ORBIT CONTROL AT BESSY II: PRESENT PERFORMANCE AND PLANS[*]

R. Bakker, K. Holldack, P. Kuske, R. Müller[†], BESSY, Berlin, Germany

Abstract

For slow orbit drift control, every second complete orbit data with a precision better than 1μm are available at BESSY II. Continuous SVD correction at 0.2 Hz keeps the orbit fixed within 0.1 μm RMS. Sending the calculated setpoints to a 16 bit DAC of the $\tilde{3}$ mrad correctors introduces noise around 0.05 Hz that is worse than the freely drifting storage ring - spoiling high resolution experiments. Presently after every re-injection the orbit is corrected when the ID gaps have reached their actual working position. With moving undulator gaps orbit changes are typically within the specified range of less than 15μm. To enable the planned continous orbit correction IO cards will be modified to 24 bit DAC precision this year.

1 OVERVIEW

Third generation sources like BESSY II have to deliver light with specified quality near the limit of todays reachable performance . Stable source point definition and small energy spread of the electron beam is critical for high resolution undulator beamlines. These requirements imply the use of both ‘passive’ and ‘active’ countermeasures against any induced noise.

Like other modern sources BESSY II utilizes a thick concrete slab, vibration damping girder structures, ultimate stability power converters, an air conditioned experimental hall etc. to guarantee a basis to orbit stability. Active orbit control has to compensate slow drifts, insertion device (ID) gap changes and eventually noise caused by the environment. Given stable beam dynamics ID changes (e.g. chicane modifications of elliptical polarizing devices) dominate the orbit effects on most experiments. For this type of perturbations reliable stability is easier to achieve feeding forward known compensations of imperfect magnetic balances and suppressing only residual noise with a feedback system.

2 DIAGNOSTICS

2.1 BPM System

Components and functionalities of the BPM hardware set up, data aquisition (DAQ) software and performance has been described [1]. Operational experiences still emphasize the high measurement precision of typically better than 0.2 μm in the vertical and 0.4 μm in the horizontal plane over the full dynamic range. A DAQ speed of 1 orbit/sec allows to safely run continous corrections at 0.2 Hz.

System reliability of 1 month mean time between failures for the DAQ software and 1 BPM per 2 month for hardware components is constantly improved. Archiving of the 2 min averages of all BPM signal as well as corrective action monitoring supplies continous surveillance of performance.

2.2 XBPM Data

Additional beam position information is available from staggered pair (dipole beamlines) and 4-blade monitors (insertion device beamline) at a rate of 5Hz. The data are complementary and consistent with the electronic BPM readings but not yet integrated into the correction procedures. Pin hole images serve as additional fast visual indicators.

3 CORRECTORS

3.1 Corrector Pattern

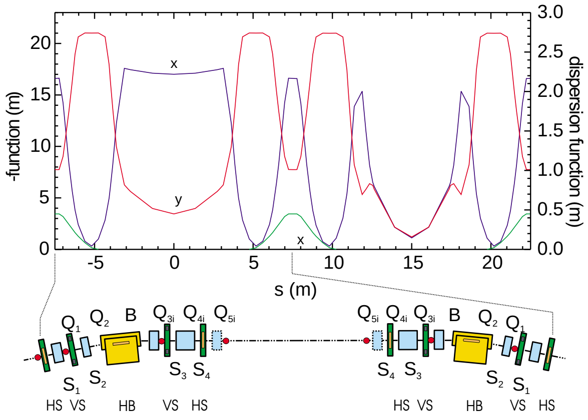

Figure 1: Sketch of Corrector and BPM Positions.

All sextupoles have additional windings that generate dipole fields without noticible hysteresis effects. In the present configuration coils in the S1 and S4 sextupoles (see fig. 1) are powered as horizontal steerers (1x HS1, 2x HS4 per cell), the S2 and S3 families as vertical correctors (2x VS2, 2x VS3 per cell). Furthermore auxiliary windings in the main bending dipoles are powered and provide additional horizontal correctors (2x HB per cell).

Drifts of the circumference of the centered orbit can be corrected by changes of the RF frequency with a granularity of 1 Hz.

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[†] Email: mueller@mail.bessy.de

3.2 *Power Supply Resolution and Stability*

As a basic conceptual decision as much ‘passive’ stability as possible has been foreseen for the storage ring beam guiding elements from the very beginning in order to avoid or ease additional ‘active’ feedback regulations. Thus thermally stabilized high end IO boards provide set points with a resolution of 16 bit and a measured precision of better that 10% of the minimal single bit step [2]. This is matched by the extreme stability of the corrector power supplies which provide the full dynamic range of 3 mrad with a typical stability equivalent to 19 bit (averaged over 100 ms).

4 AUXILIARY PROCEDURES

4.1 *Model Calibration*

Evaluation of numerous response matrix measurements allowed to determine the conversion factors of power supply currents to magnetic fields with high precision. This experimental calibration results in a high accuracy of model predictions. Thus orbit control features are reliable for various operational conditions (different energies, optics ...).

4.2 *BPM Offsets*

Prior to the start of user runs orbit measurements with respect to the magnetic center of the quadrupoles are performed to check for the effects of modifications or the amount of possible changes. An additional power supply is sequentially switched to auxiliary windings of all quadrupoles and the resulting closed orbit perturbations are analyzed. From this beam based alignment measurements the corresponding BPM offset values are derived.

4.3 *Insertion Device Imperfections*

End pole corrector magnets for both planes are installed at each undulator unit to allow for compensation of resulting orbit kicks. Gap dependent set points are generated by the undulator control system from measured tables. For planar undulators these tables are simple. For apple type undulators equipped with chicane/modulator magnets parameterized two dimensional tables are required. These tables are iteratively refined in a semi-automatized procedure of scanning the gap/shift parameter space and finding improved corrector set points by means of the continously running correction program. Satisfying feed forward procedures handling the hysteresis of the electromagnetic undulator is not available yet.

A ‘fast’ local ID source point control feedback system is under consideration [3].

5 CORRECTION PROGRAMS

5.1 *General Software Functionalities*

An ‘All-in-One’ program [4] provides orbit data presentation, statistical evaluation, control of the measurement system and manipulation of data validity, manual or automatic orbit correction with different methods under varying conditions, selection of closed orbit bumps from preconfigured lists (insertion device, achromat) or by free configuration (click on coordinate, correction element). For data correlation or response matrix measurement it handles device stepping, data logging and postprocessor launching. Program options, operation modes and parameters can be adjusted by a comprehensive graphical user interface.

5.2 *Routine Orbit Flattening*

For standard closed orbit correction the SVD method is applied to the full set of corrector magnets (exception see 6.2) and BPM signals. Only on operator interaction or hardware malfunction BPMs or corrector magnets are excluded from the correction procedure. Typically half of the eigenvectors is significant for the correction. Only obvious plausibility checks help the operators (e.g. no new DAQ since last apply, predicted improvement not achieved etc.).

6 PERFORMANCE

6.1 *Uncorrected Stability*

Today the closed orbit is typically corrected once shortly after injection. During user mode operation the characteristic drift of the unmodified and uncorrected storage ring is 3μm/h in the vertikal, 10μm/h in the horizontal plane. Dependent on ID field quality, gap driving range and additivity up to 15μm changes are measured at certain BPMs. ‘Continous’ ID scans are restricted to small perturbation regions resulting in less than 2μm orbit perturbations.

6.2 *Path Length Control*

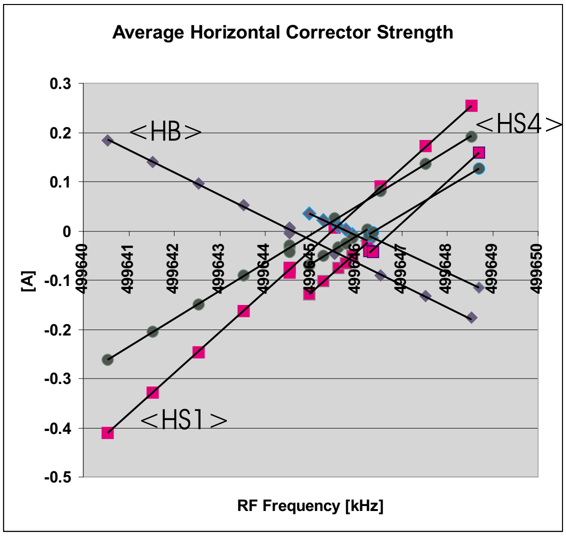

Figure 2: RF drift and built up of mean horizontal corrector strength observed during three different user blocks of 4 weeks each. Corresponding set point combinations are equivalent with respect to RMS orbit deviation.

In the horizontal plane a minimal RMS orbit deviation at the positions of the BPMs is an ambigous requirement. It has been verified experimentally that it is feasible to change RF frequency and horizontal corrector families simultaneous maintaining the 'visible' orbit and its RMS value constant. Result has been a slow and unphysical change of the RF frequency over the user run periods (see fig. 2).

In a pragmatic attempt the 'weak' HB family has been set to 0 and a large weighing factor emphasizes the additional boundary condition of minimal average kick of the HS1 and HS4 families. Now the orbit is sufficiently well defined and the RF frequency basically follows e.g. measured thermal effects during storage ring start up.

6.3 Continous Slow Drift Control

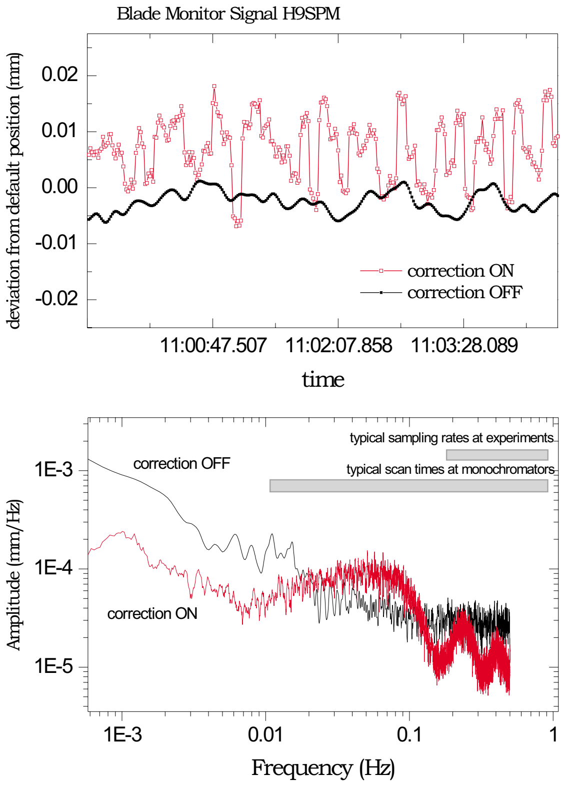

Figure 3: Noise induced by Orbit Correction and detected at a Staggered Pair Monitor.

During an hour of smoothly decaying beam intensity the continous correction running at 0.2 Hz stabilizes the orbit within +/- 50 nm RMS. As unexpected drawback of this correction additional noise is induced that can be traced back to the finite resolution of corrector set points. The connected single bit flip activity leads to a deterioration of experimental conditions in the time domain between 10 sec and 1 min (see fig. 3).

At certain high resolution experiments the orbit changes of a minimal correction step is of the same order of magnitude as the signals under study (see fig. 4).

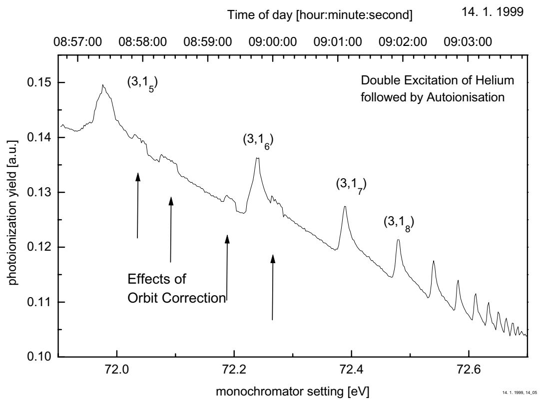

Figure 4: Example of a high resolution experiment perturbed by continous orbit drift correction [5].

Any method finding the optimal correction within the discrete space of adressable set points would be a performance improvement. Methods working with reduced corrector sets should cause smaller perturbations than SVD calculations ignoring resolution limitations. In the limit of minimal orbit deviations probably MICADO would be best in finding the most effective bit.

Reduction of power supply dynamic range as a common way to improve resolution is not considered. Local bumps with large amplitudes have proven to be a valuable diagnostic means. Modified IO boards with 24 bit effective resolution have been ordered instead. They are presently under test and will be installed this year.

7 SUMMARY

The intrinsic orbit stability of the BESSY II storage ring as well as the achieved transparency of most insertion devices is encouraging. With a few restrictions full ID gap control is given to the users already today. Perturbations induced by the experimental activities are significant but controllable. It is expected that the continous orbit correction with a 24 bit resolution of steerer set points will be appreciated even by the ultra high resolution experiments.

REFERENCES

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