SRS-2: PERFORMANCE AND ACHIEVEMENTS

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Abstract

Late in 1986 the Daresbury SRS, an early design of dedicated Synchrotron Radiation Source, ceased operation and was rebuilt with a higher brilliance lattice. The new facility, SRS-2, commenced operation for users in June 1987 and since then significant further improvements have been introduced. The present operational status is summarised and major areas of accelerator physics activity are described. User beams over 250 mA with lifetimes in excess of 25 hours are now routinely achieved. In single bunch mode user beams of 30 mA are delivered. Current-dependent beam dimensions have been investigated, including instability thresholds.

1. Introduction

In late 1986 the Daresbury SRS was shut down to convert its 8-fold FODO lattice to 16-fold, resulting in a reduction of the horizontal emittance by a factor of 10 and an increase in the brilliance by a factor of 15, depending on the location of the tangent point. The overall constraint for the conversion was that the dipole magnets and their attached beam lines must remain unaltered. Much of the equipment in the straight sections, such as injection and rf hardware, was able to remain unchanged but new vacuum chambers were required everywhere except in the dipoles.

Figure 1 shows a comparison between the original lattice SRS-1 and the modified lattice SRS-2. Their parameters are contrasted in Table 1.

SRS-2 has been operated at an annual rate of 5000 hours per year for experimental users since June 1987. Initial performance has been reported[1], but since then there has been a steady improvement. The latest performance is reported here with emphasis on those factors which are particularly relevant to the successful operation of a high brilliance source.

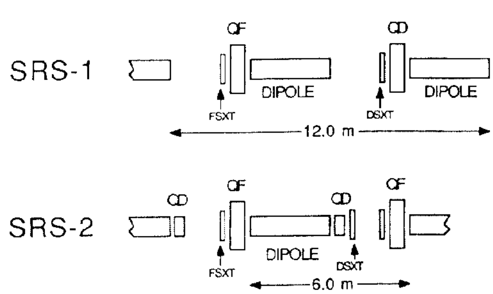

Fig. 1. Comparison between old and new SRS lattices.

Table 1. Lattice Parameters

	SRS-1	SRS-2
Circumference m	96.0	96.0
Lattice type	FODO	FODO
Number of cells	8	16
Maximum energy GeV	2.0	2.0
Betatron tune, horizontal	3.18	6.17
Betatron tune, vertical	2.22	3.37
Momentum compaction factor	0.14	0.03
Uncorrected chromaticity, horizontal	-9.0	-11
Uncorrected chromaticity, vertical	+0.5	- 4
Natural horizontal emittance at 2 GeV mm-mrad	1.5	0.11
Natural bunch length at 2 GeV mm (fwhm)	60	35

2. Beam Current

In normal multi-bunch operation, when each of the 160 buckets in SRS-2 are uniformly filled, beams of up to 300 mA are produced at the standard working energy of 2 GeV. It is possible to fill currents greater than this at the injection energy of 600 MeV, and the practical limits on injected beam current have not yet been fully explored. The 2 GeV current is normally less than that injected because beam losses take place during the energy ramp. The main reason for these losses are transient control inaccuracies in the magnet power supplies, at the level of about 0.01%, and these are presently the subject of investigation.

The betatron tune diagram in the vicinity of the standard working point of the storage ring is shown in figure 2. Resonances up to 5th order are included. At

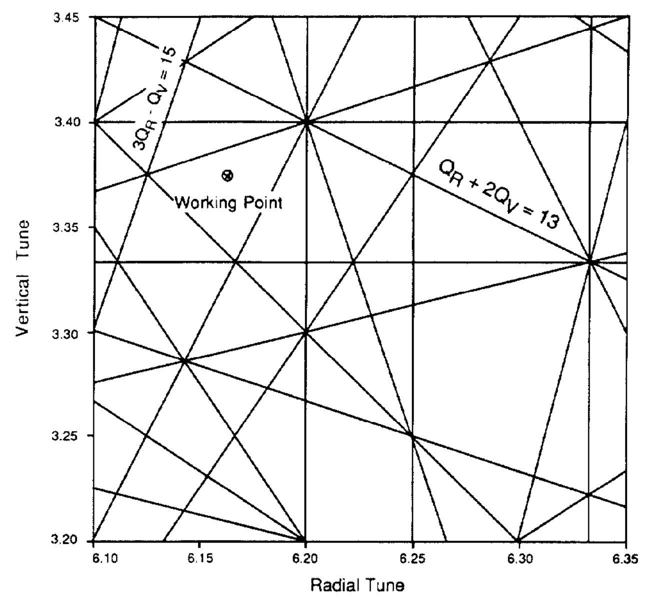

Fig. 2. Betatron tune diagram.

low energy and high current many of the resonances shown result in beam losses if crossed, and it is for this reason that the magnet power supply control accuracy has to be maintained at better than the level stated above to avoid beam losses. When the beam energy has increased to above 1.5 GeV, many of these resonances may be crossed without loss, but beam size effects are observed, as described below.

Coupled bunch motion is observed even at very low bunch currents (approx. 0.05 mA per bunch) and is evident by the appearance of synchrotron oscillation signals on the beam pick-ups. This motion is mainly longitudinal and non-destructive. The coupled motion is driven by higher order modes (HOMs) in the 4 rf cavities[2], which are partially damped by 10-15 dB broadband filters in the feeder waveguides. It is also necessary to control the HOM frequencies by means of the cavity temperatures, although it is not clear that the optimum settings have yet been established.

When operated in single bunch mode, with all the

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current loaded into only 1 of the 160 buckets, average currents of up to 50 mA have been achieved, although 30 mA is a more normal value for scheduled use. At this level of current the Touschek lifetime even at 2 GeV can be unacceptably short, especially in comparison with the very long vacuum lifetime experienced in multi-bunch. Remedial action is taken to increase the Touschek lifetime by operating the lattice at a slightly reduced brilliance and higher emittance in order to reduce the density of electrons within the bunch. With this strategy the beam lifetime at 25 mA single bunch current is about 20 hours.

The bunch length in single bunch increases with current, as has been previously reported[3], but the variation is not in accordance with normal turbulent bunch lengthening.

3. Beam Size

Although some beam size measurements have been made using an x-ray pinhole camera, most data has been derived from a dedicated optical system[4]. This uses the visible component of the synchrotron radiation which is reflected out of the storage ring by a cooled silicon carbide mirror set at an angle of 45°, into a darkened area equipped with an optical bench and other optical diagnostic equipment. The beam size data presented here has been produced using linear photodiode arays positioned at focused synchrotron radiation images of the electron beam.

At low multi-bunch currents with the orbit fully corrected the measured horizontal beam size is about 20% larger than would be expected from the theoretical natural emittance of $0.11\ 10^{-8}$ metre-radians. The measured vertical size indicates a vertical/horizontal emittance ratio of 7.5%. The action of the 5 Tesla wiggler, which is located at a position in the lattice where the dispersion is not zero, is to increase this emittance. The calculated increase for SRS-2 using a mathematical model for the wiggler based on the measured axial field distribution is 30%. In practice the emittance increase due to the wiggler is only measured as 20%.

Under user conditions the beam orbit is optimised to shine radiation into the experimental stations and the orbit is not corrected with respect to the beam pick ups. The vertical beam size produced with this orbit is considerably smaller, indicating a coupling ratio of 1.7%. Figure 3 shows the longitudinal, horizontal and vertical beam size, measured as a function of beam current under standard user conditions at 2 GeV with the 5 Tesla wiggler energised. It can be seen that above 200 mA the beam size increases in the horizontal and longitudinal axes. This is an incoherent process because no coherent signals can be detected on the beam pick ups apart from a very small synchrotron oscillation contribution. The vertical beam size increase is similarly incoherent, although its threshold appears to be only 100 mA. At present no satisfactory explanation exists for these beam growth effects.

The beam size is also influenced by the proximity of resonances within the tune space shown in fig. 2. The effect on the beam size of changing the working point in tune space is shown in fig. 4. Again this data was taken at 2 GeV with the wiggler on at standard conditions. The optimum horizontal emittance is only achieved by avoiding all resonances up to 5th order. When a high curent beam encounters the 4th order coupling resonance $3Q_r - Q_v = 15$ a dramatic reduction in lifetime results until the current has decreased to about 100 mA. The 3rd order resonance $Q_r + 2Q_v = 13$ is strongly excited by the distribution of the chromaticity correcting sextupoles and a non ideal closed orbit and when encountered causes total beam loss. Near to this resonance strong coherent betatron oscillation signals are observed on the beam pick ups and the beam size increases as shown in fig. 4. From the signal amplitudes the vertical coherent motion is estimated to be ± 0.15 mm, which is in agreement with the measured increased size.

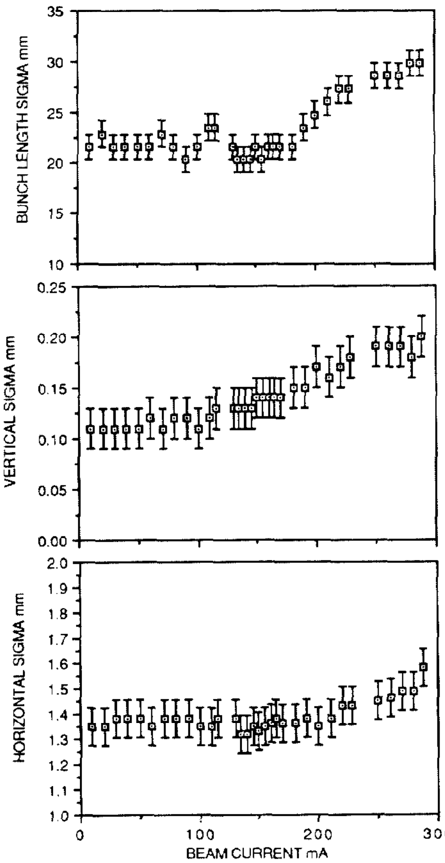

Fig. 3. Beam size variation with beam current.

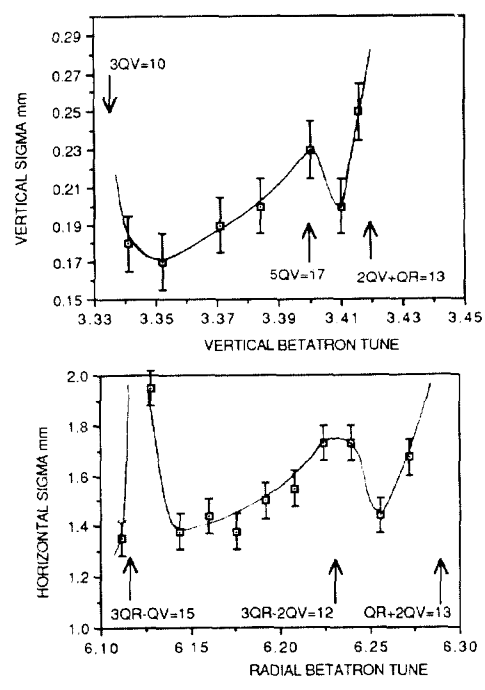

Fig. 4. Beam size variation with betatron tune.

4. Beam Lifetime

Since the conversion to SRS-2 there have been only 3 occasions when sections of the vacuum chamber have been up to atmospheric pressure. Consequently the internal surfaces of the stainless steel vacuum chamber have been thoroughly cleaned by the action of synchrotron radiation and excellent beam lifetimes are now achieved, up to 45 hours at 150 mA and 35 hours at 250 mA. Although lifetime follows the trend of the average pressure measured in the chambers, see fig. 5, exact correlation using standard formulae is not achieved. This is because the ion gauges are slightly remote from the beam chamber (about 0.3 m), and their in situ calibration is affected by stray magnetic fields and is therefore not known precisely. Quantum and aperture lifetimes are so long that they are negligible.

Figure 5 plots the improvement in beam lifetime after one eighth of the storage ring circumference (12 m) had been let up to atmospheric pressure (of dry nitrogen) to repair a leak by rewelding. The improvement in lifetime seen in fig. 5 shows a rapid increase as the opened section of chamber cleans up. The slower improvement which is still evident after 6 months represents the continuing cleaning of the entire chamber. The performance in fig. 5 was achieved without the use of in situ bakeout, which is now used only in exceptional situations.

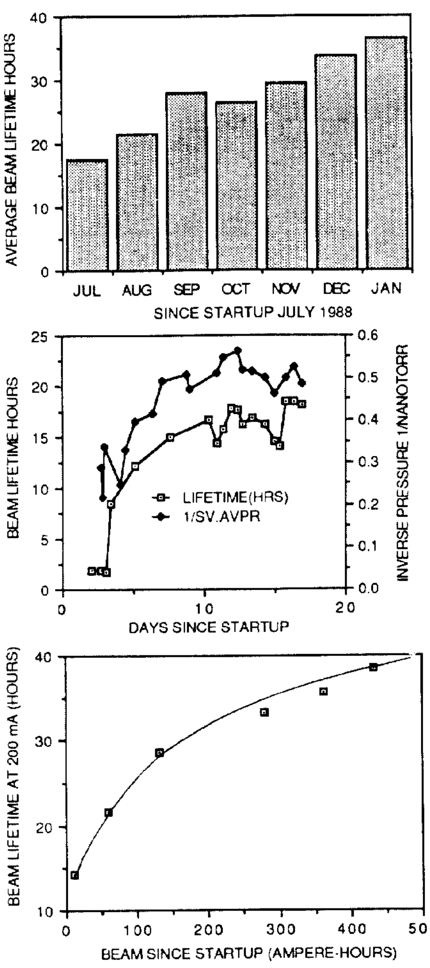

Fig. 5. Improvement in lifetime after a partial vacuum let-up in July 1988.

5. Beam Position

The generally accepted specification for vertical beam position stability in a high brilliance source is that the beam should be set to an accuracy of better than half its vertical dimension at the start of each user run and then should not change by more than the same amount during the run. A major cause of beam movement in SRS-2, both during a run and from run to run, is variation in temperature of the cooling water. The heat sink for this is a local canal whose water temperature may vary seasonally by over 20°C. The water temperature control systems were installed 20 years ago and were not designed to cope with the variations of thermal load produced by the storage ring.

Movements from run to run are corrected by adjusting the orbit correctors with reference to vertical position monitors in the beam lines. Drift during a run of up to ± 0.25 mm has been observed occasionally. Plans to upgrade the water cooling system are now being considered, but in the short term changes to the water services in the storage ring tunnel should improve stability. Figure 6 shows the correlation between drift measured on a beamline position monitor and magnet cooling water temperature, indicating that temperature regulation to better than ± 0.25°C will be required.

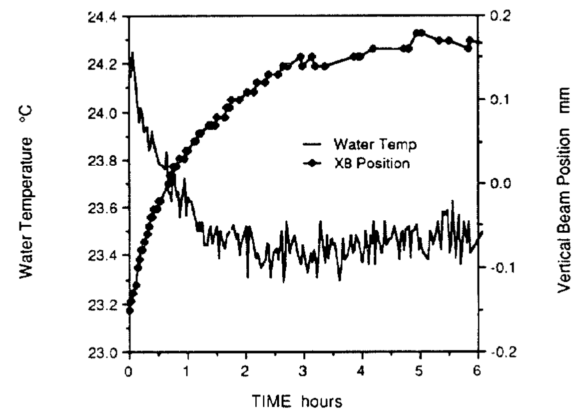

Fig. 6. Correlation between cooling water temperature and radiation beam position.

Summary

SRS-2 has generated a substantial increase in brilliance over SRS-1 and is also equalling the output flux. The very long beam lifetime which is now achieved, even at high current, is proving to be very beneficial to the research programme. However beam size growth at high current is limiting the brilliance, and an understanding and solution are being sought. It is also apparent that beam stability is as important, and as difficult to realise, as small beam size.

References

1. V.P. Suller et al, "Performance of the Daresbury SRS with an Increased Brilliance Optic', European Particle Accelerator Conference, Rome, June 1988.
2. J.N. Corlett, "Higher Order Modes in the SRS 500 MHz Accelerating Cavities'; these proceedings.
3. M.W. Poole et al, "Beam Instability Characteristics of the Daresbury SRS", European Particle Accelerator Conference, Rome, June 1988.
4. J.S. Mackay, "Electron Beam Profile, Position Systems and Measurements on the Daresbury SRS", European Particle Accelerator Conference, Rome, June 1988.