OPERATIONAL PERFORMANCE OF THE LOCAL VERTICAL SERVO SYSTEM ON THE DARESBURY SRS

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Abstract

Following the commissioning of new high-precision tungsten vane monitors, it has become possible to apply rapid response local feedback correction to stabilise the vertical position and angle of the photon beam delivered at the user sample. A compensated 3-magnet bump is automatically applied to give efficient local correction at the relevant source point while minimising residual ripple at all other points around the stored electron beam orbit. The system has been in regular operational use at many of the user beamlines and offers a dramatic improvement in observed beam stability. The slow large amplitude drifts, associated with thermal variations in the machine over a user fill, are effectively suppressed, and short term fluctuations in beam position are corrected within seconds. Techniques used to optimise the system, including minimisation of residual ripple and interference effects between multiple servo modules, are discussed and operational performance assessed.

1 INTRODUCTION

New beam diagnostic and steering systems [1,2] have been in operation at the SRS since January 1994. These high precision systems have been increasingly exploited for automatic global horizontal [3] and local vertical feedback to provide greater positional stability in the photon flux delivered to the user beamlines. The synchrotron radiation photon beam position at the sample is sensitive to movements of the source (electron beam) position and angle. Tungsten vane monitors (TVMs [2]) are used to measure the photon beam position and an independent local vertical servo (LVS) system is run for each beamline, reading the TVM and, where necessary, applying an appropriate 3-magnet correcting bump. The cycle is repeated every 30 seconds. The predominant orbit changes occur over timescales of several hours, and the system has proved highly efficient in suppressing these drifts.

2 OPERATIONAL PERFORMANCE

Over the past 12 months, a programme of local vertical servo module commissioning has been under way culminating in the regular operation of feedback systems on 6 user beamlines. A further beamline equipped with diagnostic facilities is also occasionally servoed as appropriate. The benefits of vertical feedback depend on the specific experimental techniques employed on each beamline, but the resulting dramatic improvement in vertical photon beam stability is striking: Figure 1 shows the photon beam position, as measured on the TVMs on a representative six beamlines, four of which are servoed. The servoed beamlines show constant photon beam position, within a few μm, over a period of 15 hours, while the unservoed beamlines show slow drifts of typically a few hundred microns in the same period. These can be closely correlated with thermal behaviour in the SRS following the storage ring injection cycle and during the slow decay of the stored current in the latter part of a fill. Because of the chosen repetition frequency of the feedback systems (30s), slow drifts occurring over minutes or hours are effectively eliminated; very rapid variations on a timescale of seconds or less are not corrected. Thus the system automatically ignores rapidly reversed temporary glitches.

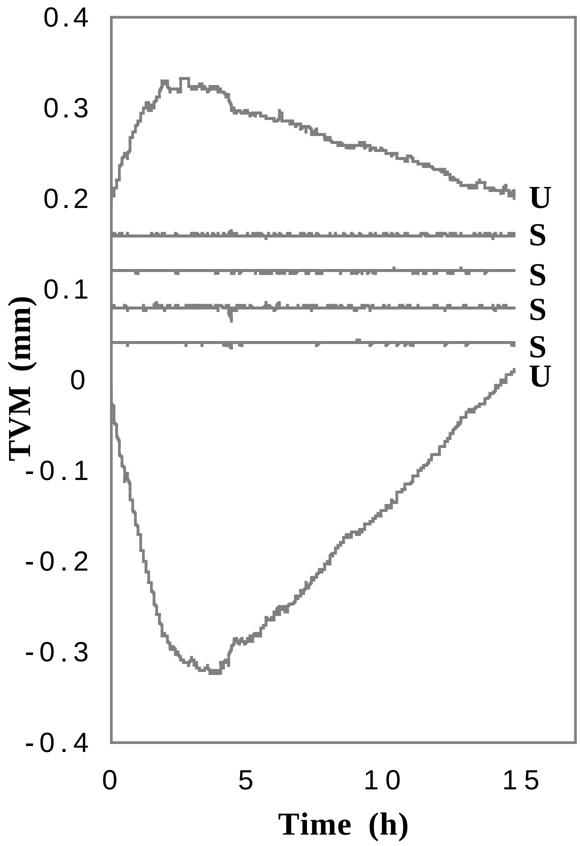

Figure 1: Comparison of servoed (S) and unservoed (U) beamlines over 15 hours of user beam. Note that an arbitrary constant has been added to each curve for diplay purposes: servoed TVMs remain close to 0μm or, if stipulated, some other constant position.

3 OPTIMISING SERVO OPERATION

Because perfect compensation of the correcting bumps cannot in practice be achieved, any feedback correction inevitably disturbs the electron beam position around the ring and it is important to minimise this effect by maintaining optimal bump compensation. Figure 2 shows a deliberately induced, unrealistically large example of servo "cross-talk". TVMs on 9 beamlines are recorded, with feedback correction on three of the beamlines. The TVM on one selected beamline (marked "S*" in figure 2) is then deliberately moved to simulate a beam position error without disturbing the electron orbit. Two large movements of around 80μm can be seen on the data from the TVM. Because of the rapid correction by the servo, the large steps appear as spikes rather than as steps. The effects of imperfect compensation of the correcting bump at servo S* are clearly seen on the unservoed TVMs (marked "U"), which show smaller but distinct step changes on correction of the large movements at S*.

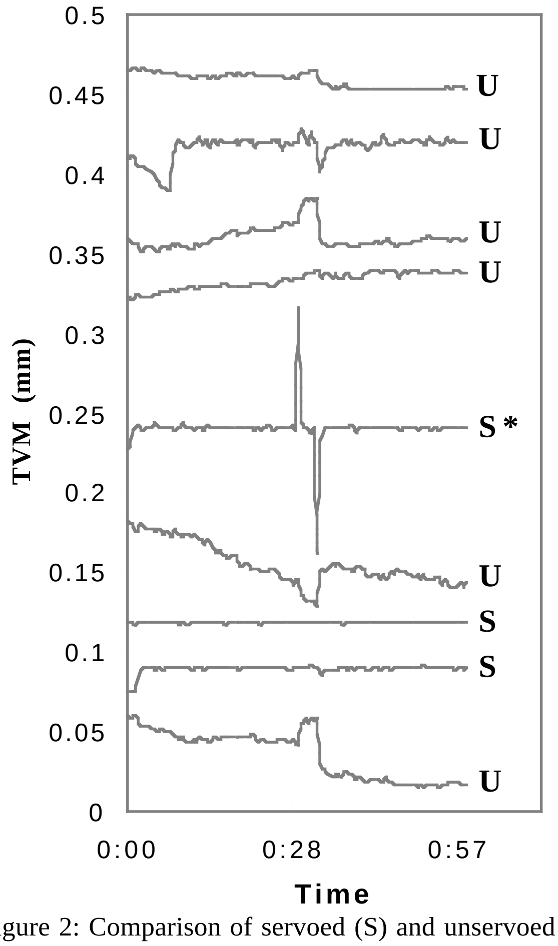

Figure 2: Comparison of servoed (S) and unservoed (U) beamlines showing correction of deliberately induced disturbance on a single servoed line (S*)

The effects of servo correction at a beamline on the other beamlines is minimised by optimising the quality of correcting bump compensation. Typically, the bumps used are compensated to better than 5%: in other words, the amplitude of the residual reipple around the electron orbit is less than a twentieth of the bump size used to correct at the servoed TVM. Compensation is empirically optimised by measuring the effect at all TVMs of the bump and of small changes at each of the bump elements. A new, improved bump is then constructed from the linear combination of these which minimises the residual at the TVMs, starting from the old bump ratios. At present, the criterion for optimisation is minimal rms residual, although other criteria (such as minimising the maximum deviation at any TVM) could be applied. The TVMs can also be weighted to take account of factors such as lever arm length (source-TVM distance). The quality of optimisation has also been studied as a function of bump size to check for non-linearity or other amplitude dependent effects: the resultant rms residual is shown in figure 3 for new bump ratios optimised at amplitudes from 0.1-0.7mm, spanning the range of correcting bump sizes normally required during operational running. The different quality of compensation is probably due to random errors in the small residuals at other TVMs; no consistent trend with amplitude is observed in the present data.

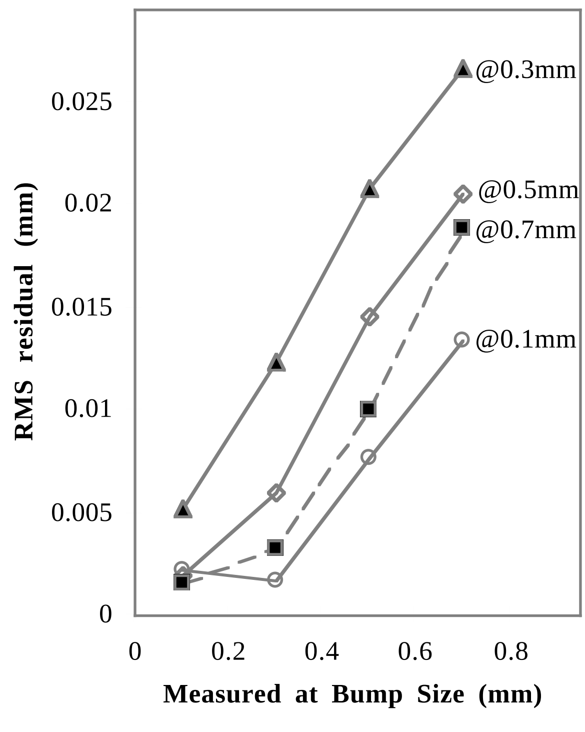

Figure 3: RMS residual at the TVMs (excluding TVM in bump) measured at different applied bump sizes for bump ratios optimised at 0.1mm, 0.3mm, 0.5mm and 0.7mm

Although the servo parameters are chosen to specifically correct slow drifts on a timescale of hours, a great deal can be learned about the correction efficiency by driving the servo feedback to limiting conditions. One technique used exploits the SRS clearing electrodes: by applying a large, oscillating potential, a triangular sawtooth beam disturbance can be induced around the electron orbit. The resulting behaviour at a TVM then depends on the time period T of the disturbance, the servo correction time τ_C (in this case, correction is applied every 30 seconds), and the calibration factor for the correcting bump. Under- and over-correction exhibit qualitatively different behaviour at the servoed TVM. The characteristic varieties of correction are shown in Figure 4 below.

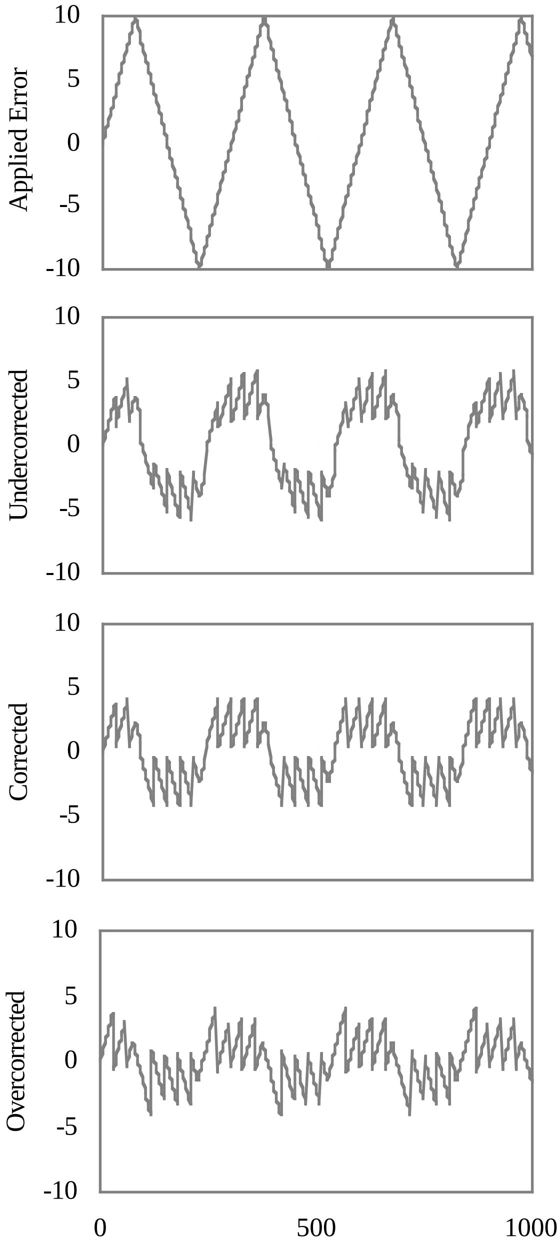

Figure 4: Induced oscillation and simulated servo performance for under-correction, exact (100%) correction and over-correction; horizontal axis shows time (s)

The upper graph in Figure 4 shows a triangular sawtooth disturbance on the electron beam of amplitude 10 (arbitrary units). The remaining three plots show (top to bottom) on the same scale the simulated residual error on a TVM for 70% under-correction - in other words, only 70% of the required correction is applied - by the servo, for correct servo calibration (100% applied) and for over-correction (130%). The data have been generated by a computer model of the correction system, which includes all parameters as applicable to the Daresbury system (such as averaging time, delay before application of correction and repetition rate). This permits free variation of all parameters and eliminates spurious beam disturbances. The trends shown in Figure 4 are closely reproduced by experimental measurements. Whether the beam position returns to 0 on each correction cycle, fails to return to the axis or overshoots immediately demonstrates unmistakeably any miscalibration of the correcting bump size needed. This diagnostic technique also shows up other deficiencies: it is trivial to show that the maximum attainable suppression ratio, defined as the ratio of the maximum deviation from zero with and without servo correction, is given by $4\tau_C/T$. In the case of a disturbance of 5 minute period (as in Figure 4) and with servo correction every 30 seconds, this gives a maximum suppression by a factor of 0.4, as seen for the example of 100% correction. The simulation and experimental studies show that, with the present correction repetition rate, drifts of up to 100μm per hour - large compared to typical drifts in the SRS - are suppressed to ~1%, or within the resolution limit of the TVM systems (typically of the order of 1μm).

4 SUMMARY AND OUTLOOK

Local vertical servo correction has been highly effective in improving photon beam stability at the sample during user operations. Work continues on introducing servo correction on all beamlines, subject to user demand. Preliminary studies are also under way to assess means of achieving global vertical servo correction, to run in tandem with local correction at each source point.

REFERENCES

[1] "A Review of the Performance and Application of New Beam Diagnostics on the SRS at Daresbury", J R Alexander, J B Fitzgerald, G Mrotzek, P D Quinn and R J Smith, Proc. Int. Workshop "DIPAC95", Lübeck, Germany, 1995

[2] "Performance and Progress of the Daresbury Photon Beam Tungsten Vane Monitor System", G Mrotzek and J B Fitzgerald, these Proceedings

[3] "The Daresbury Global Horizontal Servo Feedback System: Status and Outlook", J B Fitzgerald, B G Martlew, C Morrell and S L Smith, these Proceedings