INTRODUCING FAST ORBIT FEEDBACK AT BESSY*

R. Müller, R. Görgen, R. Lange, I. Müller, J. Rahn
Helmholtz-Zentrum Berlin für Materialien und Energie/BESSYII, Berlin, Germany

Abstract

Over the more than ten years of BESSY II operation the strategy of eliminating beam perturbation sources and precisely compensating for slow orbit drifts successfully provided the micron and sub-microradian beam stability required by the experiments. In view of increased processing bandwidth at the experiments and the demand for rapid compensation of noise spikes and new, yet unknown excitations a fast orbit feedback (FOFB) aiming at noise suppression in the 1 Hz–50 Hz range will be installed.

Phase I of the implementation foresees fast setpoint transmission plus replacement of all corrector power supplies and aims at higher correction speed. Phase II intends to replace today's multiplexed analog beam position monitors by parallel processing fast digital units to increase correction precision in combination with top-up operation.

INTRODUCTION

The level of photon beam stability required by experimental signal conditions or resolution goals varies from experiment to experiment. At 3rd generation light sources sensitivity of measurements to electron beam motion can imply micron and sub-microradian electron orbit stability. Stability time scales range from hours to microseconds, depending on experiment sampling rate, data integration period and scan duration.

At BESSY the strategy to eliminate perturbation sources wherever possible combined with a precise global orbit drift control results in an excellent basic electron beam position and energy stability [1, 2]. The installed (relatively) slow orbit correction running at a cycle of 0.2 Hz compensating drifts and imperfections of the insertion device feed forward can guarantee good experimental conditions. But this holds only in the absence of noise spikes. Most experiments today typically average data for 100 ms. So in addition the broad-band noise floor in the frequency range 1 Hz to 50 Hz has to be very low to be not the limiting factor for high resolution experiments.

ORBIT STABILITY DECODED

Hunting the sources of beam position perturbations has a long tradition at BESSY and this is still reasonably justified, since this approach avoids noise introduced by imperfections of a feedback loop running at high gain. Figure 1 gives one of the numerous examples of the successful strategy to eliminate beam quality degradation effects at a vibrating, thermally drifting or fluctuating source.

Compressors of the cryostats of the superconducting wavelength shifters transmitted their vibrations to the beam via the magnet structure. A small local feedback system brought this perturbation down to less than a tenth of the uncorrected amplitude of several μm. The same effect could be achieved by careful readjustment of the magnet suspension cords within the cryostat. In consequence this feedback pilot installation was switched off again.

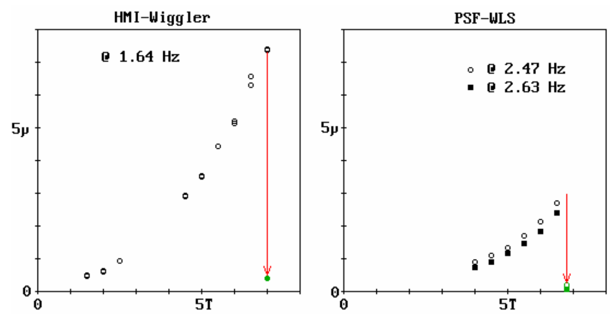

Figure 1: Example of noise elimination. Beam motion introduced by cryostats of two superconducting wavelength shifters have been reduced by an order of magnitude. This corresponds to the damping achievable with a local FOFB pilot installation.

Since several years a fast BPM data collection with a 10 kHz sampling rate and a 300 Hz to 1 kHz low pass filter is in place for diagnostic use in the 0.1 Hz to the several 100 Hz region. So it is well documented that even at unperturbed conditions there are beam motions of the order of up to 1% of the beamsize around 1.6 Hz and 16 Hz and there is a smaller broad noise floor between 10 Hz and 20 Hz (see Figure 2).

In addition spikes caused by malfunctions or insufficient compensations occur infrequently and unpredictable. A fast orbit feedback (FOFB) would definitely provide more operational headroom and would generally improved conditions for high experimental resolution.

As processing bandwidth at the experiments increases the implementation of a FOFB with a correction cycle of better than 50 Hz becomes even more important.

Figure 3 shows the destructive effect of the 1.6 Hz component of the beam motion on a newly commissioned STXM experiment running at its usual scanning speed at BESSY II. The magnetic vortex in the middle of the scan area is hardly visible.

* Work supported by the German Bundesministerium für Bildung und Forschung and Land Berlin

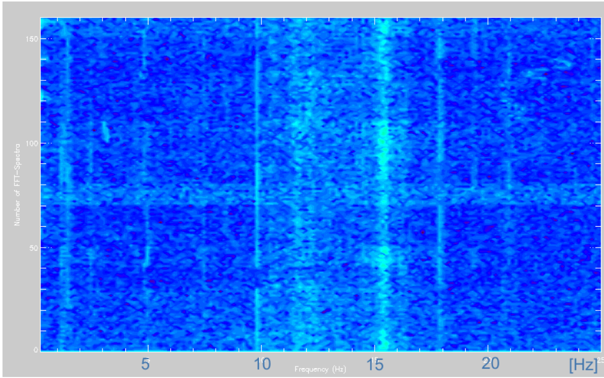

Figure 2: Remaining vertical beam motion in the frequency range 0.1–25 Hz seen by all 32 BPMs located at the 16 straight sections around the ring (1 unit corresponds to 5 subsequent measurements per BPM, starting from the injection point).

FOFB BY COMPONENTS

Many different BPM data acquisition and corrector setpoint distribution methods exist at other storage ring facilities but today it is commonly accepted that the FOFB of a 3rd generation light source has to be global. During one cycle all BPM readouts have to be available at a central (or several distributed) computing node(s) where the setpoint changes are calculated and distributed to the power supplies attached (see sketch Figure 4).

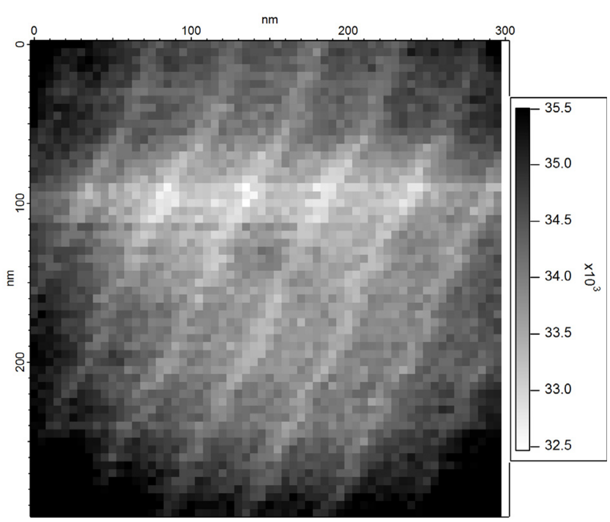

Figure 3: Effect of the 1.6 Hz vertical vibration on a STXM experiment. The stripes (nearly obscuring the magnetic vortex of interest) should disappear with a FOFB in place

Orbit data from the existing analog BPMs are already delivered to a central VME crate with scan rates up to 2.4 kHz, the central computing node can be chosen powerful enough and the transfer function measuring the effect of fast corrector magnet changes on the beam shows its limit around 200 Hz. Providing fast setpoint transmission to the power supplies and replacing the stability optimized slow devices by fast units would allow to close the FOFB loop.

At BESSY the implementation of a FOFB is planned to undergo two phases: in a first step correction speed is addressed where the primary goals can be achieved at moderate cost. It requires fast setpoint distribution (see [3]) and replacement of all corrector power supplies. By this pushing of an old installation to its limit will result in an overall system typical for the first generation FOFB setups.

A second step becomes possible as soon as BESSY switches to top-up mode operation. Then high precision digital BPM units with small dynamic range could replace the analog multiplexed BPMs allowing for better beam position accuracy.

FOFB PHASE I

Since the power supply I/O boards allow for setpoint changes at 200 Hz only the link between the central computing node and power supply I/O has to be upgraded. This will be achieved by linking the power supply IOCs and the computing node via reflective memory and by modifying the CAN based distribution from the IOC to the power supplies (see [3] for details).

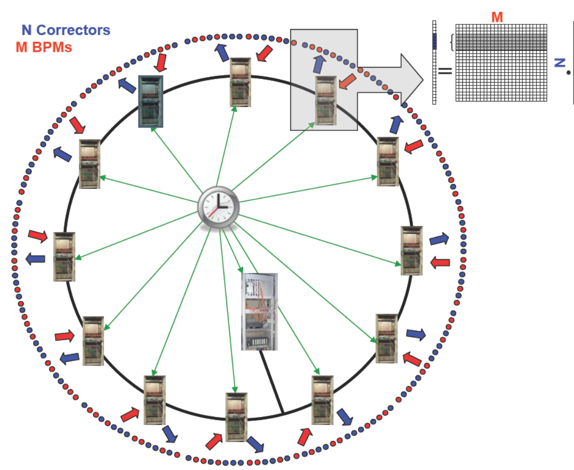

Figure 4: General FOFB setup. All BPM readings have to available at the location where N corrector setpoints have to be calculated and transmitted.

Nevertheless higher correction speed (20 Hz to 60 Hz) requires the replacement of all corrector power supplies. A small subset of 8 power supplies has been installed to be able to gain some experience with the system envisaged.

Extended to full scale the FOFB should elimination noise spikes or infrequent jumps that are harmful for difference measurement methods. The damping of broad-band noise will transform to improved intensity and contrast at certain sophisticated experiments.

When the storage ring in low-α mode is tuned to a pulse length of the order of 1 ps or less the uncorrected horizontal orbit shows frequent large jumps [2]. These can be expected to be correctable with the FOFB system allowing for new limits of short pulse user mode operation.

Suppression of yet unknown or uncorrectable resonance excitations will still require a combination of source elimination and feedback loop retuning. In any case the responses of the correctors will allow for faster noise source characterization and (re-)tuning procedures.

FOFB PHASE II

Phase II intends to replace today's multiplexed analog beam position monitors (BPMs) by parallel processing fast digital units to increase correction precision: In combination with top-up operation the large dynamic range needed for high currents in single bunch and decaying beam mode is no more necessary and the measurement of the beam orbit could be better by nearly an order of magnitude. Flexibility and speed of the BPM data acquisition then also allows for additional turn-by-turn based diagnostic tools.

By the time of a system selection there will be sufficient information available from other FOFB installations to be able to assess the advantages of a central computing node versus a fully distributed system. A central node allows for easy implementation of mode space aware feedback correction loops [4] that can be fine tuned to the ultimate suppression of beam induced noise. In a fully distributed system the setpoint of one corrector could be calculated on the FPGA of the digital BPM unit using a single row of the response matrix and forwarded to the power supply by an I/O port of the BPM unit. Here saving the intermediate layer promises to allow for cost effective solutions.

SUMMARY

Today at BESSY the fast data acquisition of multiplexed BPM data exists, 8 out of 112 fast corrector power supplies are in operation and the fast data distribution needed to close the feedback loop for a subsystem of the FOFB phase I installation is under way.

This pilot installation is expected to already provide sufficient suppression of e.g. the STXM signal distortions (Fig. 3) and will provide valuable information on possible shortcomings of the envisaged setup.

REFERENCES

[1] J. Feikes, K. Holldack, P. Kuske, R. Müller, "Orbit Stability at BESSY", RPAE035, PAC'05, Knoxville, USA (2005).

[2] J. Feikes, P. Kuske, R. Müller, G. Wüstefeld, "Orbit Stability in the 'Low Alpha' Optics of the BESSY Light Source", THPLS017, EPAC'06, Edinburgh, UK (2006).

[3] R. Lange, R. Görgen, I. Müller, R. Müller, J. Rahn, "Preparing Slow Controls at BESSY for Fast Orbit Feedback", THP063, ICALEPCS'09, Kobe, Japan (2009).

[4] M.T. Heron, M.G. Abbott, J.A. Dobbing, G. Rehm, J. Rowland, I. Uzun, S. Duncan, "Diamond Light Source Electron Beam Position Feedback: Design, Realization and Performance", THB003, ICALEPCS'09, Kobe, Japan (2009).