# OPERATION OF THE DARESBURY SYNCHROTRON RADIATION SOURCE WITH REDUCED VERTICAL APERTURE

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*Abstract*

The 2 GeV Synchrotron Light Source at Daresbury Laboratory already contains two superconducting wigglers and a permanent magnet undulator. Three additional insertion devices have been proposed as an upgrade to the facility. The source properties of these devices depend critically upon the smallest vertical aperture which can be allowed. Operation of the SRS with reduced vertical aperture has been studied in detail: aspects such as lifetime, injection and ramping have been assessed. This paper presents the conclusions of these studies which allows a specification of the new devices.

## 1 INTRODUCTION

To expand the number of stations on the SRS at Daresbury, it has been proposed to install three new insertion devices in the space remaining in the storage ring [1]. Two multipole wigglers and one undulator [2] have been assessed. In order to maximise the performance of these devices it is desirable that they utilise the smallest magnet gap possible. As a consequence, studies have been performed to assess the minimum vertical aperture which the SRS can tolerate at the positions planned for the insertion devices. The mechanical design of the insertion device vacuum chambers also make a small reduction of the horizontal aperture at these positions highly desirable.

Three factors must be taken into consideration when specifying the minimum acceptable aperture:

- Lifetime reduction during user operational periods.
- Orbit drift during energy ramping from 600MeV to 2GeV.
- Injection requirements.

These considerations are most important for the two principal operating modes of the SRS (multibunch and single bunch, which utilise different working points) but for future flexibility other operating regimes should be taken into account. The three factors are now dealt with in turn.

## 2 LIFETIME

### 2.1 Multibunch Operation

The SRS presently possesses a typical beam lifetime of over 25 hours (depending upon vacuum conditions) during multibunch operational periods, which account for about 90% of user allocated shifts; this necessitates one refill per day, and gives the best compromise between beam intensity and positional stability for users. After work affecting the machine vacuum, the lifetime can deteriorate to under 10 hours until the machine vacuum has reconditioned (typically within a few days), and in this regime two refills per day are usually required. The operational requirement for the new insertion devices is that the beam lifetime is not significantly affected by their introduction, so that the above regimes are maintained for users.

Using collimators in one of the storage ring straight sections, studies have been made of the effect of restricted apertures upon beam lifetime at 600MeV and 2GeV (the injection energy and the final stored beam energy after ramping). Typical behaviour is shown in Figure 1; the collimators will have no effect upon the lifetime above a 20mm full aperture since the most restrictive aperture is then elsewhere in the ring. With a 10mm full vertical aperture at the collimators there is a reduction in beam lifetime of about 15% due to the increased gas scattering loss, which is considered operationally acceptable. In the planned insertion device locations this scales with $\sqrt{\beta}$ to a full aperture of 15mm. In terms of multibunch lifetime, 15mm is therefore the minimum acceptable full aperture for the proposed IDs.

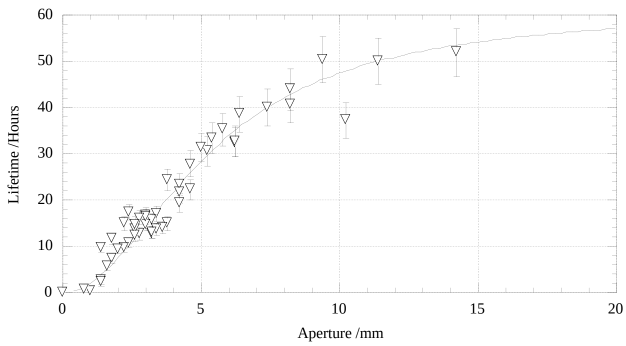


Figure 1: Variation of lifetime with (full) vertical aperture at the vertical collimators in multibunch mode, 2GeV, with a machine pressure of 1 nTorr.

### 2.2 Single Bunch Operation

Single bunch lifetime is dominated by Touschek scattering, giving an approximately constant current-lifetime product (CLP); to maximise the CLP, horizontal-vertical coupling is increased during single bunch operation by moving the single bunch working point close to a 2nd-order coupling resonance. Gas scattering does however make a significant contribution (~50 hours at a machine pressure of 1 nTorr) to the overall single bunch beam lifetime.

As well as the gas scattering effect, it is important that the increased coupling used in single bunch does not produce any adverse quantum lifetime effects (see Section 3 below). Measurements made with the collimators at 10mm full vertical aperture indicate that even with 100% coupling there is a negligible decrease in the quantum lifetime. This means that an ID full vertical aperture of 15mm is acceptable in terms of beam lifetime.

### *2.2 Horizontal Aperture*

To minimise the ID magnet gap and so maximise the ID output demands that the ID vacuum chamber be as vertically small as possible on the outside. The exterior vertical size of the vacuum chamber is dependent upon the minimum chamber wall thickness which may be supported, which in turn is dependent upon the horizontal chamber aperture.

To allow sufficient aperture for the synchrotron radiation fan from the dipoles preceding the ID vessels, an asymmetric vacuum vessel will be used. The vessel design calls for a reduction of the present aperture of 63mm in this region to 53mm on the inner side of the storage ring, to allow thin walls to be used. Again, lifetime studies indicate that this will have a negligible effect upon the overall lifetime, the vertical aperture being much more restrictive in terms of gas scattering, while a significant quantum lifetime reduction only occurs at horizontal apertures below 10mm, well below the aperture required.

## 3 RAMPING

As the booster has a peak energy of 600MeV and the operating energy of the storage ring is 2GeV, the stored electron beam must be ramped in energy. Due to lattice errors, the machine orbit for a particular set of correctors changes with energy, and so the orbit must be corrected during the energy ramp, either by servoing the correctors on the electron BPMs or by discrete correction at particular energies using stored corrector settings. The latter method is presently used at the SRS; without correction, the orbit drifts vertically by typically ~4mm over the course of the energy ramp.

The principal restriction upon the vertical aperture during ramping is from the quantum lifetime contribution to the overall lifetime:

$$\tau_Q = \tau_d \frac{\exp\left(2A^2 / \sigma_v^2\right)}{\left(2A / \sigma_v\right)^2}$$

where $\tau_d$ is the radiation damping time, $\sigma_v$ the vertical beam size and $A$ the half-aperture at the most restrictive point. $\sigma_v$ changes with the working point and coupling used, but is typically between 150μm and 500μm through the ID. If the electron beam moves to within a certain distance of the aperture limit the quantum lifetime drops sharply and the beam becomes hypersensitive to instabilities, since any vertical blow-up will cause very rapid beam loss. This is especially important in single bunch operation, where the natural emittance and the coupling is increased to give a sufficient Touschek lifetime. For the SRS, the 'safe distance' from the aperture limit to prevent losses during ramping has been assessed to be 3mm in the ID sections for both operational modes.

In order to minimise the aperture required during ramping the orbit drift must therefore be minimised, since any drift will add on to the 'safe distance' required. It is proposed to use a novel method of discrete correction during the ramp [3]. This has been demonstrated to restrict the orbit drift to within a ±2mm envelope (see Figure 2). Since the required corrector settings change as the lattice elements undergo long-term movement [4], the orbit drift will increase, necessitating frequent updating; this is a now a routine procedure and it is believed that correction can be maintained within ±2mm. However, the use of vertical servoing during the ramp (either globally or locally) is also being explored. Together with the quantum aperture limit, the minimum possible vertical aperture during ramping is estimated as 10mm at the vertical collimators, again implying a minimum recommended ID gap of 15mm.

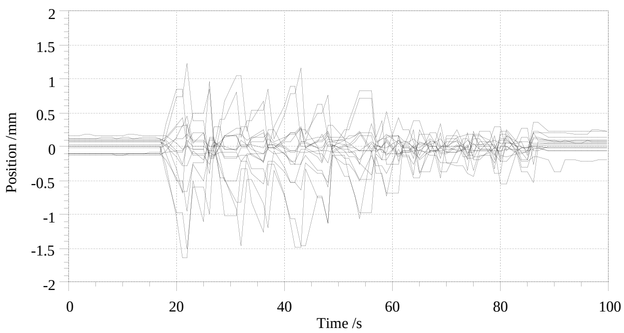


Figure 2: Typical variation in vertical position of electron beam at the 16 BPMs during the energy ramp, using discrete orbit correction.

## 4 INJECTION

Since the construction of the SRS the booster design has remained the same, giving an output emittance of 5.5mm-mrad. Experiments have shown that with rematching satisfactory injection can be achieved with a reduced full vertical aperture of 10mm at the collimators (see Figure 3). The proposed small reduction in horizontal aperture has a negligible effect upon injection. Since upgrading the injector system will be prohibitively expensive, it is proposed that the present booster be used after the ID installation, albeit giving a loss in injection efficiency. This is not expected to adversely affect the operation of the storage ring.

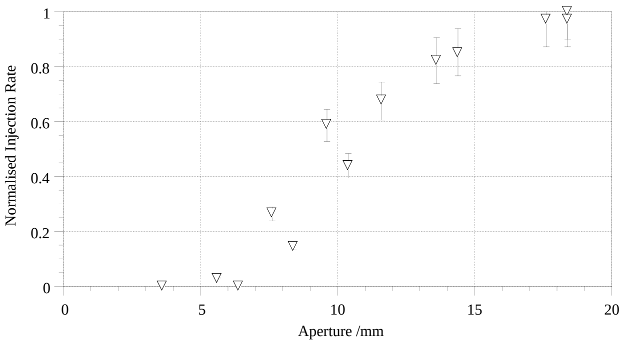


Figure 3: Variation of injection rate with full vertical aperture at the collimators, in the multibunch mode. 20mm represents the point below which the collimators are the limiting aperture. Single bunch behaviour is similar.

Beam lifetime is also a consideration during the injection phase, as there must be no significant loss of current at 600MeV before the energy ramp. However, the lifetime requirement is much more relaxed than for the 2GeV case since the beam only remains at 600MeV for at most a few minutes before the energy ramp commences; a beam lifetime of only a few hours is sufficient to avoid significant beam loss. A 10mm full vertical aperture at the collimators therefore poses no problems in terms of lifetime at injection. Again, this implies a 15mm full aperture for the IDs.

## 5 CONCLUSIONS

From the considerations above the present ID designs specify a 15mm internal vacuum chamber aperture. It is believed that this represents the minimum realistic aperture for SRS insertiondevices. Work is presently underway to routinely operate the SRS with a reduced vertical aperture, to gain more experience of its effect on machine performance during user operational periods.

## REFERENCES


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