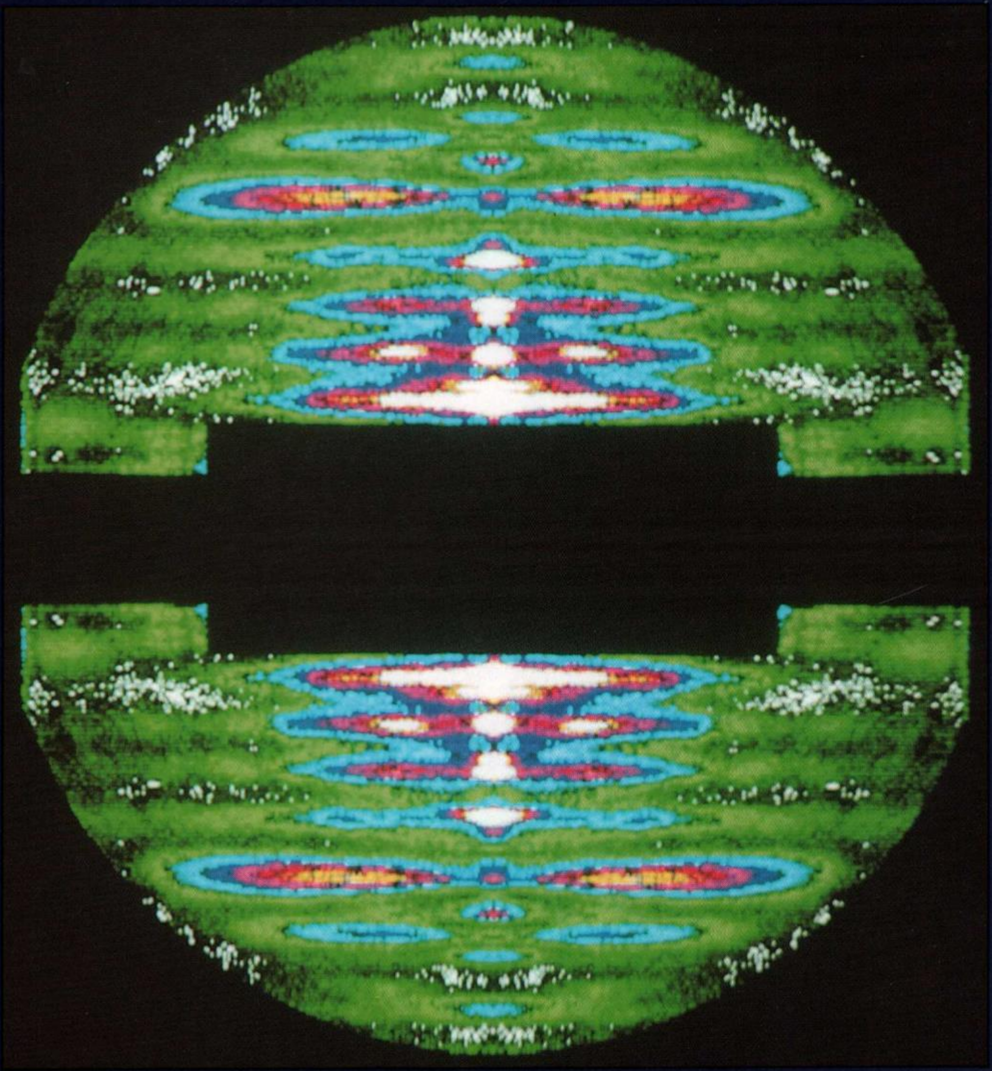
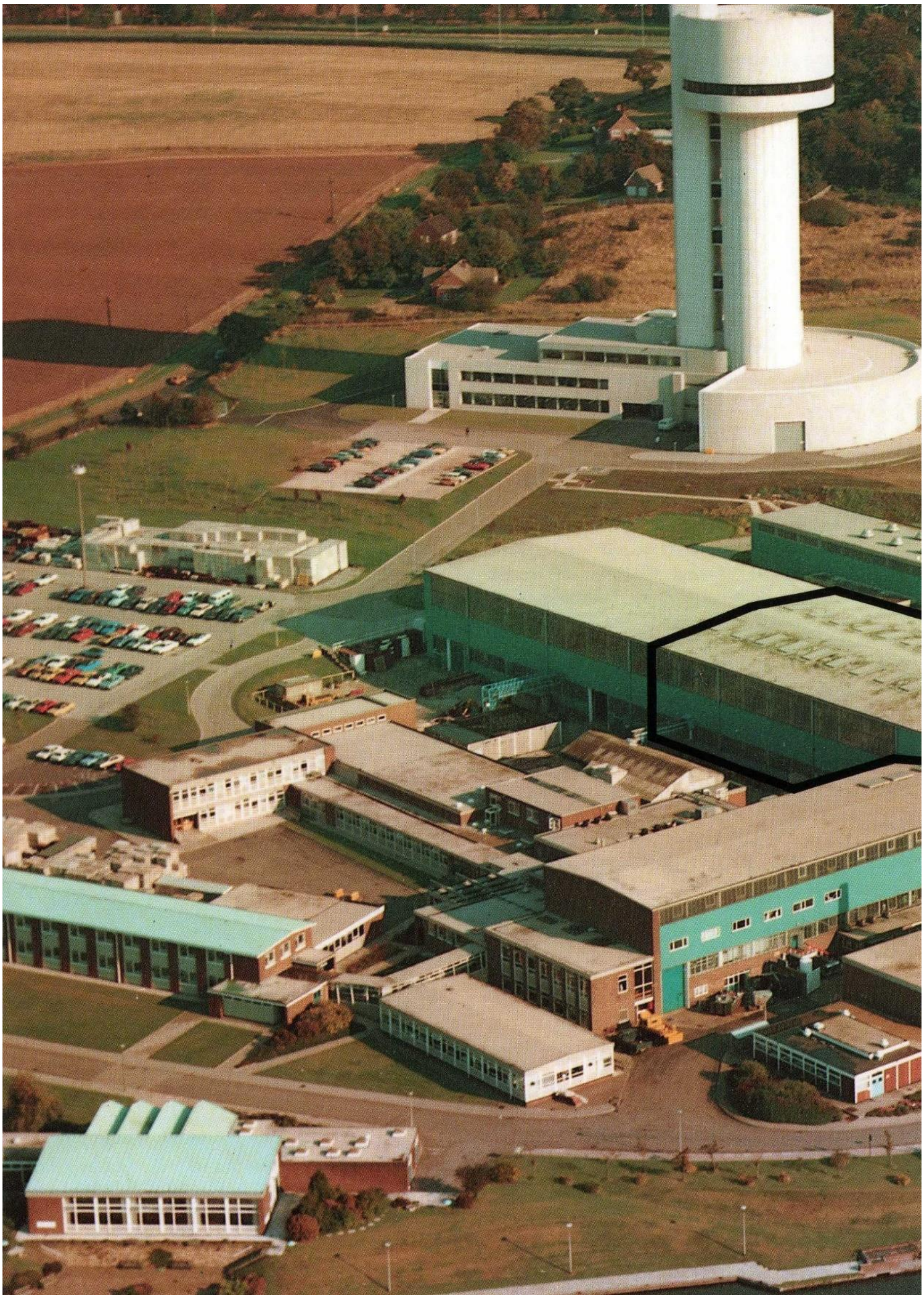
SYNCHROTRON RADIATION RESEARCH



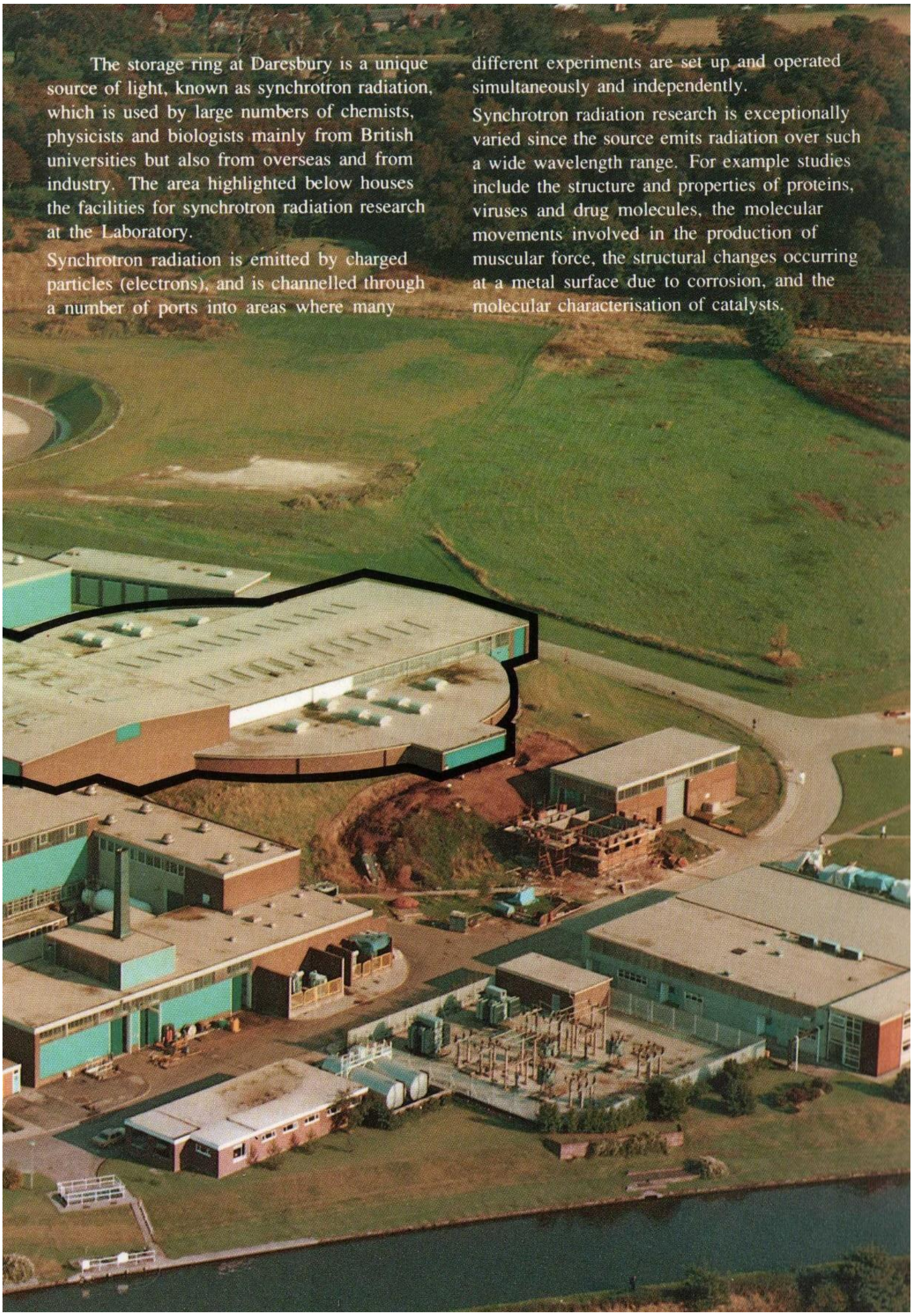
DARESBURY LABORATORY



The storage ring at Daresbury is a unique source of light, known as synchrotron radiation, which is used by large numbers of chemists, physicists and biologists mainly from British universities but also from overseas and from industry. The area highlighted below houses the facilities for synchrotron radiation research at the Laboratory.

Synchrotron radiation is emitted by charged particles (electrons), and is channelled through a number of ports into areas where many different experiments are set up and operated simultaneously and independently.

Synchrotron radiation research is exceptionally varied since the source emits radiation over such a wide wavelength range. For example studies include the structure and properties of proteins, viruses and drug molecules, the molecular movements involved in the production of muscular force, the structural changes occurring at a metal surface due to corrosion, and the molecular characterisation of catalysts.



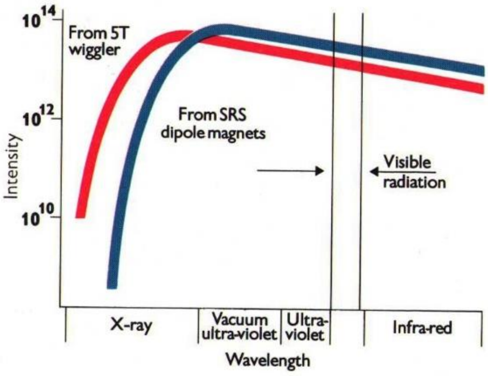
The Source

The Synchrotron Radiation Source, or SRS, is the world's first high energy electron accelerator dedicated to the production and utilisation of synchrotron radiation.

Electrons (emitted from a hot cathode) are first accelerated to 12 million electron volts (12 MeV) in a linear accelerator (LINAC), then pass to the booster synchrotron where their energy is raised to 600 MeV. Next they are extracted from the booster and injected into the storage ring, where they receive their final increment of energy, to 2000 MeV (2 GeV). Sixteen dipole magnets are used to bend the electrons' path into a nearly circular orbit within the vacuum chamber.

Synchrotron radiation is emitted when the high energy electrons are deflected in the fields of these dipole magnets. A high power radio-frequency accelerating system is required both to accelerate the electrons from 600 MeV to 2 GeV, and to restore the energy lost by them as synchrotron radiation. Electrons can remain in orbit for 20 hours or more, traversing the 96 m circumference of the storage ring 3.12 million times a second.

Synchrotron radiation has many unique properties which make it a highly desirable research tool:



- It is very intense, being orders of magnitude brighter than conventional sources.
- It is highly polarised with 100% polarisation in the plane of the storage ring.
- It is well collimated, with a divergence angle smaller than most laser beams.
- It has a smooth, continuous spectrum stretching from x-rays to infra-red in the electromagnetic spectrum.
- It has a precise time structure which is imposed on the source electrons by the r.f. acceleration process.

At two places on the storage ring, special magnets are positioned to modify the trajectory of the electrons, and thus change the spectral distribution of the radiation they emit.
The **Wiggler** magnet uses superconducting technology to produce a high (5 Tesla) central magnetic field, in which radiation of shorter wavelengths is generated. The **Undulator** is a series of permanent magnets of alternating polarity which causes the electrons passing through the pole gaps to undulate, and so emit a greatly enhanced amount of low-energy x-radiation. A second wiggler magnet is under construction, for installation in the early '90's.

Beam Lines

Synchrotron radiation is beamed down evacuated pipes from **ports** on the storage ring to a variety of experimental stations. Each beamline includes a shutter, to block off the radiation when not wanted, and in most cases a mirror to focus the light into each experimental apparatus.

X-ray Spectroscopy

Structural information on metals, glasses, biological, catalytic and other materials is provided by using the technique known as

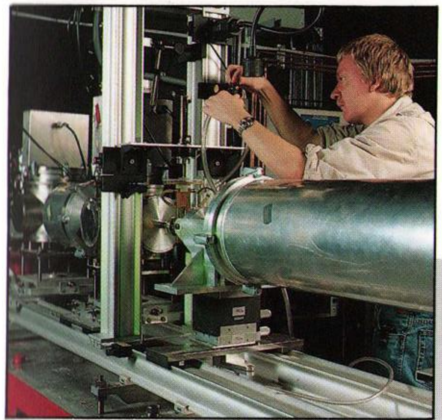
EXAFS (Extended X-ray Absorption Fine-Structure Spectroscopy). Several stations provide EXAFS measurement facilities in absorption, fluorescent or energy-dispersive modes.

Surface Science

Properties of surfaces, for example metal crystals, alloys and semiconductors under ultra-high vacuum conditions, can be studied by a variety of methods. Photoemission yields details of the electronic structure, and infra-red spectroscopy gives vibrational properties of adsorbed molecules. Some experimental stations are equipped to determine the geometric structure of surfaces, e.g. the stepped/terraced arrangement at the surface of a silicon crystal.

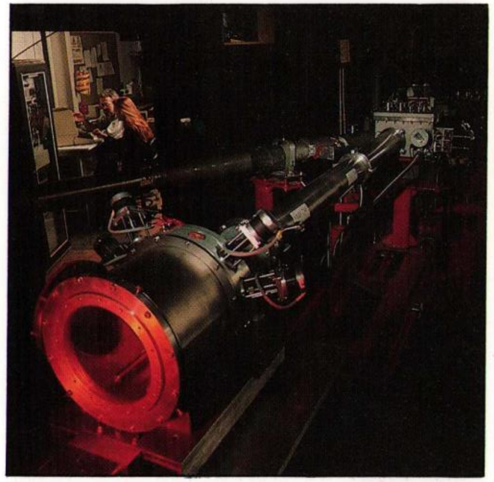
Non-Crystalline Diffraction

Small angle x-ray scattering is used to study the size, shape and distribution of particles in biological and materials science. In addition, kinetic techniques have been developed to study reaction processes, e.g. in cell biology, the assembly and disassembly of tubulin and microtubule protein into microtubules (an essential process in cell division).



Protein Crystallography

Provided they can be prepared in crystalline form, protein and virus structures can be determined by x-ray diffraction measurements. Amongst structures successfully determined in this way is that of the Foot-and-Mouth disease virus.



Powder Diffraction

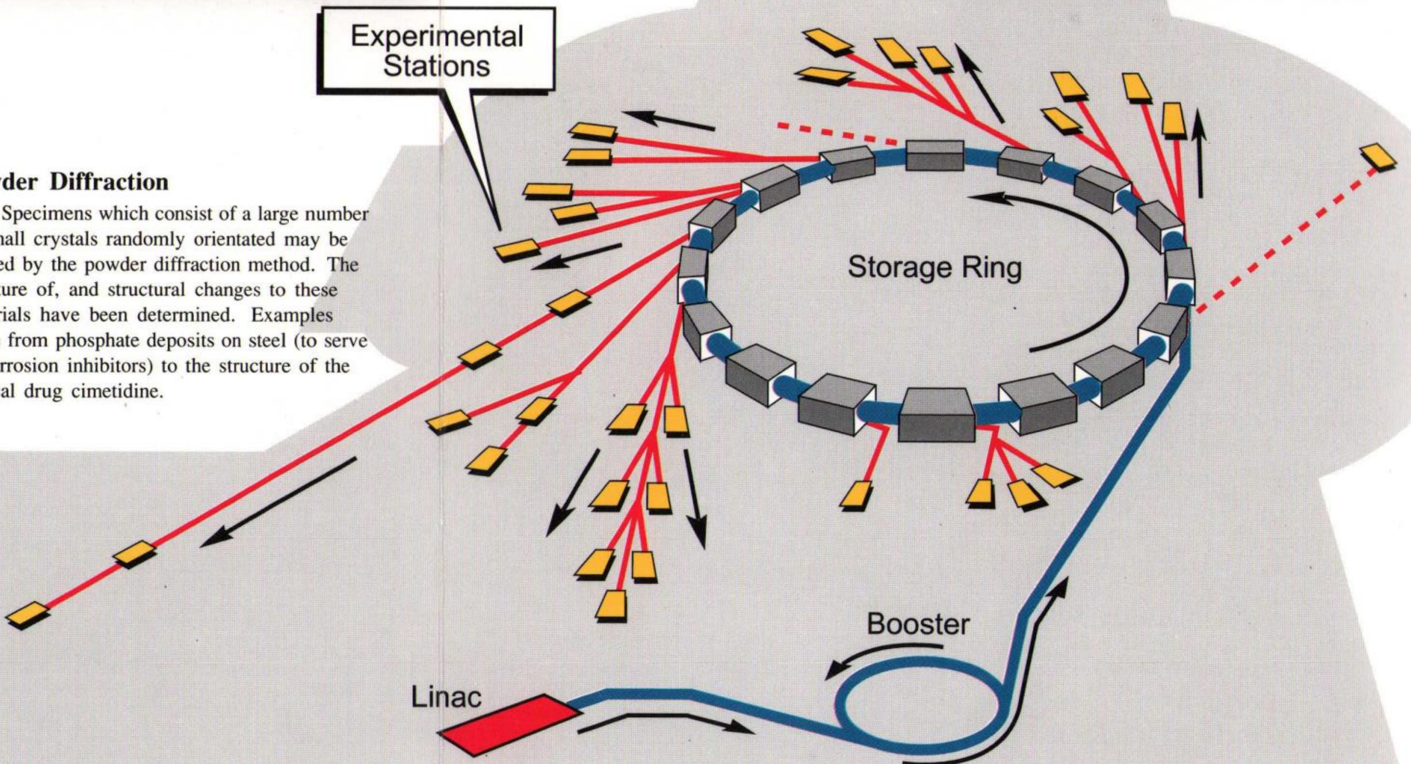
Specimens which consist of a large number of small crystals randomly orientated may be studied by the powder diffraction method. The structure of, and structural changes to these materials have been determined. Examples range from phosphate deposits on steel (to serve as corrosion inhibitors) to the structure of the clinical drug cimetidine.

X-ray Topography

This is another application of x-ray diffraction, which produces images of "single crystal" specimens, in which defects, grain boundaries, magnetic domains, and other variations in the lattice structure may be studied. Ice, diamond and silicon carbide are amongst the crystals being investigated.

Soft X-ray Microscopy

A scanning transmission x-ray microscope, using a Fresnel zone plate as an x-ray lens, has been tried out on the undulator beamline. Images of such things as a grain of wet, hydrated cement, and a rabbit muscle myofibril, have been obtained.



Biological Spectroscopy

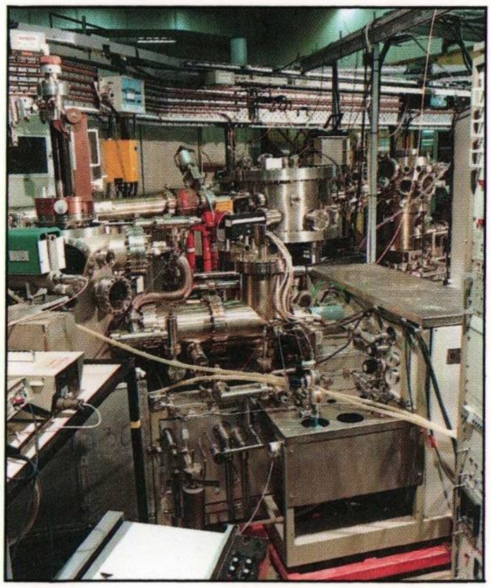
The time-resolved spectroscopy stations are used for kinetic studies of biopolymers, membranes and other macromolecules. Fluorescence decay measurements in the 10^{-9} to 10^{-12} second range have been made on phosphoglycerate kinase (PGK), DNA photolyase, and mutant staphylococcal nucleases.

Atomic and Molecular Spectroscopy

Using vacuum ultra-violet radiation, measurements are made of photoexcitation, dissociation and ionisation processes arising from the interaction of light with free atoms, molecules and clusters. Molecular fragmentation and fluorescence can be studied in cooled molecular beams. The results test predictions based on fundamental theories of atomic and molecular structure.

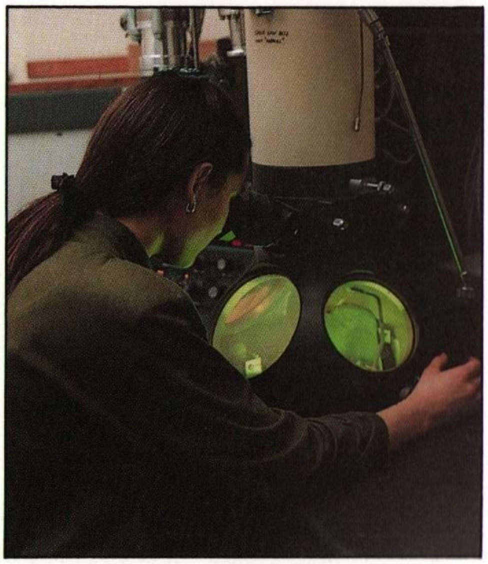
Data Acquisition

The SRS data acquisition system provides facilities for the control of experimental instruments, data collection, and preliminary data analysis. It comprises a local computer system at each experimental station, with links to larger computers possessing more comprehensive peripherals, and to the CONVEX C220 mainframe computer, for further data analysis.



Ancillary Facilities

Biology and materials science laboratories are available for sample preparation.



Theory and Computational Science

Theorists are involved in developing the fundamental principles underlying the distribution of the electrons in atomic, molecular, surface and bulk environments. Physical properties, such as the stability of structures and their magnetic state, and chemical properties such as reactivity can then be understood. SRS experiments can be analysed by combining complicated structural information with details of how the electrons absorb, emit or scatter the synchrotron's light. The resulting calculations inevitably involve large computer codes and the theory group collaborates strongly with computational scientists in developing appropriate computational methods and fully exploiting the power of the computing hardware. Daresbury has access to a wide range of computers including powerful main-frame vector super-computers and parallel computers. These perform, for example, calculations of the energies of electron states in molecules or calculations of the electrons photoemitted from alloy surfaces. Combined number crunching and graphics super-computer workstations allow for detailed analysis and visualisation of results.

DARESBURY RESEARCH SERVICES

Daresbury Research Services (DRS) aims to improve the interface between science and industry by offering access, on a commercial basis, to scientific facilities which are unique in the U.K. This service represents a major step forward by making both the Laboratory's world class equipment and its scientific expertise available to industry. Beams from the SRS are used by industry for research into many areas of chemistry, molecular biology and materials science. Equally industrial interest is evident in advanced computational science; access to scientific databases; computing and networking expertise; electronics; and the high-technology of large particle accelerators. All of these form a powerful basis for the speedy and highly confidential service offered to industrialists by DRS.

How to use the SRS

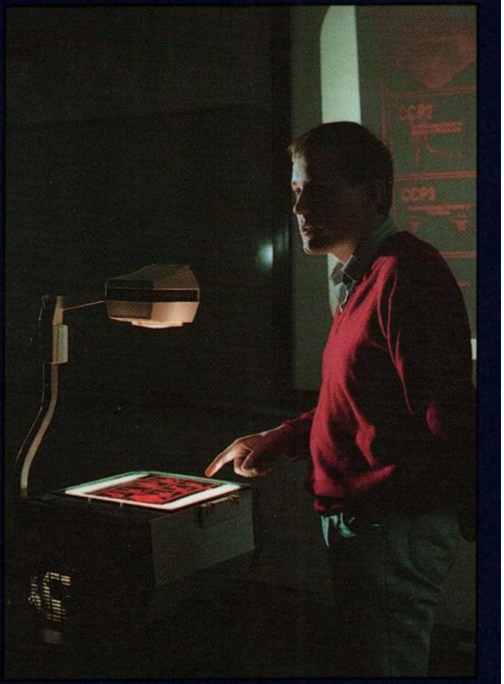
Applications from academic institutions to use the SRS should be sent to the Science & Engineering Research Council, Polaris House, North Star Avenue, Swindon SN2 1ET after discussion with the Head of the Synchrotron Radiation Source (Science Programme), at Daresbury.

Tel. 0925-603507 or 0925 603346;
Fax: 0925 603174
Electronic Mail: INDX @ UK.AC.DARESBURY.

Where is Daresbury Laboratory?

Conveniently situated close to the motorway network in North Cheshire (Junction 11 on the M56), the Laboratory is also accessible via Inter-City rail links (Warrington or Runcorn) or from nearby airports at Manchester or Liverpool.

For further information contact:
SERC Daresbury Laboratory,
Warrington WA4 4AD.
Tel: 0925-603000; Telex 629609; Fax: 603100.



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