An Advanced Beam Steering System for the SRS at Daresbury.

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Abstract

The storage ring beam steering systems at the SRS are being replaced to allow automatic real time correction of the electron beam position. This paper briefly summarises the stability problem and the proposed solutions. Progress on development of the constituent systems is reviewed and some data from early performance trials is presented.

1. INTRODUCTION

The Daresbury SRS is a 2 GeV electron storage ring dedicated to providing synchrotron radiation to approximately 32 stations on 10 beamlines. It came into operation in mid 1981 and was upgraded with a high brightness lattice in 1987[1].

Beam position stability issues at the SRS have been described in detail elsewhere[2]. Briefly, thermal cycling of the magnet lattice during normal operations gives rise to short term beam movements and long term drifts in vertical and horizontal reference closed orbits. Typical position drifts during a single beam lifetime are $\pm 50\ \mu m$ and $\pm 10\ \mu rads$ although considerable variation is observed depending on, for example, the length of time taken to inject. Beam position stability will be improved by operating global feedback based on the output of a new high resolution electron beam signal processing system. In addition, local feedback will be provided for sensitive experimental stations based on the output of new high resolution photon beam monitors. The remainder of this paper describes progress on the development and testing of these new systems over the last two years.

2. ELECTRON POSITION MONITORING

The present system which multiplexes the RF outputs of button BPMs and hybrid combiners to a single detector chassis will be replaced with a new arrangement with local signal processing at each BPM location. A block diagram of the new system is given in Fig 1[3]. The output of new high performance hybrids is down converted to one of three different frequencies depending on the application. A wideband analogue multiplier is then used as a dual channel phase sensitive detector to process both sum and difference signals on the same chip. Tests on prototype circuits have demonstrated excellent down converter dynamic range(>80dB) and detector linearity equivalent to a position measurement resolution of $\pm 10\ \mu m$ over a 34dB input signal range.

3. PHOTON BEAM POSITION MONITORING

A new dedicated position monitor test facility, 4m from the source on a dipole beam line, has been commissioned in the second half of 1991. The facility is equipped with a 0.5 μm resolution servo controlled linear drive. A subsidiary drive allows a selection of cooled filters–to be positioned immediately in front of the monitor. Extensive tests on a prototype tungsten vane monitor (TVM), based on a device initially developed at the NSLS[4], have been completed. The device is simple and robust with tungsten vanes fastened to a water cooled copper block by beryllium oxide shims which provide excellent thermal contact. On the test facility the vane currents are amplified and measured by 6 digit DVMs connected through GPIB to the computer controlling the linear drive. Calibration is easily achieved by scanning the monitor through the beam and calculating either the difference/sum or the log ratio of the vane currents(Fig 2). A high quality log ratio amplifier is being developed for routine use on beam lines as this will provide increased linear position range and will not require gain switching dependent on the stored beam current[5]. A positive bias voltage on the copper cooling block clears the emitted photo electrons and extends the useful linear range of the monitor. Negative bias forces low energy photo electrons back onto the vanes making the monitor sensitive to harder radiation in a smaller opening angle. This limits the linear range of the monitor but improves the resolution. Calibration plots for different bias voltages are shown in Fig 3.

The same increase in sensitivity at the expense of range

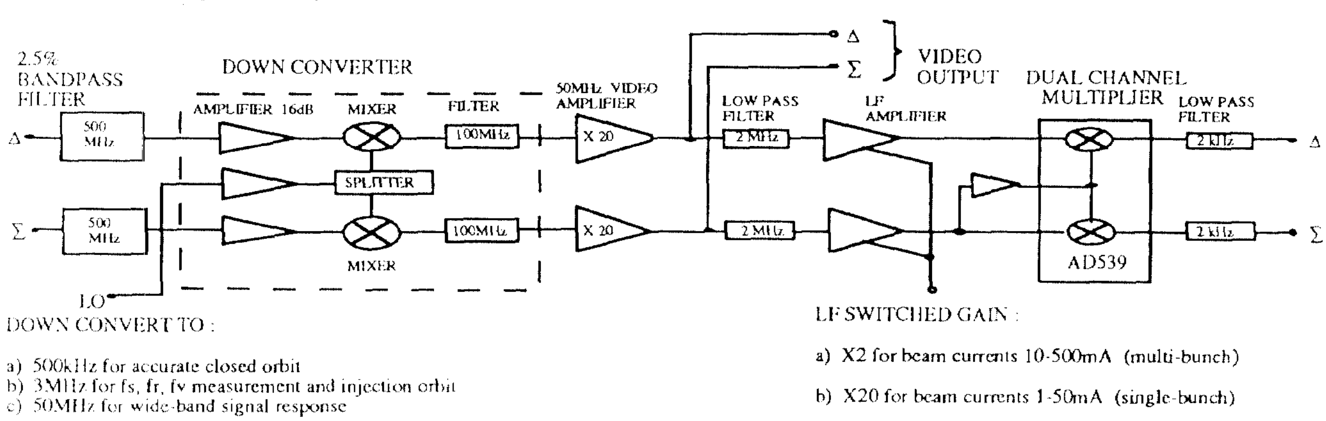


Figure 1. BPM Down Converter and LF Detection System

is produced by the insertion of a filter in front of the the monitor. The calibration factor changes from ~1500 microns per unit change of log ratio output to ~400 for a 500 micron thick BeO pre-filter(Fig 4). The results shown were all obtained with a vane separation of 1 mm at 4 m from the source which is approximately equal to the vertical sigma of the source at the critical wavelength. In the balanced condition, currents of around 20 μA per vane were recorded with 200 mA of beam in the SRS. A typical beam drift plot obtained with the monitor over a 14 hour period is shown in Fig 5 and exhibits structure at the 2 or 3 micron level. Fig 6 shows part of a scan through the beam at 5 microns per step. The noise at each individual position is probably beam movement but the device can clearly be expected to resolve 1 micron movements. Significant improvement on this figure is expected when the new low noise log ratio amplifier is connected local to the detector head. The vertical source size of the SRS decreases as the beam current decays, introducing a systematic error into the monitor output away from the balanced condition. Initial calculations suggest that this error will only be a few % of the total drift observed. Ultimately the monitor will be maintained in the balanced condition by the automatic steering system or, if necessary, the true drift may be measured precisely by arranging for the monitor to track the beam centre and recording the optical encoder output.

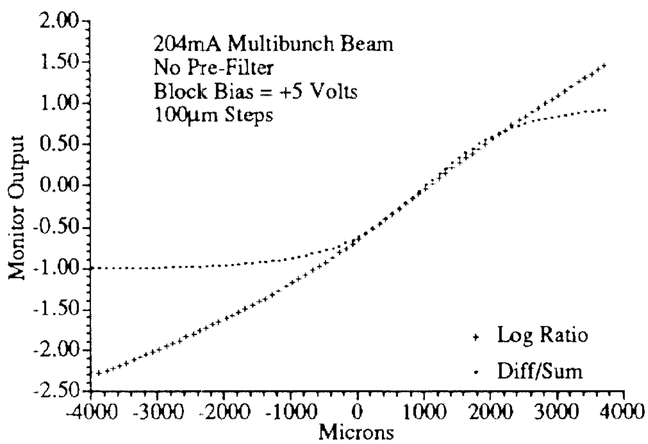


Figure 2. Comparison of Δ/Σ and Log Ratio Outputs.

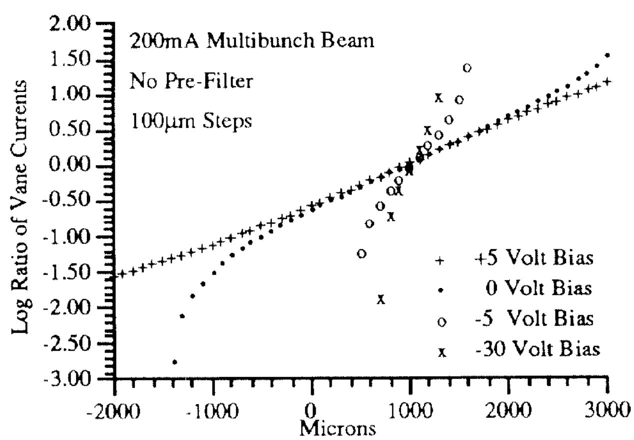


Figure 3. Effect of Block Bias on TVM Output.

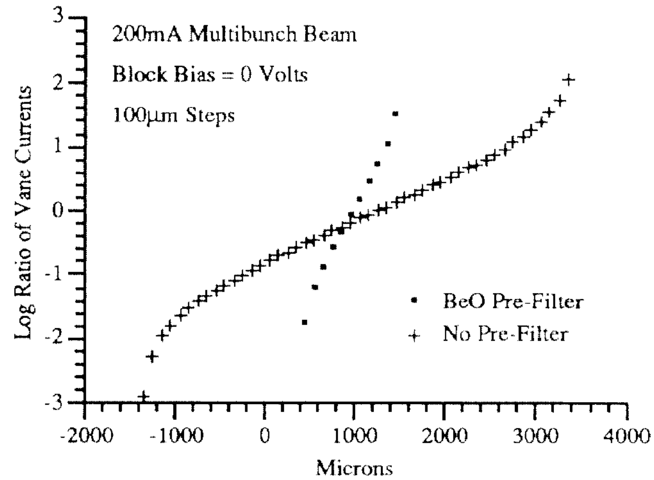


Figure 4. Effect of 0.5 mm BeO Window on TVM Output.

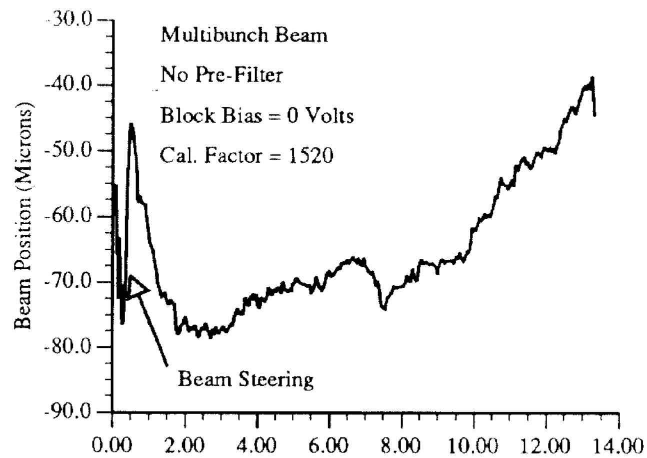


Figure 5. Beam Position Drift 4 m from Source.

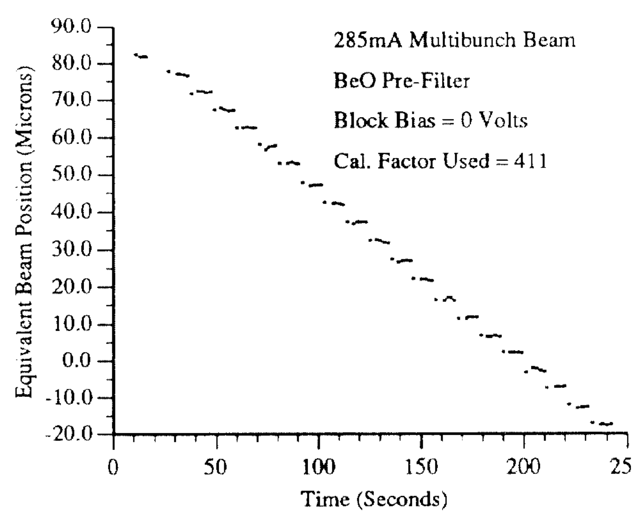


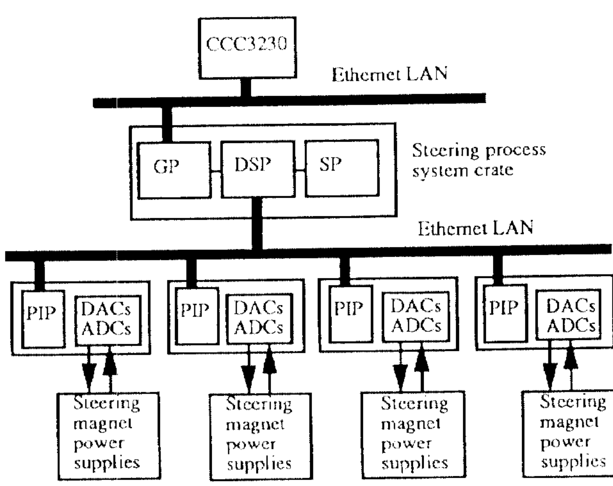
Figure 6. 5 μm Step Scan through the Beam

4. VME-BASED STEERING SYSTEM

Steering elements on the SRS consist of 16 vertical steering magnets, 16 trims produced by backleg windings on the main dipole magnets and 16 multipole magnets each made up of 12 individually powered windings which provide a combination of horizontal and vertical steering, together with other harmonic correction if required In total there are 224 individual power supplies which are driven from 12 bit CAMAC DACs. By selecting different combinations of corrector elements it is possible to construct compensated local beam bumps which are used to adjust the beam position down each beamline individually. The present arrangement allows a minimum position change of 2 μm and a minimum angle change of 1.4 μrads at the source [6]. To permit smoother automatic adjustment of beam position an improvement by a factor of 8 is required to provide increments of less than 1 μm at 4 m from the source.

16 bit DACs and ADCs were obtained from several manufacturers and initially subjected to performance checks over a range of temperatures in an environmental chamber. As the SRS controls area is an electrically noisy environment, further checks were carried out with a test configuration as close as possible to the final arrangement in the storage ring. Drift and resolution of individual channels were checked by recording a test magnet coil current for several days under the influence of an input incrementing by 1 least significant bit every 30 minutes. Channel cross talk was checked by applying large square and rectangular waveforms to adjacent channels. Finally low frequency noise spectra were recorded from 0.1 Hz to 1 kHz with an FFT dynamic signal analyser. Significant variation in performance between rival commercial units has been observed. The testing has established that over a realistic operating temperature range, true 15 bit performance can be obtained from multiplexed analogue hardware without resorting to digital addressing of DACs incorporated into individual power supplies.

The configuration of the new VME system is shown in Fig 7. The Steering Process system crate contains three processors: Gateway, Database Server and Servo. The Gateway processor is the interface to the Concurrent Computer Corporation 3230 machine which supervises the existing control system[7]. The 3230 and the Gateway



GP: Gateway Processor. DSP: Database Server. SP: Servo Processor.
PIP: Plant Interface Processor

Figure 7. Arrangement of VME based Steering System.

processors are nodes on a dedicated Ethernet LAN. The Database Server processor contains the steering system database and is connected to another Ethernet LAN which also has plant interface crates as nodes. The Servo processor contains global and local feedback algorithms. All three processors have access to the database which is held in shared memory. The plant interface crates contain a processor (PIP) and enough DACs and ADCs to service one quarter of the storage ring steering magnets. In addition, these crates will have ADC channels to read in signals from electron and photon beam monitors and various environmental parameters. The Gateway processor has access to the hard and floppy discs while all other VME processors in the system are ROM based systems. The database will be continously updated by a process in the Database server communicating with the plant interface processors. The Gateway processor runs under Professional OS/9(V2.4) while all others run under Industrial(ROM based) OS/9. Application software is written in C and the communication protocol is TCP/IP.

All system hardware has now been purchased and will be installed by the end of the year. Software drivers for the DACs and ADCs and the ROM based systems for the Database Server and the PIPs have been produced and tested. At present. the software to interface into the existing control system and initial application programs are being completed.

5. CONCLUSION

The new beam monitoring and steering systems for the SRS are now in an advanced state of preparation. Final installation has been held back to allow a major upgrade of the storage ring to include a 6 Tesla superconducting wiggler. First automatic steering trials are now expected to take place early in 1993.

6. REFERENCES

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