THE SRS AT DARESBURY LABORATORY: A EULOGY TO THE WORLD'S FIRST DEDICATED HIGH-ENERGY SYNCHROTRON RADIATION SOURCE

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Abstract

2008 marks the last year of operation of the Synchrotron Radiation Source (SRS) at Daresbury Laboratory, which circulated its first 2 GeV beam in 1981. This paper provides a look back at the significant milestones passed on the way and records the achievements of many of those involved in its thirty-year programme. Many of the technologies and techniques developed at the SRS at Daresbury are now standard practice at synchrotron light sources around the world; and there are few light source laboratories that do not benefit from the skills of someone who spent their formative years working on the SRS. The provision of synchrotron light for the UK is now being met by DIAMOND, whose success is a testament to the skills of its designers, honed as they were on the SRS at Daresbury. These skills are now being used to design the UK's next-generation light source, to provide the pulsed and longer-wavelength light that DIAMOND cannot.

IN THE BEGINNING

Synchrotron Radiation (SR) research started at Daresbury Laboratory in 1968. A facility to exploit the radiation from the high-energy physics accelerator NINA, a pulsed 6GeV electron synchrotron, was approved in 1969 and ran until the closure of NINA on 1st April 1977. In this period a strong and diverse community of SR users built up in the UK.

The first international symposium for SR users took place at Daresbury Laboratory in 1973 and provided early impetus for the development of the world's first dedicated x-ray synchrotron radiation source. This was to be a second-generation source whose primary source of radiation is the lattice dipoles.

Work on the science case and costs then started in earnest, leading to approval for the SRS at Daresbury in October 1974. The 4-year project started in April 1975 with £3M for the accelerators and £300k for the initial beam ports and beamlines.

By the end of 1979 the construction and commissioning of the 600 MeV injector, consisting of a linac and a booster synchrotron, were complete. The construction of the 2 GeV electron storage ring was well advanced and schematic diagrams of the first two beamlines were under development.

A major milestone, circulating the first beam in the storage ring was achieved on 30th June 1980 (see Fig. 1), initiating an intense period of accelerator physics study. Construction of the first two beamlines on ports 6 and 7 was now top priority and on the 7th November 1980 the SRS was formally opened by the Minister of State for Science. Parameters of SRS 1 are shown in Table 1.

Table 1: SRS 1.0 parameters

Parameter	**Value**	**Units**
Linac energy	12	MeV
Booster (injection) energy	600	MeV
Stored beam energy	2	GeV
Storage ring circumference	96	m
Lattice type	FODO	
Number of cells (2 dipoles/cell)	8	
Dipole bend radius	5.6	m
Dipole field	1.2	T
RF frequency	500	MHz
Revolution frequency	3.123	MHz

FIRST OPERATION

The first scheduled operation of the SRS for users started in the spring of 1981. There were facilities for Extended X-ray Absorption Fine Structure (EXAFS), protein crystallography and x-ray topography on line 7 and for surface electron diffraction and surface EXAFS on line 6. Development of beamlines for UV/visible timing experiments and infra-red spectroscopy approached completion.

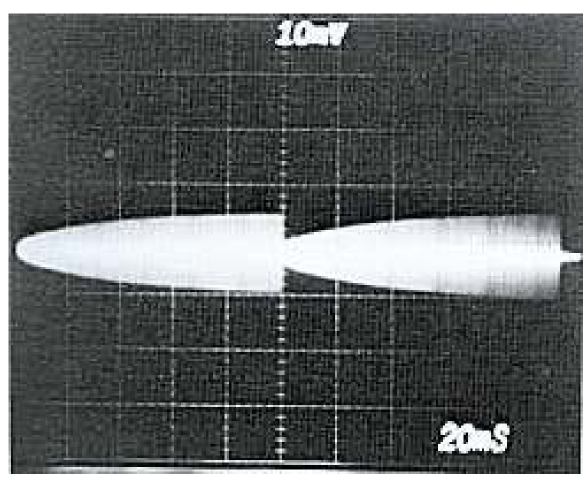

Figure 1: The first beam in the SRS storage ring.

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The electron beam operating current and energy were built up over several months and achieved full design specification at 2 GeV in March 1982. Normal high current operations of the SRS used all 160 RF buckets with a total circulating current typically around 300mA. Additional work to allow operation at low current with all charge in a single bunch for a special class of time-resolved SR experiments was also completed in March 1982.

UPGRADES

Superconducting Wiggler

The first major storage ring modification was the installation of a 5 tesla superconducting wiggler magnet to extend the spectrum of x-rays available to higher energies. This device was brought into operation for users in November 1982.

Full-Time Operation

In 1983 the SRS switched from 16 hour per day to 24 hour operations but suffered severe disruption to the user programme towards the end of the year due to repeated failures of RF cavity windows. A recovery programme was launched which ultimately led to some RF system design changes which solved the problem.

First Undulator Installed

The period between 1984 and 1986 was characterised by high-reliability operations for users for over 5000 hours per year. The first undulator device was installed in October 1984 (see Fig 2).

High Brightness Lattice

SR research internationally was growing rapidly and the emphasis in the output properties of the sources was changing from very high intensity to very high brightness, requiring a reduction in the dimensions of the electron beam source. The design of a major modification to the SRS to achieve higher brightness was planned and completed in this period.

The SRS was shutdown in October 1986 for the upgrade to the so-called “High Brightness Lattice” (HBL). The eight original twin-dipole cells were split by the addition of a further sixteen quadrupoles to produce a sixteen cell lattice. Further sextupoles and steering magnets were also added to the storage ring. This major engineering reconstruction of the storage ring required the reconstruction of every straight section by staff working two shifts a day to complete the construction programme on schedule by March 1987. After this upgrade the normal multibunch circulating current was 220mA, while in single bunch operation it was around one-tenth of this. In order to achieve a reasonable lifetime in single bunch operation, a special lattice tuning, known as LoQ was used to increase the vertical beam size. The normal multibunch lattice tuning was christened HiQ. HBL parameters of the SRS are shown Table 2.

Improvements to the Photon Beam Quality

Following re-commissioning of the storage ring and the beamlines, user operations on the SRS resumed in September 1987. Attention then shifted to projects which would improve the quality of the photon beam for users. These included a modernisation of all beamline photon position monitoring systems and an upgrade of the systems to monitor and control electron beam position. Approval was also given for a design study to consider a second superconducting wiggler magnet at 6 tesla.

The 6 tesla wiggler project was funded in 1990, installed during the November 1991 - June 1992 shutdown and available for use by users in July 1993. There was good progress on SRS beam stability systems with the establishment of a photon beam monitor test facility and the replacement of the steering magnet control system.

The conclusion of the beam quality projects came in 1994 with the replacement of electron beam position monitoring systems and wide-scale introduction of new photon beam position monitors around the facility. Global beam position stabilisation in both planes was established; in the vertical plane this used the photon beam position data and an SVD-based algorithm.

Table 2: SRS “High Brightness Lattice” parameters

Parameter	**Value**		**Units**
Stored beam energy	2		GeV
Storage ring circumference	96		m
Lattice type	FODO		
Number of cells (1 dipole/cell)	16		
Dipole bend radius	5.6		m
Dipole field	1.2		T
RF frequency	500		MHz
Bunch spacing	2		ns
Bunch length (typical)	50-100		ps
	HiQ	**LoQ**	
Horizontal tune	6.19	4.21	
Vertical tune	3.37	3.21	
Momentum compaction	0.029	0.058	
Emittance (2 GeV)	104	258	nmrad

Gapped Beam

Over the next three years, the SRS operated with very high reliability throughout a heavy schedule of over 6500 hours per year total operating time with 5500 hours for users. Beam lifetime was enhanced by the introduction of a gap in the stored beam filling structure to stop ion trapping. Pioneering work was carried out operating the SRS at extremely low current (“microamp beam”) for calibration of astronomical detectors.

Nobel Prize

In 1997 a share of the Nobel Prize for chemistry was awarded to Dr. John Walker for determining the structure of F1-ATPase. Data collected at the SRS formed a vital part of this research, and this is believed to be the only Nobel Prize to include work on a SR source.

Multipole Wigglers

A second major rebuilding of the storage ring was undertaken in 1998 to install two 2 tesla hybrid permanent magnet multipole wigglers designed at Daresbury and constructed by Sincrotone Trieste. One consequence of this upgrade was the need to relocate all four RF accelerating cavities. The SRS shutdown in October 1998 for the three-month upgrade installation with staff working seven days a week to achieve a challenging programme to minimise the loss of experimental time. First turns after this work were achieved during the afternoon of the laboratory’s Christmas party, and user operations resumed on schedule in January 1999.

THE FINAL YEARS

In 2000, after 20 years of storage ring operation, it was necessary to review the investment needed to maintain the SRS’s reliability in the face of obsolescence in some systems. Projects were launched initially to replace the power supply for the storage ring klystron and to replace the liquid helium cryoplant for the two superconducting wigglers. Smaller engineering enhancements have included replacement of many pulsed powers supplies, replacement of the electron BPM monitoring electronics, replacement of parts of the accelerator timing systems and venting of the booster synchrotron to replace all vacuum seals and orbit correction windings. These improvements will ensure the reliable operation of the SRS through to the end of its life.

APPLE-II Undulator

However, there was also funding for three further major enhancements; a new protein crystallography facility requiring a 2.4 tesla hybrid permanent magnet multipole wiggler and an advanced infra-red beamline. The installation of this insertion device filled the final remaining straight section space in the storage ring. A new Apple-II type variable polarisation undulator (see Fig. 3) was installed in 2004, which required the removal of the existing undulator. The successful design, magnet block sorting and shimming of this device pushed the boundaries of Daresbury’s insertion device capability further. This device was the first SRS accelerator component for which control was handed over to the user, allowing them to select not only the wavelength, but also polarisation (linear, L or R circular or elliptical).

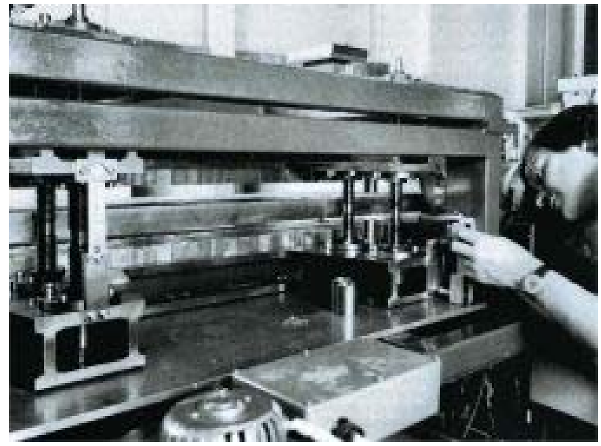

Figure 2: The first insertion device installed in the SRS in 1984, the U5 undulator.

Figure 3: The last insertion device to be installed in the SRS, in 2004, shown on test; it is an Apple-II-style undulator, which replaced U5.

THE END

User operation of the SRS is scheduled to end in August 2008. Prior to this, a programme of phased decommissioning of experimental stations and beamlines is underway. This will be followed by complete dis-assembly and disposal of the accelerator in the subsequent year.

CONCLUSION

The closure of the SRS is the end of an era at Daresbury Laboratory and it is clear that the future will be very different. However, everybody involved with the SRS can look back with pride at what was achieved, and the *esprit de corps* generated will serve the laboratory well in its future endeavours.