BEAM POSITION STABILITY IN THE SRS AT DARESBURY

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Abstract

For efficient exploitation of the high brightness source characteristics it is necessary to stabilise the electron orbit to ± 10 μm. At present the stored beam suffers from a combination of slow drift, step position changes and intermittent oscillations that prevent this specification being achieved. Details of the observed beam behaviour are presented and the mechanisms that can contribute are reviewed. A strategy that attempts to minimise such movements at source in combination with the development of improved monitoring and a feedback system is described.

Introduction

Beam position stability is now a major subject for research and development at all synchrotron radiation laboratories due to the increasing sophistication of existing facilities and the ambitious nature of new experimental projects. Many experimenters now request beam position variation of less than a small fraction of the beam size setting a target stability specification of better than ± 10 μm and ± 10 μrad in the vertical direction for modern low emittance machines.

The higher brightness lattice modification to the SRS was commissioned in 1987[1] and has an emittance of 0.11 mm.mrad and a vertical source size (σ) of 120 μm at the 2 GeV operating energy. Electron beam position stability has been monitored routinely and, without any corrections, the source moves by a maximum of up to ± 100 μm and ± 25 μrad vertically over a twelve hour period between refills.

This paper describes how beam position is monitored at the SRS and presents data on uncorrected performance. The underlying causes of the beam movement are discussed and the extent to which it can be reduced without automatic correction systems is considered. The paper concludes with an outline of development work leading up to automatic orbit control at the SRS.

Measurement techniques

A block diagram of the electron position monitoring system at the SRS is given in Figure 1 and is described in detail in Ref. 2. The performance of the system is limited at present by noise in the switching circuits which limits the accuracy and repeatability of position measurement to ± 50 μm. In its present form, therefore, this system is too inaccurate to assist in the diagnosis of beam drift across a fill and is used principally for gross orbit correction and for monitoring long term and larger drifts in the horizontal and vertical closed orbits.

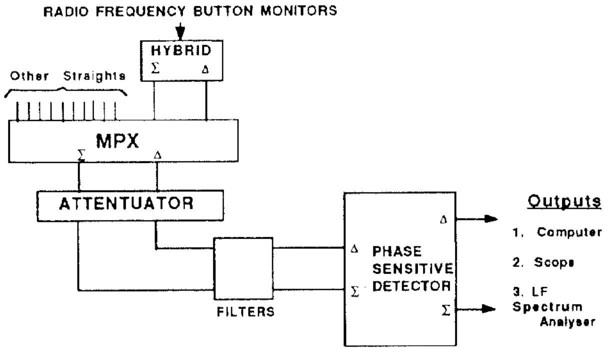

Fig. 1. Block diagram of electron beam position measurement system.

All the photon beam drift data in this paper have been obtained using two independent monitoring systems on beamline X8. The disposition of these monitors is shown in Figure 2. The scanning pin hole ion chambers are stepper motor driven and plot the source profile with a resolution of 50 μm. They are equipped with a precision reference micro switch which is used to set the start position of each scan to 10 μm accuracy. These devices are not cooled and can only be used to sample the beam position at infrequent intervals. The two wire monitor is based on a design developed at the NSLS[3] and provides a permanent real time output proportional to beam position. The calibration curve in Figure 3 shows that this monitor with 12 mms wire spacing at 21 m from the source has a useful range of 3 mm. The beam current dependence of the monitor has been checked by repeating the calibration procedure at several different current levels and by comparing the results with those obtained from the scanning pin hole ion chambers. These measurements are difficult to interpret because the source profile is known to change with current and this effect cannot at present be separated from the data. The result of both effects is, however, less than 50 μm per 100 ma beam change and is insufficient on its own to explain the slow drift of beam position described below.

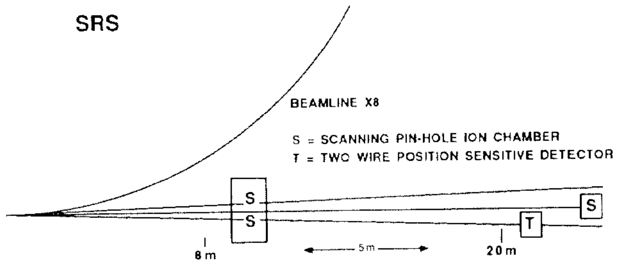

Fig. 2. Disposition of photon monitors on beamline X8.

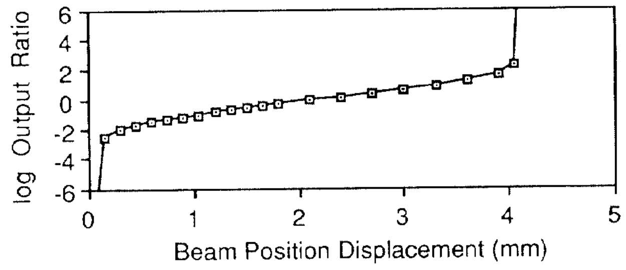

Fig. 3. Calibration curve for two wire position sensor.

Long Term Closed Orbit Drift

The 2 GeV closed orbit of the SRS with all steering elements set to zero is measured periodically to give an indication of the long term positional stability of the lattice. The changes in horizontal and vertical orbits as measured in each straight section of the SRS over a period of 6 months are shown in Figure 4. Calculated quadrupole movements have been necessary on two occasions in the last two years to compensate for the horizontal drift and to maintain the user orbit within the range of the correction magnets. The drift is assumed to be in response to the thermal cycling of the lattice during normal operation although long term ground settlements will also make a contribution. One family of quadrupoles experiences temperature differentials of up to 15°C after the energy ramp from 600 MeV to 2 GeV.

Beam Stability during a Single Fill

The vertical beam position movement during a single fill is a much more critical effect for users and can be conveniently

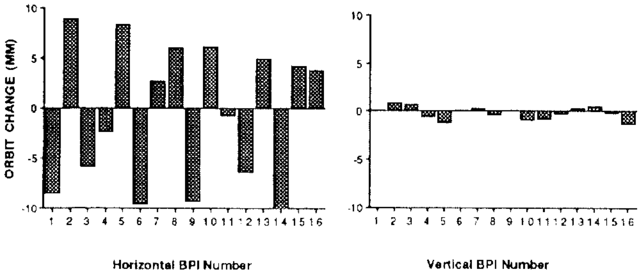

Fig. 4. SRS bare orbit drift over 6 months.

split into three separate classes: slow position offset drift, regular oscillatory movement and irregular step-like behaviour.

Slow Position Drift

Typical SRS behaviour, measured at 21 m from the source on line X8, is shown in Figure 5a. The beam moves up to a peak displacement of 250 µm ± 100 µm in the first three hours of the fill and then follows a roughly linear decay at approximately 20 µm/hr for the remainder of the fill. The time constant of the initial rise is well matched to the time taken for the temperature of the quadrupoles to stabilise following the energy ramp and correlation has been observed between the amplitude of the initial rise and the time taken to reinject the machine. For example, the extent of the initial rise is consistently higher after each morning refill when a mandatory inspection of the accelerator adds up to 30 minutes to the total refill time. The association with temperature stability is reinforced by observing the behaviour of the beam during the first fill after the magnet lattice temperature has reduced to ambient levels (Figure 5c) during a shutdown period.

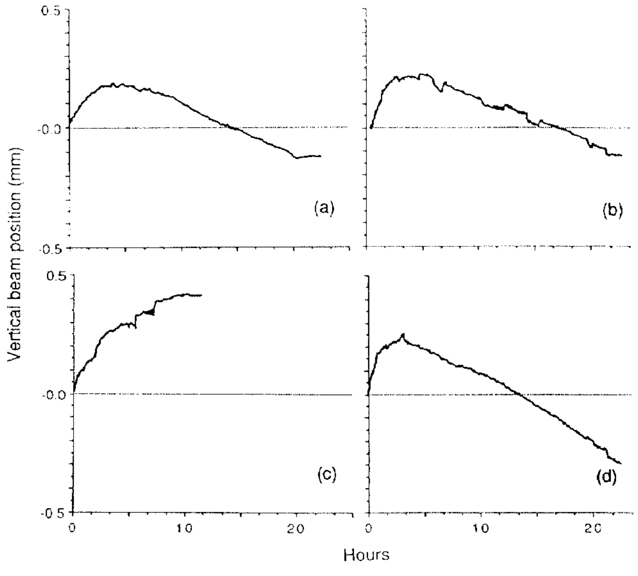

Fig. 5. Beam movement measured at 21 m from the source.
a) Typical fill. b) Showing noise due to power supply instability. c) First fill after a two day shutdown.
d) Abnormally high drift with beam current above 300 mA.

The linear decay section of the beam drift has been far less consistent over the last two years. The total beam shift in this region has varied between 100 and 600 µm but is typically around 300 µm and may vary on a day to day basis by over 100 µm. The highest shifts always occur with stored beams in excess of 300 mA. Attempts to correlate this behaviour with other parameters have so far proved inconclusive. The magnitude of the drift has been measured as a function of clearing electrode voltage to check for the presence of ion effects. Initial results were encouraging, showing a substantial reduction in drift (at the expense of source size) with the clearing electrodes grounded. However, several further attempts to repeat this result have been unconvincing.

Regular Oscillatory Movements

A power spectrum of the position signal from the X8 two wire monitor is shown in Figure 6. Signals at 10 and 16 Hz are related to the booster synchrotron ac magnet drive and the superconducting wiggler cryosystem compressor respectively. The largest component is at the mains frequency of 50 Hz represents a peak to peak displacement of less than 5 µm at the detector. At present, vibrations and electrical noise are clearly only a minor problem in the stability of the SRS.

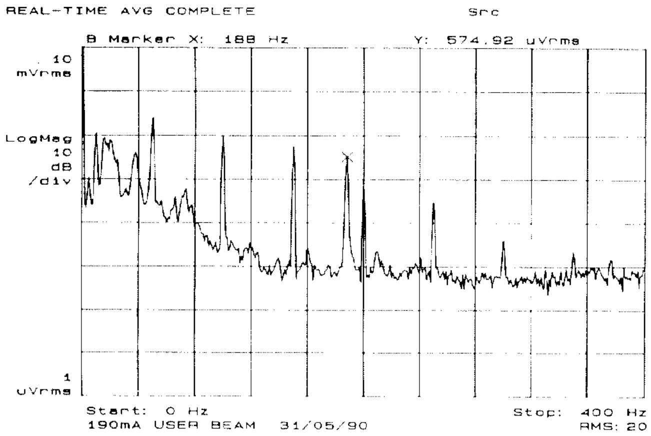

Fig. 6. Power spectrum of vertical position signal 21 m from the source. Calibration is 1 V/mm.

Irregular Step Like Movements

An example of this form of movement is given in Figure 5b. Normally, intermittent low level instability in one of the 224 steering magnet power supplies is responsible and the condition is easily cured. The irritation factor associated with these shifts, however, is high and new software diagnostics have been implemented within the last year to provide rapid indication of suspect power supplies. Occasionally steps of up to 50 µm have been observed at the detector which do not correlate with any power supply instability. The regulation specifications for all SRS power supplies have been checked empirically by making small changes to the output of every supply in turn and observing the consequent deflections on beam line monitors.

Reduction of Movement at Source

The water cooling plant at the SRS was adapted from existing equipment more than ten years ago and is not, therefore, optimally designed for a modern high stability storage ring. The plant is shared with the experimental areas and is now approaching the limits of its capacity. Provision of a new, dedicated and highly regulated system will bring immediate benefits in reducing the temperature excursions experienced by the magnets during the normal operational cycle of injection and ramping. The main sources of heat in the storage ring tunnel are the coil assemblies on the dipole and quadrupole magnets. Installation of air conditioning in the storage ring tunnel would also be beneficial although a complete analysis of the consequent reduction in thermal cycling has yet to be carried out. A multiplexed system of linear displacement transducers (accurate to 1 µm) and temperature monitors is being commissioned in the storage ring tunnel. This system will be used to quantify in detail the expansion and contraction of magnets and any displacement they may suffer with respect to the equipment stands.

New water plant and air conditioning will both require substantial capital outlay but will only alleviate part of the problem. With lifetimes in excess of thirty hours at the SRS, fill lengths up to 24 hours are common and the drift in position following magnet temperature stabilisation will dominate. In the absence of a mechanism to explain this effect, preparations are being made for automatic correction of the machine orbit.

Feedback Systems

Many authors have now published assessments of feedback systems appropriate to SR storage rings (see refs. 4, 5 and 6 for a selection). There are three major elements to consider in a feedback system: electron and photon position monitors; the correction algorithm; and finally the detailed configuration of the steering system and its power supplies.

Beam Position Monitoring

It has already been stated that the existing electron position monitoring system at Daresbury is not sufficiently accurate for observing typical drift during a single fill. In order to implement global feedback techniques for orbit control it will be necessary to upgrade the entire system. A system comprising a new high performance hybrid combiner with separate down conversion electronics local to every monitor is now under development and is expected to achieve 30 μm resolution.

Local feedback loops for individual beamlines require highly stable permanent beam monitors capable of dealing with high power loading. Although the two wire monitor in use at the SRS has performed well with a resolution of 10 μm at 21 m from the source, it will require substantial re-engineering to maintain its dimensional stability closer to the source. Following work at the NSLS[7], we propose to build and evaluate a prototype tungsten vane monitor which is extremely robust and which has achieved resolution below 1 μm.

Two new test facilities are now under development at the SRS. The first at 4 m from the source within the ring tunnel will intercept 5 mrad of beam and is simply a vessel fitted with a high precision vertical drive and encoder to study the behaviour of new monitor designs. The second[8] is an x-ray hutch at 60 m from the source and will contain a single crystal silicon calibrator for accurate determination of source profile and equipment for low power testing of position monitors. Both these facilities should be operational by early 1991.

Correction Algorithms

Global orbit correction software using a lattice model and least squares error reduction is already in routine use at the SRS and could be adapted into a feedback system. A theoretical evaluation of the effectiveness of such a system has not yet been completed and alternative techniques such as harmonic analysis specifically for the SRS lattice will also be considered. Local feedback systems will use existing compensated orbit bumps built from different selections of corrector elements.

Steering Control Systems

Individual steering elements will eventually contain current contributions from three separate sources: the basic corrected orbit file, the global feedback system and a local feedback system. The feedback contributions will require frequent updating in a carefully controlled and smooth fashion. These requirements are outside the capability of the present control system and a new design with increased bandwidth and local intelligence, based on VME systems, is now in the early stages of development.

Conclusion

Beam position stability in the SRS has been studied extensively over the last year and the nature and extent of the problem is now well understood. Development work on the necessary systems for automatic correction has been initiated and first trials on the storage ring are expected during 1991. The long term objective of this work is to reduce the movements of the beam in the SRS by an order of magnitude.

References

[1] V.P. Suller et al, "SRS-2: Performance and Achievements", presented at the Particle Accelerator Conference, Chicago, March 20-23, 1989.

[2] T. Ring, "Beam Position Monitors for the High Brightness Lattice". Daresbury Internal Report DL/SCI/TM42A.

[3] S.M. Heald, "A Simple Photoelectron X-ray Position Monitor for Synchrotron Radiation", NIM A246 (1986) 411-412.

[4] T. Katsura et al, "Beam Position Stabilisation at the Photon Factor", presented at SRI Tsukuba, Japan, August 1988. KEK Preprint 88-97.

[5] L.H. Yu et al, "Real Time Harmonic Closed Orbit Correction", NIM A248 (1989) 268-285.

[6] R.O. Hettel, "Beam Steering and Stabilising Systems: Present Status and Considerations for the Future", NIM A266 (1988) 155-163.

[7] E.D. Johnson and T. Oversluizen, "Compact High Flux Photon Beam Position Monitor", Rev. Sci. Inst. 60 (7) July 1989, 1947-1950.

[8] D. Laundy et al, "Characterisation of a Source of X-ray Synchrotron Radiation", Daresbury Internal Report DL/SCI/P683E.