from the Severn barrage led to a happy marriage between numerical analysis and control theory. A study of stress and displacement in soft rocks was carried out for British Coal, while the results of computer modelling of loss of coolant accidents in pressure water reactors was employed in the Sizewell enquiry. Finally, Rolls-Royce provided funding to study strapping a multigrid solver on to an existing three-dimensional combustion and turbulent flow code for use in modelling the RB-211 engine.

The solution of these problems and the understanding gained was of distinct value to industry: the software produced provided useful tools for their design engineers. But, more than that, these projects meant that industry had the advantage of an academic consultant without paying him a salary, that potential employees were receiving more relevant training, and, because it was relatively inexpensive, that industry could undertake feasibility studies that they would not normally have undertaken in-house.

A number of the problems which came to UCINA were not of direct or immediate value to industry (and so

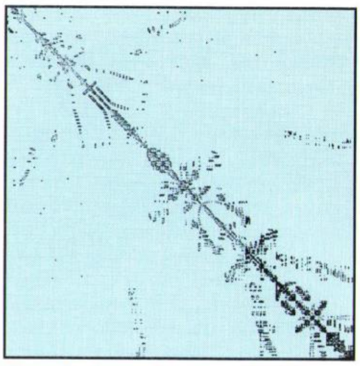


Figure 2a: Symmetric pattern of stiffness matrix from dynamic analysis of structures. The order of the matrix is 2003 and the number of nonzero entries is 83883. This matrix has been used in the tuning and testing of sparse codes developed by the Numerical Analysis Group at SERC's Rutherford Appleton Laboratory.

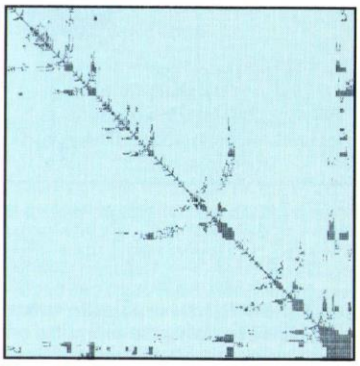


Figure 2b: Symmetric pattern of the Cholesky factors produced by a direct sparse solver developed by the Numerical Analysis Group. The original matrix was from a five-point discretisation of the Laplacian operator on a 20 x 20 grid.

Flow past boiler tubes in an advanced gas-cooled reactor (AGR).

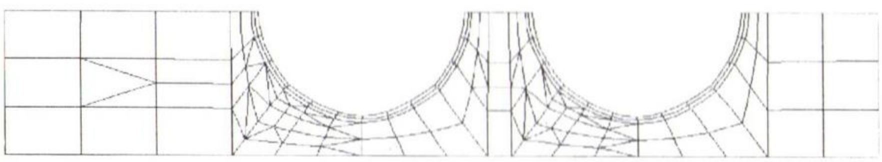


Figure 1a: Finite element mesh

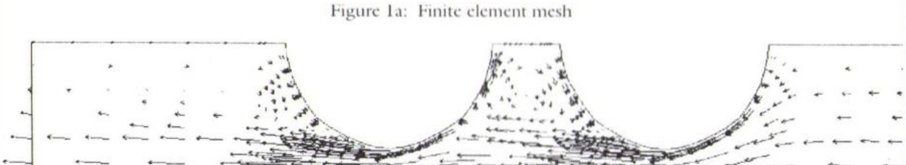


Figure 1b: Velocity flow field

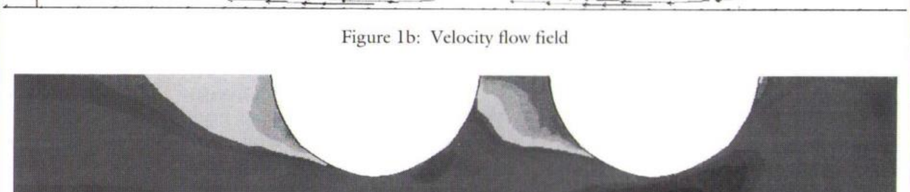


Figure 1c: Turbulent velocity plot

were not funded by industry) but all the same had an intrinsic importance for the future of numerical analysis and were undertaken within the overall programme, part-funded by SERC. Problems arose which related to numerical conformal mapping; the evaluation of specific special functions not contained in standard software libraries; approximation and, in particular, surface fitting and optimisation problems.

Activity in the UK

There are a number of centres of numerical analysis activity in the UK, with clear research ideas and with distinct goals. The research products are invaluable tools for industrial research and yet no industry would back them directly because of the long timescales involved in algorithmic derivation and mathematical software development. Some of the major groups are:

♦ Numerical Algorithms Group (NAG) is probably the world's leading mathematical software company. They have always worked closely with the academic community to the mutual benefit of both. As a result the company has been able to keep its lease price low producing effective positive feedback both for the company and for the numerical analysis academic community.

♦ Professor Iain Duff's group at the Rutherford Appleton Laboratory is another good example of a small team of numerical analysts who have produced and are producing the world's best sparse matrix software for large-scale matrix computations and optimisation problems.

The recently announced Harwell sparse matrix library, a subset of the Harwell subroutine library is the result of collaboration with NAG and will be marketed by them.

♦ Professor Bill Morton was a member of the Steering Committee of UCINA from the beginning, taking over as chairman in 1985, following his appointment at Oxford. A UCINA meeting was dedicated to computational fluid dynamics and this led, at least in part, to Professor Morton setting up the Institute of Computational Fluid Dynamics, which was strongly supported by SERC; Professor John Whiteman is another member of the UCINA Steering Committee. He is the director of the Brunel Institute for Computational Mathematics, which has been successfully offering expertise to industry, principally in the areas of elasticity and plasticity, over many years;

♦ numerical analysis has a history of contributions from engineers and the group at Swansea, and in particular Professor Olec Zienkiewicz FRS, has made a substantial contribution to the development of the finite element method and its applications;

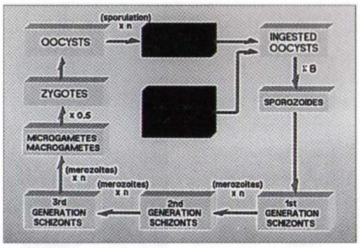
♦ a more extreme example is the brilliance of Professor Michael Powell FRS, Cambridge, without whom the field of optimisation would be many years, if not decades, behind its present position.

There are numerous groups throughout the UK involved in numerical analysis research, notably Dundee, Imperial College, London, Liverpool, Manchester, Reading and Strathclyde, with some quality theoretical work being carried out at Bath and Sussex. The National Physical Laboratory has an active group in curve fitting, while Leeds are involved in an industrially funded algorithm development project called SPRINT. There are many scientists for which the use of numerical analysis is essential: pattern formation in biology requires the numerical solution of sets of reaction-diffusion equations while computational statistics relies upon, for example, sparse large-scale optimisation.

The future of numerical analysis

There are many ways in which numerical analysis could be fostered and made available for use by industry; some have already been mentioned. SERC could play an important role here. For instance, the UCINA idea was, and is, a success; it is now more than ten years old. The original SRC report (1977) suggested three regional centres, one in the south of England and one in the north and the third in Scotland. Proposals for the latter two centres could and should again be encouraged. There could be a special initiative for industrial numerical analysis, or, more generally, industrial mathematics. Cooperative research with UK and European companies should be encouraged, to help academic numerical analysts to appreciate goal-oriented research better, as opposed to purely academic objectives.

There is no doubt that the future of numerical analysis lies in parallel architecture machines. Yet there is no British access to CRAY YMPs which are relatively commonplace in the US. Another weakness in the British system is networking. JANET is not capable of dealing with graphics files or indeed any large files. It is also inadequate for interactive work on a supercomputer like the CRAY.



Coccidiosis in chickens — biological model

Model equations

Govern how the 5 variables change with time

$$\dot{x}_0 = a_4 x_4 (t-t_1) - d_0 x_0 - b_0 x_0$$

$$\dot{x}_1 = F(t) + b_0 x_0 - b_1 x_1$$

$$\dot{x}_2 = a_1 x_1 - b_2 x_2$$

$$\dot{x}_3 = \frac{a_2 x_2 (t-t_2)}{1 + KI(t-t_2)} - b_3 x_3$$

$$\dot{x}_4 = a_3 x_3 (t-t_3) - b_4 x_4$$

Coccidiosis in chickens — mathematical model

How will numerical analysis develop in the future? Solving large systems of linear equations is fundamental to so many calculations that this area will remain vital for years to come. Global optimisation, particularly large-scale mixed integer programming, would also appear to be an important area impinging as it does on industrial scheduling generally. A modular general partial differential equation solver is a goal that should be striven for, despite the fact that the Navier Stokes equations and other classes of nonlinear equations will not be understood completely a hundred years from now. Parallelisation suggests that domain decomposition applied to large three-dimensional problems is also an important area for development.

But has numerical analysis got a long-term future? After all, numerical analysts have been attempting to make themselves redundant by designing the best algorithms and encoding them within robust software. The answer must be yes for the subject depends intimately on the computer and how it will develop. From historical evidence of the last few decades, it seems that computers will become cheaper, faster and able to store a great deal more information. Computer architectures as yet unconceived will be developed. Greater use of interactive graphics can be expected, possibly using holographic displays. Algorithmic complexity will be reduced through the correct interplay between mathematical formulation and an appropriate knowledge-based system. The intelligent personal computer will emerge. Optimal algorithms in a parallel, possibly stochastic, environment are and will be very different from those on a von Neumann or sequential machine. It is here that the future of numerical analysis lies.

Professor S McKee
Department of Mathematics
Strathclyde University

Ground-breaking: Dr Ben Garling (left) and Sir Michael Atiyah turn the first sods for the new Isaac Newton Institute for Mathematical Sciences in Cambridge.

Isaac Newton Institute, Cambridge

The ceremony to mark the start of building work for the Isaac Newton Institute for Mathematical Sciences took place in Cambridge on 22 April 1991. The ground-breaking was performed by Dr Ben Garling (President of St John's College) and Professor Sir Michael Atiyah PRS (Director of the Institute and Master of Trinity College) on a site near the new Royal Greenwich Observatory in western Cambridge.

The Institute will be an international research centre for mathematics and its applications to statistics, physics, computing, engineering, biology and other subjects. Funds for construction of the Institute have been provided by St John's College and Cambridge University, and SERC is supporting the scientific programme.

SERC has awarded a grant of £1,603,216 over four years, and the promise of this support was a significant factor in the establishment of the Institute. Support has also been promised from other academic, business and publishing bodies.

All four of SERC's Boards are contributing to the funding with the major contribution coming from the Science Board. The Mathematical Sciences are of underlying importance in science and engineering and the Institute will provide the focus for visitors from a wide range of disciplines to participate in a series of extended programmes. Four separate six-month programmes will be run each year and those already announced include:

Low-dimensional topology and quantum field theory (1992);
Magnetohydrodynamics (dynamo theory) (1992);
L-functions and arithmetic (1993);
Epidemic models (1993).

Building work should be completed by July 1992 when the first research programmes, supported by SERC, will begin.

SERC/MRC agreement on joint biology programme

Dr Dai Rees FRS, Secretary of the Medical Research Council (left) and Sir Mark Richmond, Chairman of SERC.

The Medical Research Council (MRC) and SERC signed an agreement in May to enable joint support for biologists to continue for a further three years at SERC's Daresbury Laboratory.

The MRC has contributed to the biology programme at Daresbury's Synchrotron Radiation Source (SRS) for many years, including contributions towards the operating costs, the provision of the Biology Support Laboratory, the installation of the High Brightness Lattice and the construction of a time-resolved X-ray diffraction station.

The MRC has now agreed to pay 50% of the costs for the development and operation of specific biology programmes at the SRS representing a total contribution of £3.8 million over three years. This partnership provides recognition of the great potential of the SRS for the achievement of pioneering breakthroughs in the biological sciences and the development of world-class facilities.

The SRS is a 2-GeV electron storage ring which provides an intense source of X-ray and ultraviolet radiation. Importantly, the use of synchrotron radiation techniques enables structural determination at atomic resolution with an accuracy and speed not practicable using conventional crystallographic techniques. It also allows real-time applications such as following the interactions that take place between two or more biological systems. The techniques used are peculiar to synchrotron radiation and have required substantial developments in X-ray detector technology at the Laboratory.

The importance of synchrotron radiation in achieving first-class biological science is shown by recent successes in protein crystallography and non-crystalline diffraction studies, and it has also been used to study the mechanism of enzymes. For example, it has been possible to obtain a series of structures showing the various stages of reactions catalysed by glycogen phosphorylase. An Anglo-American group have succeeded in discovering more about the mechanism of muscle contraction by time-resolved measurements on frog muscle.

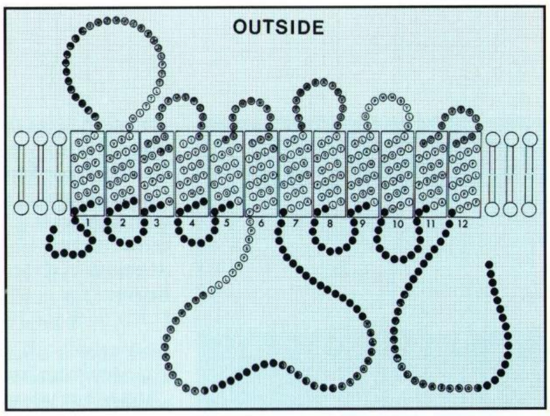


Figure 1: Probable arrangement of the human erythrocyte sugar transporter in the membrane. Regions of the amino acid sequence against which antibodies have been raised for use as topological probes are shown shaded.

Sugar transport across biological membranes

Sugars play a vital role in the metabolism of living organisms, ranging from bacteria to ourselves. Because they are hydrophilic molecules, their passage across biological membranes requires the assistance of proteins which provide a hydrophilic pathway through the otherwise hydrophobic lipid bilayer. In mammals, where blood glucose levels are relatively high, most cells contain passive transport proteins which catalyse the flow of sugars across the membranes and down their concentration gradients. However, a few mammalian tissues and many bacteria contain membrane proteins that can actively transport sugars against large concentration gradients, using the energy provided by ion gradients or 'energy-rich' molecules such as ATP. The properties of both active and passive sugar transporters are described here by Dr Steve Baldwin of the Royal Free Hospital School of Medicine.

Before sequence information on these proteins became available in the 1980s, it was natural to assume from their different kinetic properties that the active and passive sugar transporters were fundamentally different in design. It therefore came as something of a shock when in 1987 it was found that the mammalian passive glucose transporters are related in amino acid sequence, and so almost certainly in three-dimensional structure, to a family of active sugar transporters in bacteria which derive their energy from proton gradients. Unfortunately, despite this new sequence information, we still understand little about the mechanisms of any of these physiologically important transporters at the molecular level. In part, our ignorance stems from the difficulty of purifying, much less crystallising, these hydrophobic proteins. One of the aims of the SERC Initiative on the Molecular Basis of Biological Membrane Function, set up in 1985, has been to remedy this situation by funding research on sugar transporters as part of its general target of investigating the mechanisms of solute translocation across membranes and its selectivity.

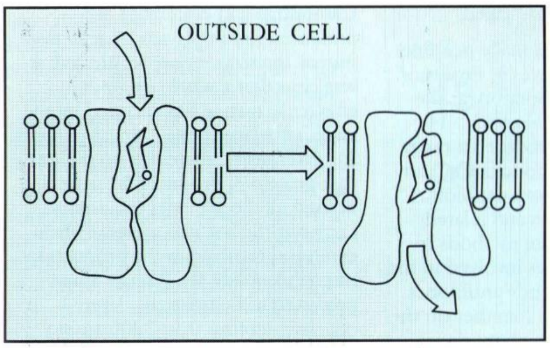


Figure 2: An alternation between two conformations of a membrane-spanning protein is probably central to the mechanism of sugar transport across the lipid bilayer. (The sugar molecule and the protein are not drawn to the same scale).

One area of research receiving support involves the best understood of the passive sugar transporters — that from our own red blood cells. The red cell transporter is a rather hydrophobic protein which is known from biophysical studies to be largely alpha-helical. From the distribution of hydrophobic regions along the polypeptide chain it has been proposed to span the membrane 12 times in the form of hydrophobic or amphipathic alpha-helices (helices which are hydrophobic on one side and hydrophilic on the other) as illustrated in figure 1. A similar 12-helix 'motif' has recently been predicted from the sequences of many other transport proteins, and it probably represents a widely-used arrangement of helices within membrane proteins. Within a bundle or bundles of such helices amphipathic segments are likely to be clustered to form a hydrophilic channel across the membrane through which the sugar or other substrate is transported. However, kinetic evidence on sugar transport indicates that the channel is gated: a single substrate-binding site within the channel is probably alternately exposed to each side of the membrane by a change in the protein (figure 2).

Direct evidence of the proposed topology of figure 1 is still rather sparse, and is being sought using a variety of membrane-impermeant probe molecules to tag, and so identify, the parts of the sequence that really are exposed at each face of the membrane. One approach has been to raise anti-peptide antibodies against different regions of the protein (shown shaded in the figure). Many of these recognise the intact protein and have been used to confirm features of the model, including the cytoplasmic location of the two ends and middle of the protein sequence. Such information is being combined with molecular modelling approaches, also funded by the Initiative, to build testable models of the protein structure. It is hoped that the constraints placed upon a membrane-associated polypeptide by its need to exist within the hydrophobic environment of the bilayer will render such basic molecular modelling studies easier than for soluble proteins.

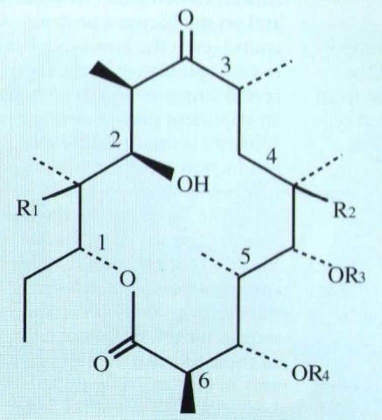
Three-dimensional models of the transporters are urgently needed to facilitate interpretation of site-directed mutagenesis experiments aimed at clarifying structure/function relationships in the proteins. Many of these are currently under way, both on the mammalian transporters, which can be expressed in the oocytes of the African clawed toad (*Xenopus laevis*), and on the bacterial proteins. Of course, even the best models will remain speculative in the absence of a crystal structure and so crystallisation is an important goal. Consequently the Initiative is funding attempts at production of large amounts of the mammalian transporters in insect cells using the Baculovirus expression system. Several of the bacterial sugar transporters have already been overexpressed to high levels in bacterial membranes. Only two requirements remain for the successful crystallisation of these proteins — a lot of hard work and an inexhaustible quantity of good luck! With plenty of the latter we may eventually start to see how these fascinating and physiologically vital constituents of the membrane actually perform their job of sugar transport.

Dr S A Baldwin
Royal Free Hospital School of Medicine

Hunting the enzymes of polyketide biosynthesis

Filamentous bacteria from soil are important sources of antibiotics and other useful compounds. Many of these are polyketides, a diverse and numerous class of natural products that includes the antibiotic erythromycin, the antitumor agent daunorubicin, and the immunosuppressant FK506 which is used in transplant surgery. A rational approach to enhancing their production, or to discovering even more potent compounds, depends upon knowledge of the pathways involved in their biosynthesis.

The remarkable enzymes (polyketide synthases) that catalyse the formation of bacterial polyketide chains are now being studied for the first time. Dr Peter Leadlay of Cambridge University describes here the experimental steps that have led to the initial characterisation of one such polyketide synthase, and discusses the implications for the future.



a) 6-deoxyerythronolide B (R_1=R_2=R_3=R_4=H)
b) erythromycin A
(R_1=R_2=OH, R_3=desosamine, R_4=cladinose)

Figure 1: The chemical structures of (a) 6-deoxyerythronolide B and (b) erythromycin A. The numbers 1-6 refer to the new bonds made during the stepwise attachment of six three-carbon units to the starter (propionate) unit.

SERC's Biotechnology Directorate and Biological Sciences Committee, in partnership with the Department of Trade and Industry and a consortium of four companies — SmithKline Beecham Pharmaceuticals, Celltech, Glaxo and ICI — recognised the importance of fundamental research into antibiotic producing microorganisms. They set up the Antibiotics and Recombinant DNA Club, with the long-term aim of exploiting the results of such research in programmes for rational improvement of commercial production strains. The Club has now been superseded by a LINK project, involving Glaxo and SmithKline Beecham and four universities, which aims to foster work specifically on *Streptomyces* and related bacteria.

The work at Cambridge being funded under the umbrella of the Club/LINK project involves the antibiotic erythromycin A, one of the best-studied polyketides. In particular, we wish to understand how seven three-carbon units (propionate units) are coupled together to forge the polyketide backbone of 6-deoxyerythronolide B (figure 1a) which is the known precursor of erythromycin A (figure 1b). However, at the outset of this work nothing was known of the properties of the '6-deoxyerythronolide B synthase', and attempts to detect it had failed.

The breakthrough was made possible by fundamental advances in Professor David Hopwood's laboratory at the John Innes Institute, Norwich. He and his colleagues introduced a range of experimental tools for cloning and manipulating genes from antibiotic-producing *Streptomyces* and related bacteria, and used these methods to demonstrate that genes involved in the biosynthesis of polyketide antibiotics are routinely clustered together on the bacterial chromosome. Also, their sequencing of several genes from two biosynthetic clusters, for the aromatic polyketides tetracenomycin and granaticin, gave the first experimental clue to the enzymology of the synthases: one small gene in each cluster apparently encoded a protein with significant similarity to an acyl carrier protein (ACP). This clearly demonstrated the long-suspected link between the biosynthesis of polyketides and that of fatty acids.

In all fatty acid synthases, chain assembly proceeds by the successive addition of (acetate) units to the chain, which is anchored on an ACP. Other enzymes then act in ordered sequence, reducing the chain and preparing for the next cycle of addition. A key point is that each enzyme in this set acts once in every cycle. This seems to be true of the tetracenomycin and granaticin synthases too.

Complex enzyme system

The extension of these findings to erythromycin A and to other 'complex' polyketides rapidly followed, when nucleotide sequencing of the clustered genes was carried out, both here in Cambridge and at Abbott Laboratories in Chicago. Again, the DNA sequence of the genes can be used directly to infer the sequence and nature of the encoded enzymes. The tremendous extent of the 6-deoxyerythronolide B synthase genes (a total of about 45,000 nucleotides) gave an early hint of the complexity of this enzyme system, and a crucial difference between this enzyme and the acetate-utilising synthases rapidly became clear. In the erythromycin-producing synthase, there exist multiple versions of the set of enzyme activities that is required for a round of chain extension. The Abbott group proposed (rightly) that there was a different set of enzymes for each round making six sets in all. This explained the exquisite specificity of the synthase, but raised another problem. How could nearly 40 different proteins be orchestrated to act in the correct order and produce a single, defined product?

Meanwhile, the sequencing in Cambridge had confirmed the presence of multiple sets of activities, but, as the sequencing progressed, it was clear that a whole group of enzyme activities was encoded by the same, very large gene (gene 3 in figure 2). Eventually, there was no doubt that protein 3, produced by gene 3, housed all the activities required to carry out the last two cycles of chain extension involved in the production of erythronolide B. Protein 3 was predicted to be unusually large, containing more than 3000 amino acids. Curiously, this organisation of the polyketide synthase is similar to the organisation of animal fatty acid synthases: even the order of comparable active sites along the chain is identical. The existence of two further giant genes (the adjacent genes 1 and 2 in figure 2), each encoding the enzymes for two cycles of chain extension, was predicted and this has now been confirmed by further DNA sequencing. Figure 2 gives a schematic idea of how the polyketide chain of erythromycin A 'grows' as it is passed from one active site to the next.

Even with the completion of the DNA sequence, there remained doubts about whether such giant proteins really were produced in *Saccharopolyspora erythraea.* We have now obtained direct proof of their existence as follows: first, a 'mini-gene' was constructed artificially, containing the last two activities only from the end of the predicted protein 3. This was expressed in bacterial cells by standard methods to obtain a 'mini-protein', which was used to raise antibodies in rabbits. It was reasoned that the antiserum produced should cross-react not only with the 'mini-protein' but also with the parent multifunctional protein in extracts of the erythromycin-producing organism.

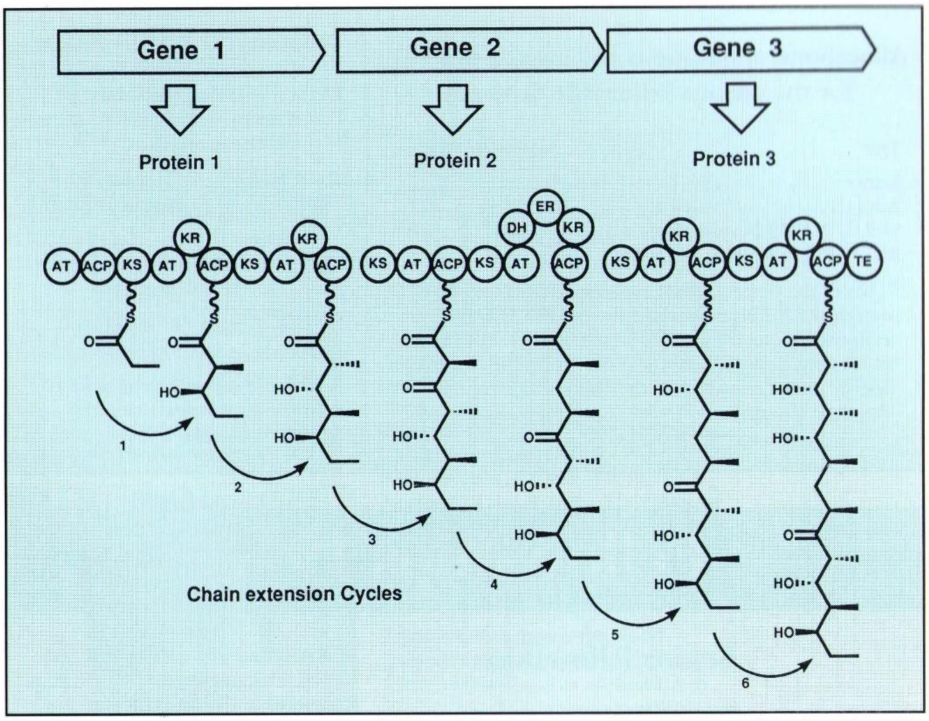


Figure 2: Schematic diagram showing the growth of the polyketide chain of erythromycin on the three giant polypeptides of the synthase, and the probable order in which the enzymes (indicated by KS, AT, KR, DH, ER, ACP) act.

Figure 3 shows that the antiserum does indeed detect a single, large polypeptide in extracts of *Saccharopolyspora erythraea.* This is a turning point in the enzymology of erythromycin biosynthesis, because such antisera should provide a specific assay, to guide the purification of the enzyme and allow it to be studied in detail.

Future prospects

The modular organisation and the unusual protein structure of bacterial polyketide synthases such as 6-deoxyerythronolide B synthase have important implications for both fundamental enzyme research and for the rational manipulation of synthase specificity to improve commercial production of antibiotics. Highly targeted mutations of synthase genes have already been used at Abbott Laboratories, to produce altered erythromycins. The gene clusters for biosynthesis of many other important polyketides are now turning out to encode giant multifunctional enzymes akin to those found here. The molecular organisation of the synthase remains a formidable challenge to the enzymologist interested in molecular recognition. In Cambridge, a joint programme of research on polyketide biosynthesis is under way, which links the author's group in the Department of Biochemistry with that of Dr Jim Staunton in the University Chemical Laboratory. The aim of this work is to establish the molecular basis for the recognition of growing polyketide chains by individual enzyme active sites, integrating results from chemical synthesis, biophysical techniques for protein structure determination, protein chemistry and enzyme kinetics, as well as recombinant DNA technologies. This will further underpin the continuing search for new or hybrid polyketides with potentially valuable properties.

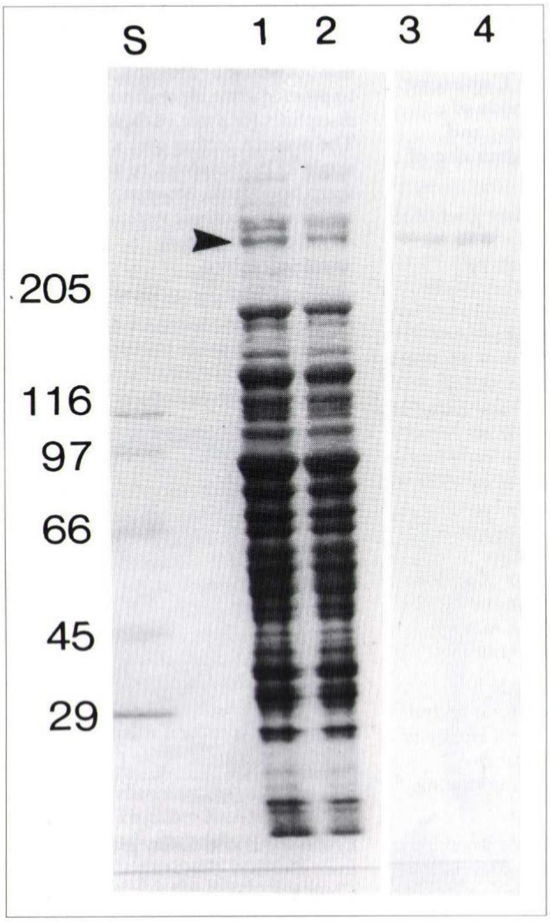


Figure 3: Lanes 1 and 2: the proteins in a cell-free extract of S. erythraea, separated by size (largest at the top); 3 and 4: specific detection of protein 3 of the erythromycin producing polyketide synthase using polyclonal antibodies raised against a portion of protein 3. (S contains marker polypeptides, whose sizes are shown in kilodaltons.)

Dr P Leadlay
Department of Biochemistry
Cambridge University

Allocations, applications and awards in 1991 for the various Fellowship Schemes

Type	Allocation	Applications	Awards
Senior	4	30	5
Advanced	28	125	28
SERC/NATO Postdoctoral	81	334	81 *
RS/SERC Industrial	7	16	7

* Two of the postdoctoral fellowship awards offered were designated for support under the NATO Science Fellowships programme. A further nine awards tenable in Western Europe were taken over from the Royal Society, and two awards in the Natural Environment Research Council's field were also NATO-supported.

Industrial fellowships

Dr D B Adams (Sunderland Polytechnic) — to ICI Witham Materials Research Centre

Dr R Mackenzie (Heriot-Watt University) — to Proctor Insulation Ltd

Dr J Murdoch (British Aerospace plc) — to Leeds University

Dr C K Wright (Birmingham University) — to Smiths Industries

A further three awards became available for distribution in the Summer of 1991.

Professor David Lilley

Fellowships 1991

Senior fellowships

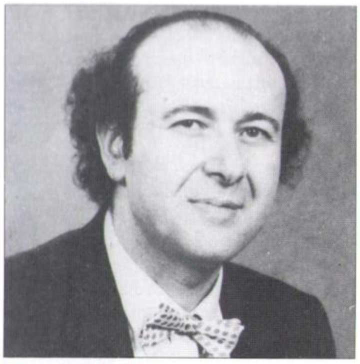
Senior fellowships have been awarded tp Professor Dov M Gabbay of Imperial College of Science, Technology and Medicine, London; Professor David Lilley of Dundee University; Dr Kevin Roberts of Strathclyde University; Professor C T C Sachrajda of Southampton University; and Professor Robert Vaughan also of Imperial College.

Professor Dov M Gabbay graduated in 1966 in Mathematics and Physics from the Hebrew University, Jerusalem, where he remained until 1970, obtaining his MSc in 1967, his PhD in 1969 and remaining for a further year as an instructor. He spent the period from 1970 to 1975 at Stanford University. He was Associate Professor at Bar-Ilan University from 1975 and held the post of Lady Davis Professor of Logic there from 1977 to 1983. Since 1983 he has been Professor of Computing Science at Imperial College of Science, Technology and Medicine, London. He has held visiting positions at the Universities of Tübingen, Munich, Georgia, Stuttgart and Oxford.

Professor Gabbay has made fundamental contributions in several research areas including the theory of non-classical logics, modal and temporal logics and non-monotonic reasoning.

During the course of his fellowship, Professor Gabbay aims to develop a general algorithmic proof framework of labelled deductive systems (LDS) which can serve as an underlying unifying foundation for both the areas of monotonic and non-monotonic logics. He hopes to present existing logics within this framework in a way which will highlight their relationship and their logical and proof theoretic properties. In the non-monotonic case, the framework will allow him to classify the diverse variety of systems of non-monotonic reasoning, as well as to provide some algorithmic proof disciplines for some of these systems. The research further tries within the single LDS framework to weaken the sharp boundaries between monotonic and non-monotonic systems, possibly identifying interesting interrelationships.

The discipline will enrich logic itself in exporting field experience from artificial intelligence into pure logic while providing general support to artificial intelligence efforts in the UK.



Professor Dov Gabbay

Professor David Lilley graduated from Durham University in 1969 in Chemistry. He remained at Durham until 1972 when he completed his PhD on 'Theoretical and experimental investigations of structure, reactivity and bonding in some organic systems'. He then moved to Imperial College, London, and took an MSc in Biochemistry, receiving the Ewart Stickings prize for excellence. After periods at Warwick and Oxford Universities and Searle Research Laboratories, he moved to Dundee University in 1981, where he presently holds a personal chair in Molecular Biology. He held a Royal Society Research Fellowship from 1983 to 1989, and was elected a Fellow of the Royal Society of Edinburgh in 1988.

During the course of his fellowship Professor Lilley proposes to investigate several structural aspects of DNA and RNA, and their interaction with proteins. He intends to study:

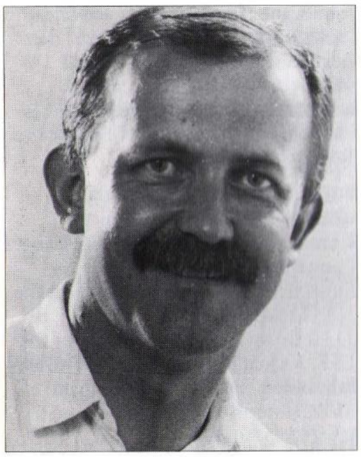
- DNA junctions believed to be important in the mechanism of recombination.
- The interaction of DNA junctions with resolving enzymes.
- Structure and recognition in RNA molecules.
- The importance of DNA supercoiling in the living cell.

Professor Lilley's research will aid our understanding of structural events underlying important biological phenomena, thus making significant progress in the development of biological chemistry. In particular, the contribution of the four-way DNA junction and its interaction with proteins as a structural basis for genetic recombination is a major topic of molecular biological research with potentially applicable spin-offs in being able to control such an event.

Dr Kevin Roberts graduated in 1974 from the Department of Physics at Portsmouth Polytechnic in association with the Admiralty Materials Laboratory, AWRE Aldermaston and GEC Hirst Research Centre. His PhD thesis, 'Characterisation and growth mechanisms in flux grown yttrium aluminium garnet' (submitted in 1977) was also carried out at Portsmouth Polytechnic in association with the GEC Hirst Research Centre; it was funded by an SERC Cooperative Award in Science and Engineering.

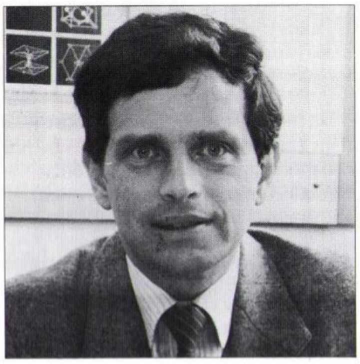
Between 1977 and 1982 Dr Roberts was a research assistant in the solid state group at the Department of Pure and Applied Chemistry, Strathclyde University. Between 1982 and 1984 he held a Royal Society European Exchange Fellowship at the Crystallography Institute at the Technical University of Aachen, Germany where he carried out research into the role played by lattice pseudo-symmetry in the kinetics of solid-state phase transformations. He returned to Strathclyde in 1984 as a lecturer, and is now a Senior Lecturer in Physical Chemistry. From 1987 to 1990 he held a 50% secondment at SERC's synchrotron radiation facility at Daresbury Laboratory where he was involved in the development of new techniques using synchrotron radiation for the structural characterisation of 'real' surfaces and condensed interfaces.

During his fellowship, Dr Roberts will undertake a major research effort in the development of the theory associated with crystal growth from the liquid phase together with its experimental verification. He plans to investigate the structure of crystal growth surfaces using high-resolution X-ray diffraction facilities at Strathclyde and high energy synchrotron radiation for in-situ measurements at Daresbury. The overall aim is to understand, in detail, the nature of solid-liquid interactions at the crystal/solution interface and to use this information for the development of theory. The ultimate goal is to provide a computer modelling approach based on crystal structure which is not system-specific and which can be used by chemical process engineers to predict, control and optimise the particulate properties of speciality materials prepared in batch crystallisers.



Dr Kevin Roberts

Professor C T C Sachrajda graduated from Sussex University in 1971 in Mathematical Physics. In 1971 he went to Imperial College, London to study for a PhD in the theory of elementary particles; he received his PhD in 1974. Between 1974 and 1976 he continued his research in theoretical particle physics at the Stanford Linear Accelerator Centre under a Harkness Fellowship. In 1976 he went to the Theory Division of CERN, Geneva, first as a CERN fellow and between 1978 and 1979 as a member of the research staff. In 1979 he joined the Physics Department at Southampton University as a lecturer, becoming Professor in January 1990.



Professor C T C Sachrajda

During the past four years, in collaboration with a group at the University of Rome, Professor Sachrajda has been developing the theoretical techniques required for his proposed work. In addition with colleagues in the European Lattice Collaboration he has performed some of the first lattice computations relevant for studies of hadronic structure, with promising results. His priority now is to improve the precision of these calculations, in particular by reducing the systematic uncertainties. This will require the improvement of theoretical and computational techniques, as well as the exploitation of the latest computing resources. Precise results are required for an understanding of the properties of the fundamental forces of nature and also in order to separate the effects of 'standard model physics' from possible signals of new interactions such as those from Grand Unified Theories and Supersymmetric Theories.

During his fellowship the principal objective of Professor Sachrajda will be a detailed study of the structure and properties of elementary particles, primarily through the development and exploitation of the lattice formulation of quantum field theory. Lattice Quantum Chromodynamics in particular promises to develop into the most important quantitative technique with which to study the strong nuclear force.

Professor Robert Vaughan FRS graduated from University College London in 1966 in Mathematics. He submitted his PhD thesis entitled 'On the representation of numbers as sums of squares, cubes and fourth powers and as sums of powers of primes' at UCL in 1970. After a one-year Postdoctoral Fellowship at Nottingham he spent two years as a Junior Research Fellow at Sheffield. From 1972 until the present he has held posts at Imperial College, London, where he was appointed to Chair of Pure Mathematics in 1980. He has been Visiting Professor at the University of Michigan, the Mittag-Leffler Institute, Sweden, and the Institute for Advanced Study at Princeton. He was elected a Fellow of the Royal Society in 1990.

Professor Vaughan is the world authority on the Hardy-Littlewood Circle method and its application to Waring's and Goldbach's problems and is a leading figure in analytic number theory in general.

During the five years of his fellowship Professor Vaughan will continue to pursue his main interests in additive number theory, especially the Hardy-Littlewood method as applied to diagonal equations and in particular Waring's problem. In 1981 Professor Vaughan wrote a monograph on the Hardy-Littlewood method, but in the past five years he has introduced a host of new ideas which has revolutionised knowledge concerning Waring's problem. Other problems which Professor Vaughan will undertake during his fellowship are the Duffin-Schaeffer problem, a famous and resistant problem of metric diophantine approximation, and Redheffer's matrix in which numerical experimentation on a computer will be required.

Professor Robert Vaughan

IN SUPPORT OF INTERNATIONAL SCIENCE — NATO AND THE ESF

The first impressions gained from a visit to the headquarters of the NATO Science Committee and the European Science Foundation (ESF) suggest these two organisations have little in common. Protected by armed guards and security fences, the large low-rise building of glass and concrete that houses the NATO bureaucracy seems a far cry from the converted monastery on a river-side street where, on the second floor, the offices of the ESF can be found. Andrew le Masurier of SERC's International Section sets out to explore the two bodies.

Despite contrasting outward appearances, the two organisations do have much in common. Both are sited in one of the new breed of cosmopolitan 'Eurocities', NATO in Brussels and the ESF in Strasbourg, and both aim to support and encourage international scientific collaboration on a budget rather less than that of a typical SERC subject committee. They both place the emphasis on bringing scientists from different countries together to exchange information and coordinate research activities, leaving the basic costs of equipment and consumables for national funding agencies to provide. So, if what you really need is a new piece of instrumentation, then neither the NATO Science Committee nor the ESF will be able to help, but if funds to improve international cooperation are required, then they may well be worth approaching.

The NATO Science Committee

Article 2 of the North Atlantic Treaty states that "progress in science and technology can be decisive in determining the security of nations and their positions in world affairs" and it was in this spirit that the NATO Science Committee was created in 1957. With an annual budget of about £16 million, the Committee seeks to enhance the scientific capabilities of the Alliance.

It operates four principal schemes. Three of these are administered from Brussels and are open to applications from any scientist in a NATO country. ***Advanced Research Workshops*** are meetings lasting about five days involving 30 to 50 people and designed to allow intensive advanced-level discussions between experts from different countries on a topical area of science. ***Advanced Study Institutes*** are short courses of about ten days, involving 12 to 15 lecturers and 60 to 80 students studying a particular topic. Some 80 Workshops and 60 Institutes are held each year.

Collaborative Research Grants provide the travel and subsistence costs of scientists wishing to make short visits (one to two weeks) to collaborating partners in different NATO countries. About 600 such grants are awarded annually.

The fourth scheme is the largest. Each year, NATO provides funds for about 1400 ***Science Fellowships*** but these are administered, not from Brussels, but by national funding agencies; in the case of the UK this means that NATO makes a contribution towards the cost of SERC's own activities in the promotion of postdoctoral fellowships.

Most of the Committee's budget is allocated to unsolicited applications from individual scientists but about 7% of the budget is directed by the Committee to particular Special Programmes. Currently, there are five of these, covering advanced educational technology; global environmental change; chaos and non-linearity; nanoscale science and supramolecular chemistry.

Looking ahead to the future, the Committee is hoping to involve more closely in its activities the countries of Eastern Europe. In July 1990, the leaders of the Alliance countries issued the London Declaration on a Transformed North Atlantic Alliance, and the Science Committee responded to this by increasing East European participation in its schemes and by embarking on a series of seminars and workshops in which scientists and administrators from East and West can exchange views on the management of science.

The ESF

The ESF has a budget even smaller than that of the NATO Science Committee, at about £2 million a year, but its influence is greater than the size of its purse would suggest. The reason is that, unlike NATO or the European Commission, it is a federation not of governments, with all the political considerations that implies, but of research councils and academies of science. All five of the British research councils are members, along with the Royal Society and the British Academy. In all, there are more than 50 members from 20 countries, mostly in Western Europe although the ESF is now spreading eastwards. The Hungarian Academy of Sciences joined in 1990 and it is unlikely to be long before the Academies of Poland and Czechoslovakia follow suit.

The ESF aims to bring European researchers closer together so that research activities in different countries can be more closely coordinated. Mostly, it works by providing limited funds to support meetings and workshops involving scientists working on a particular topic. A good example of just how successful this approach can be is the activity which produced the detailed proposals for a European Synchrotron Radiation Facility (ESRF), now under construction at Grenoble and due to be completed in 1994. In all, since the ESF began in 1974, it has sponsored about 80 different activities across the whole range of science. Many of its activities, such as the ESRF, arise from discussions in the ESF's own advisory committees, but others originate from unsolicited applications sent in by individual scientists. The latter type usually begin as 'Scientific Networks', consisting of a series of meetings over a period of usually three years. Recent topics have included surface crystallography, non-linear system and developmental biology.

Under its British Director-General, Michael Posner, the ESF is planning a significant expansion in its activities, looking to triple its budget over the next six or seven years. This will involve an increase in its current activities and also some new schemes, including a programme of European Research Conferences.

Further information about the schemes of the NATO Science Committee and the European Science Foundation, and how to apply for funds from them, is available from the NATO Scientific Affairs Division, B-1110 Brussels, Belgium and from the ESF, 1 Quai Lezay-Marnesia, F-67000 Strasbourg, France; and also from SERC International Section.

Dr A le Masurier
International Section
SERC Swindon Office

The magic of star-gazing is brought right to the classroom when Starlab is inflated at the children's own school. A grant from the Holmes-Hines Memorial Fund made the visits possible.

Reach for the stars

Thousands of youngsters were captivated by the magic of astronomy as Starlab, a mobile planetarium, visited schools in deprived areas earlier this year. Starlab is one of the many projects run by Inter-Action, an educational charity which develops and implements creative and 'hands-on' programmes to motivate learning, particularly in disadvantaged young people.

A substantial award from the SERC-run Holmes-Hines Memorial Fund enabled the portable inflatable Starlab to reach some 4,800 children and young people in schools in the Inner London Boroughs of Hackney and Tower Hamlets and in Lincolnshire, the Midlands and the Orkneys, as well as in play schemes and family shows outside school.

The Starlab visits, and the accompanying cross-curricular packs of material, stimulate interest in the general study of the sciences in all age ranges. One appreciative teacher wrote: "The infants have transformed their Wendy House into a Space Rocket, have planets made from balloons and lots of art work triggered off by the visit."

The Holmes-Hines Memorial Fund provides annual prizes, scholarships, exhibitions or research grants, the incidental expenses of visiting scientists, the purchase of scientific apparatus and equipment and funds for "such other purposes for the advancement of scientific knowledge as the Council shall select." It can be used to help individuals achieve their scientific aspirations and to sponsor activities related to science for which public funds are not available.

Applications for awards from this fund should be made to the Council's Finance Officer, P Maxwell, at SERC Swindon Office.

Some publications from SERC

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

Studentships
The 'green book', *SERC Studentships 1991-92*: from ext 1041.

Laboratories in the 1990s
Report by Dr Tony Hughes (then Director Laboratories, now Director Programmes, SERC): from Kathy Squires, ext 1186.

Rutherford Appleton Laboratory
Rutherford Appleton Laboratory 1990 annual report: from the Library, RAL, telephone (0235) 821900 ext 5384.

Daresbury Laboratory
An introduction to the Daresbury Laboratory: from the Library, Daresbury, telephone (0925) 603397.

Science Board and industry
Report of the Industrial Strategy Panel chaired by Professor D G Scotter: from Alan Brittain, ext 1081.

Mathematics
Mathematics: Strategy for the future, the report of the Mathematics Strategy Review Panel chaired by Sir John Kingman: from Claire Moger, ext 1027.

Chemistry
Achievements in chemistry 1991: from Anne-Marie Hilder, ext 1305.

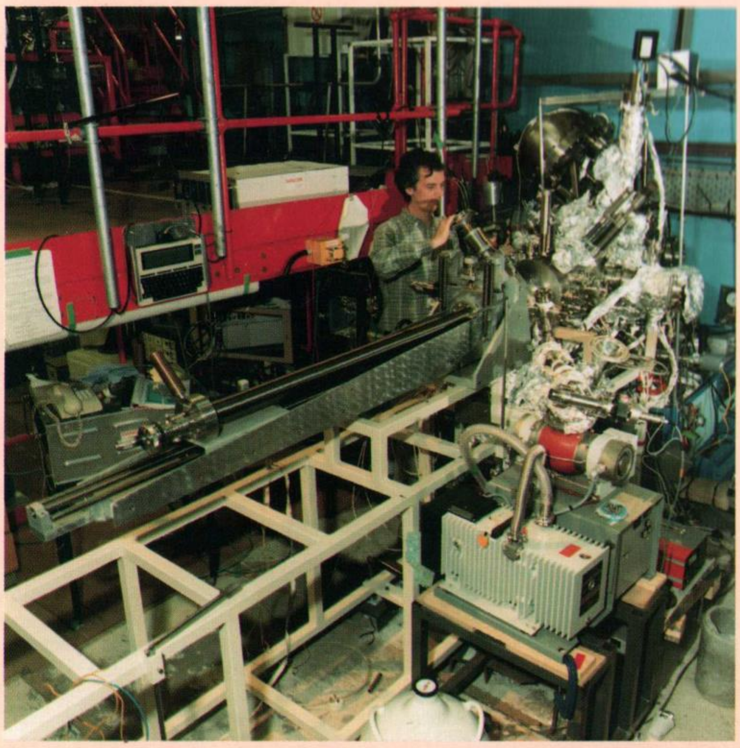
Engineering
Construction Committee and Environmental Civil Engineering Committee *Summaries of research reports September 1991*: from Lisa Cartman ext 1493;
Electro Mechanical Engineering Committee *Grants current at 1 January 1991*: from Tracey McGuire, ext 1054; Process Engineering Committee *Grants current at 1 July 1990*; *Reports on projects June 1990* and *Separations newsletter*: from Tanya Cottrell, ext 1075.

Joint ESRC-SERC Committee
Review Panel report: from Dr R Liwicki, ext 1429; *Newsletter*: from Julie Hutchinson, ext 1427.

ACME Directorate
Research funded by the ACME Directorate of SERC 1991 (status reports); *Computer-aided production management*; *Manufacturing research for the 90s*; and *Applications of Computers to Manufacturing Engineering Directorate Strategy*: from Gay Ford, ext 1106.

Marine technology
Software directory for the offshore industry 1990, price £85 a copy: from S Thurley, Hollobone Hibbert & Associates, 28/30 Little Russell Street, London WC1A 2HN;
New technology for ocean science by Dr John Woods (the second Mike Adye Memorial Lecture), price £5 a copy; from The Secretary, The Marine Technology Directorate Ltd, 19 Buckingham Street, London WC2N 6EF.

Global environment
Global environmental change: the UK research framework, the first report of the Inter-Agency Committee on Global Environmental Change: from the IACGEC Secretariat, c/o UK GER Office, Polaris House, North Star Avenue, Swindon SN2 1EU; telephone (0793) 411734.



Professor Massimo Sancrotti, of the Polytechnic of Milan, making the final adjustments to the 'Universal spectrometer' at Daresbury Laboratory.

International collaboration on the Daresbury SRS

The instrumental requirements for successful research in surface science are becoming increasingly exacting and expensive. Professor Peter Weightman, assistant director of the Interdisciplinary Research Centre in Surface Science at Liverpool University, describes one piece of equipment, internationally designed and built, that is helping surface scientists in their quest.

It has long been recognised that synchrotron radiation is an essential part of a research programme in surface science and this community makes up one of the largest and most active user groups of the Daresbury Laboratory's Synchrotron Radiation Source (SRS). However a high performance synchrotron can only be effective in this field if the station used in the experiments is equipped with a sophisticated and expensive spectrometer comprising an ultra-high-vacuum chamber, an array of detectors and associated electronics and secondary facilities for specimen characterisation.

There is always a need to expand and improve the instruments deployed on synchrotrons and it is also becoming increasingly clear in surface science that progress is often limited less by the characteristics of the source and the spectrometer than by the facilities for in-situ specimen preparation and characterisation. Ideally the surface scientist requires the latest electron spectrometer, with extensive specimen characterisation facilities, permanently installed on a station of the SRS which is equipped with a wide range of monochromators. The system would be linked to a dedicated molecular beam epitaxy type of apparatus but with more versitility than those installed in growth facilities.

Such an ideal will not be realised in the immediate future but substantial progress towards it was made with the commissioning in June 1990 of a new 'Universal spectrometer' at Daresbury.

The new instrument is designed for use on station 1.1 of the SRS and on stations 4.1 and 4.2 of the new beam-line being built by the Liverpool Interdisciplinary Research Centre in Surface Science in conjunction with the Daresbury Laboratory. It was designed by an international team drawn from the interfaces group of the Liverpool IRC in Surface Science and the physics departments of the University of Rome (La Sapienza) and the Polytechnic of Milan. The construction of the instrument is supported by funds from the IRC, Liverpool University and the European Community (EC). The research to be carried out on the new instrument is part of a study of the electronic and physical structure of interfaces which is coordinated by a 'twinning contract' between Dublin and Liverpool Universities and the Polytechnic of Milan and funded by the EC's Science programme. The contract also supports the construction of equipment for complementary experiments in Dublin and for the use of the Universal spectrometer, in conjunction with a scanning electron beam source, in the Liverpool IRC.

Universal spectrometer

The construction of the Universal spectrometer was divided into seven major sections and the responsibility for building each section assigned to one of the three groups. The Liverpool group took responsibility for the design of the main experimental chamber, electron energy analyser and the detection system which were constructed by VSW of Manchester. They also designed the system for monitoring the beam flux on the SRS, which was constructed in the physics department workshop of the University, and the computer system. The latter involved writing software to control both the spectrometer and the synchrotron radiation monochromator on station 1.1.

The specimen preparation chamber, pumping system and facilities for in-situ growth of specimens were designed and constructed in Milan. The specimen manipulator with xyz translation, tilt and rotational motion was designed by the Rome group and constructed in Milan.

All the sections were completed separately in Italy and the UK in the first six months of 1990 and, after preliminary tests in the Liverpool IRC, the instrument was assembled at the Daresbury Laboratory for use on station 1.1 of the SRS in June 1990. The instrument was used successfully for a four-week period of experimental work in June and July 1990 as part of the IRC's programme of research on the SRS. It was also used by the Dublin group under the terms of a recent agreement between the EC and the Daresbury Laboratory.

Professor P Weightman
Surface Science IRC
Liverpool University