A NEW UK SYNCHROTRON

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Synchrotrons are powerful X-ray sources, used to probe the structures of materials at the atomic level. They have a wide range of applications. The UK already has a major Synchrotron Radiation Source, at Daresbury, Cheshire. The decision to build a new national synchrotron has raised issues over its design and location.

This POST Note examines the need for a new UK synchrotron and analyses the issues that arise.

WHAT ARE SYNCHROTRONS?

Synchrotrons accelerate electrons to nearly the speed of light and confine them to a ring using magnets. When accelerated in a circular path, the electrons emit synchrotron radiation. This covers a range of frequencies, from infra-red, through visible light to X-rays, although most applications use X-rays.

“Beamlines” are placed at tangents to the ring. These are arrays of mirrors, lenses and filters to provide X-ray beams of varying wavelength and intensity to the users. Each beamline is designed for a specific type of scientific technique. The ability to select different radiation wavelengths and the high intensity allow experiments that would otherwise not be feasible.

The UK has a major synchrotron radiation source (SRS), at Daresbury near Warrington. Its main ring has a circumference of 96m. There are over 40 experimental areas and 2500 registered users.

SCIENTIFIC APPLICATIONS

Synchrotrons are used in a range of applications, including chemistry, physics, engineering, materials and earth sciences and the bio-sciences. X-rays from a synchrotron are shone onto a target material, interacting with the atoms and molecules in the sample. The pattern of light produced gives information about the material’s atomic structure (see **Box 1**).

Historically, synchrotrons have been used predominantly by physical scientists. However, recent advances, particularly automated genome sequencing, will increase the demand from biological scientists for synchrotron radiation. For instance, the 1997 Nobel Prize was awarded to John Walker for determining the structure of the enzyme F_1 ATPase, using work done at Daresbury. A recent review by the Biotechnology and Biological Sciences Research Council concluded that the UK owed its leading position in structural biology to the SRS at Daresbury.

BOX 1: APPLICATIONS OF SYNCHROTRON RADIATION

Protein crystallography. X-rays are used to determine the structure and function of biological molecules such as proteins. This is extending understanding of more complex molecules, including those in living cells. UK groups are among world leaders in this field.

Non-crystalline diffraction. Used to determine the structures of non-crystalline biological and other materials, such as membranes and molecules on surfaces, including the brain. This can be important for research into biomaterials, plastics, biosensors, pharmacology, food science, Alzheimer’s disease and Parkinson’s disease.

X-ray spectroscopy. One form of X-ray spectroscopy, EXAFS, involves measuring the change in the absorption of X-rays by a material as the energy of the X-rays is gradually increased. It can reveal information about the environment surrounding a particular element in the material. Example materials include semiconductors, iron stored in the brain, and clay traps for radioactive waste.

Time-resolved analysis. Chemists use synchrotron techniques such as absorption spectroscopy, surface scattering and diffraction to study chemical reactions as they occur. This allows them to go beyond static analysis before and after the reaction, to directly observe the kinetics of the reaction *in situ* and in real time.

NEED FOR A NEW SYNCHROTRON

The Daresbury SRS was the world's first dedicated high-energy synchrotron source, with the first user experiments in 1980. It uses "second generation" synchrotron technology but is now becoming obsolete as "third generation" synchrotron sources are developed worldwide. These include machines in France, Italy, Switzerland, Germany and the USA. Third generation devices are optimised to take more "insertion devices" (arrays of magnets which modulate the output intensity of radiation) and are therefore more powerful than the SRS. Insertion devices can be installed only on straight sections of the storage ring and thus are limited in number.

Daresbury SRS was upgraded in 1985, but is thought uneconomic to upgrade further. The basis for a new synchrotron source is detailed in the “Woolfson Report”, a review of needs of the wider science community in relation to synchrotron radiation science, published by the Engineering and Physical Sciences Research Council in 1994.

The Council for the Central Laboratory of the Research Councils, (which manages both the Daresbury and Rutherford Appleton Laboratory sites) completed a pre-feasibility study for the new facility, named Diamond, in 1997. However, construction was delayed until funding was found.

FUNDING

In summer 1998, the Wellcome Trust declared that it would contribute a total of £110m to the new SRS.

UK Government funding of £35m over the first two years of the project was allocated in October 1998. The total cost of the project, for construction and running, will be about £550m. The estimated capital cost is around £152m (excluding VAT), of which about £30m will come from the Wellcome Trust. It is assumed that further funds will be forthcoming in the next Comprehensive Spending Review.

In August 1999, the French Ministry of National Education, Science and Technology announced that the UK and French Governments would co-operate on the new SRS. France has committed £35m for its construction, and £6-8m per year for operation.

France had been planning to build a lower energy synchrotron source called "Soleil" to replace the two sources at the LURE research facility outside Paris, but this plan has now been abandoned. It is estimated that the French allocation on the new machine will only supply one third of the long-term demand for synchrotron time in France, so the French government is negotiating to rent beamlines on other European sources. However, the French have a particular interest in the UK project to develop their life sciences research capabilities.

DESIGN

The new synchrotron will be designed to fulfil, as far as possible, the demands of its potential user communities. The energy of the electrons in the synchrotron is an important parameter: this is 2 Giga electron Volts (GeV)[1] in the SRS at Daresbury.

Two consultation exercises on the design took place, to determine the views of UK and some overseas synchrotron users. These covered the communities of biological sciences and physical sciences/ engineering. The various science communities have similar energy requirements, depending on the techniques used and the materials analysed:

- a 3GeV source would meet the requirements of much of the physical sciences community. Users working on structure determination would prefer a machine energy of 3.5GeV and atomic and molecular scientists use lower energy X-rays and would therefore prefer a 2GeV source.
- the minimum energy acceptable to all areas of the biological sciences community is 3GeV, although 3.5GeV would allow more flexibility in the future.
- the French Soleil design was for 2.5GeV.

A consensus has been reached within the UK community for a 3GeV design, optimised to study molecular structures, which will be more specialised than either Diamond or Soleil.

The circumference of the ring is likely to be around 400m. Users stressed the need for experiment and support laboratories near the beamlines, sufficient space around the beamlines to accommodate a range of experiments, and a number of insertion devices. It is seen as a priority to keep the "dark time" between the closure of the Daresbury SRS and the opening of the new synchrotron to a minimum.

BOX 2: SITING CONSIDERATIONS

- Links to research programmes in local institutions, complementary techniques, international collaborations and opportunities for future development. The ISIS neutron and muon source is located at RAL. This provides beams of sub-atomic particles used to determine the structure of matter on a microscopic scale. There is some similarity with SRS applications.
- The current location of the UK's expertise in synchrotron radiation and the transfer of staff.
- Scientific requirements in relation to the technical design of the facility.
- Building and staff costs.
- Implications for the period of "dark time".
- The spread of scientific activity across the country.

LOCATION

The pre-feasibility study assumed that the new synchrotron would be sited at Daresbury. However, it has been suggested that Rutherford Appleton Laboratory (RAL), outside Oxford, would be a better location on scientific grounds. A decision on the site has yet to be made, although it was expected in early autumn 1999. In November 1999 the Secretary of State for Trade and Industry, Rt. Hon. Stephen Byers MP announced the initiation of a study to look at the views of the user community on siting, and an engineering survey of potential sites. Some factors involved in the siting decision are detailed in **Box 2**.

The Wellcome Trust favours RAL and has stated that the final decision on location must be based on a strong scientific case or it would have to consider alternative options. It is, however, committed to supporting a new synchrotron facility for UK biomedical scientists. The French Government are also reported to prefer RAL.

FURTHER INFORMATION

Diamond: *srs.dl.ac.uk/top/diamond.html*
CLRC: *www.clrc.ac.uk*
Wellcome Trust: *www.wellcome.ac.uk/synchrotron*

The Parliamentary Office of Science and Technology, 7 Millbank, London SW1P 3JA, tel: [0171] 219 2840.

See also www.parliament.uk/post/home.htm

[1] Electron volts are measures of energy commonly used in high energy physics. An electron volt is the energy of an electron accelerated through an electric field of 1 volt. A Giga electron volt is 1 billion electron volts.