Fast and Flexible BPM-System: Valuable Commissioning Tool for BESSY II

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Abstract

The BESSY II Beam Position Monitor (BPM) systems consist of analog and digital processing units for the pickup signals and permit both fast and accurate tracking of the beam position. Software on VME computers in EPICS context process and give access to these signals. A Graphical User Interface (GUI) on a UNIX platform handles the BPM data-flow, online beam-line modeling and machine-control. For the commissioning the system has proved to be a valuable tool, for example, to monitor and correct the closed orbit, extraction bump-control in the booster and tune-measurements.

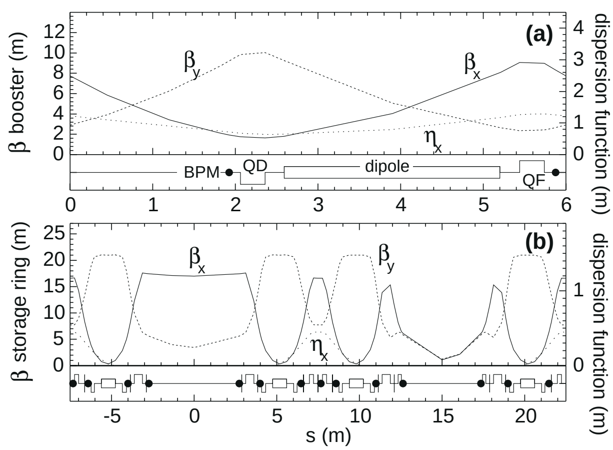

Figure 1. Machine functions in 1 of the 16 section of the booster (a) and in 1 of the 8 sections in the SR (b). Optical components and BPM-positions (dots) are indicated.

1. INTRODUCTION

At BESSY II [1] an electron beam emerging from a 50 MeV racetrack microtron is transported through a beam-line (injection line) to a booster-synchrotron. The booster accelerates 1 nC to a maximum energy of 1.9 GeV with a repetition rate of 10 Hz [2]. A transfer-line transports the accelerated beam to the storage-ring. Non-destructive monitoring of the beam-position is performed with the aid of 157 stations, each consisting of 4 pickup-antennas in the vacuum chamber of the beam-lines. The signals are processed by a total of 3 BPM systems: one for the injector (injection-line, booster and transfer-line) and two for the storage ring (SR).

The BPM system for the injector is optimized for fast monitoring of the 32 pickup-stations in the booster during the 50 ms in which the electron beam is accelerated. The positions of the stations are indicated in Fig. 1. Additionally there are 6 and 7 stations installed in the injection line and the transfer line, respectively.

For the SR two complementary systems are installed: a slow system to accurately monitor the closed orbit and a fast system to detect single-turn effects. The slow system processes the signals of 112 stations, see Fig. 1, with high accuracy. For single-turn measurements a subset of 64 stations are employed.

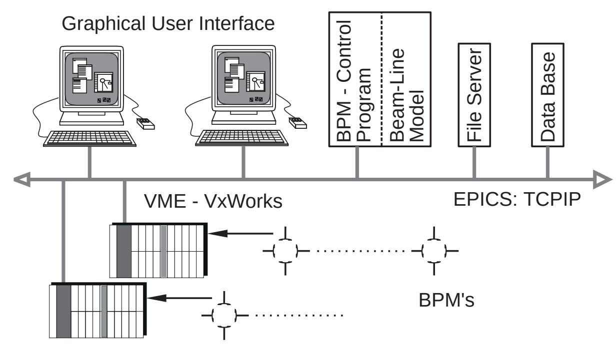

Figure 2. Overview of the signal processing. Pickup-signals are recorded and processed on VME-crates and made available on the network. Unix software tools are used for logging and orbit-manipulation.

An overview of the digital-processing scheme of the orbit data is given in Fig. 2. Signals obtained from the BPM-stations are processed on VME computers and made available to other computers through the EPICS Channel Access (CA) protocol compliant with the BESSY II control system [3,4]. Unix Tools with access to this network are used for data-logging and orbit manipulation. Details of the hardware and software are presented in sections 2 and 3, respectively. In Sec. 4 some commissioning results are discussed.

2. HARDWARE SETUP

2.1 The injector

The pickup signals of the injector BPM system, see Fig. 3, are transported over 2 stages of fast in-house built multiplexers to a recording unit, sensitive to the 500 MHz component of the signal, i.e., the main rf-frequency. The recordings are digitized with the aid of 4 12-bit, 10 MHz, ADCs (Joerger VTR1012-512). The pickup-stations in the injection- and transfer-line are guided into this system over the free input channels of the second multiplexer

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stage. The multiplexers and ADCs are locked with an external triggering- and addressing-unit, synchronized to the 10 Hz injection frequency in the booster. Sequential sampling of all BPM-stations permits the recording of successive closed orbits in time-bins of 200 µs, i.e. a recording of 256 closed orbits over the ramping cycle of the booster. Note that the sampling frequency of the ADCs (100 ns) permits much faster acquisitions. At present this enables us to average the recordings of multiple turns in the booster (300 ns) for a more accurate recording of the closed orbit. In the future it could also be used to measure single-turn effects. The present specifications are summarized in Tab. 1. The observed shot-to-shot variation includes both the noise of the BPM electronics and the natural orbit jitter in the booster.

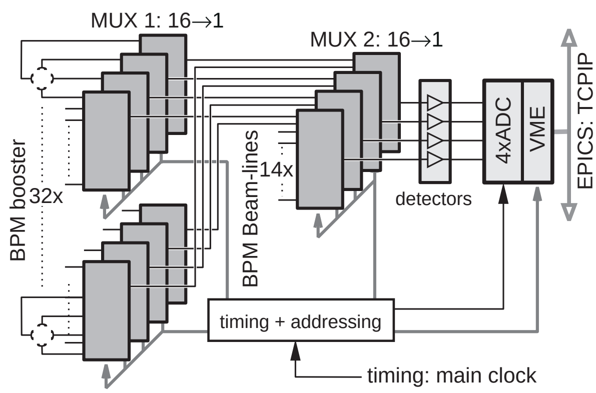

Figure 3. Overview of the injector BPM setup.

Table 1. Specifications of the BPM systems where Δ and σ stands for the dynamic range and the recorded jitter of the beam position, respectively.

System	Δ mm	σ_x µm	σ_y µm	I_{min} mA	Speed s
Booster	±16	300	150	0.5	$200\ 10^{-6}$
Closed Orbit*	±10	2	< 1	0.1	$1\ 10^{-3}$
Single Turn*	±16	1000	1000	<0.1	$800\ 10^{-9}$

* Preliminary results.

2.2 The Storage Ring

An overview of the BPM-systems in the SR is given in Fig. 4. For closed-orbit measurements, an in-house built unit processes the four pickup signals to analogue values of the beam-position in both planes. Each unit includes an automatic input-gain control and a 250-Hz band-pass filter to obtain accurate measurements that are independent of the beam current. The output-signals are recorded with a 16-bit 10-kHz ADC (ESD-AIO16). A computer then averages multiple samples over a preselected period of time, presently set to 100 ms. The whole system is much slower, however, as software synchronization between the 17 VME crates consumes up to 2 seconds. Specifications are presented in Tab. 1. The variations are mentioned reflect the observed orbit jitter per BPM station over the 100 ms period mentioned.

For single-turn measurements the individual pickup signals are first multiplexed and then recorded with the aid of 64 12-bit, 10-MHz ADCs (Joerger VTR1012-256). The multiplexers switch at 10 Hz, i.e., the injection frequency. One single-turn recording is thus obtained from four successive injections into the ring where, for each injection, one pickup of a BPM station is sampled. Input gain control of the detector unit permits the system to be relatively insensitive to the beam current. After the main trigger the ADCs sample a total of 32,767 turns in time-bins with a duration of 50 ns each, separated by the revolution time of the ring, i.e., 800 ns. An external timing-unit provides an individual trigger signal for each ADC in such a way that time-delays, caused by geometrical position of the pickup-stations and the computer, are compensated. The performance is summarized in Tab. 1. The accuracy mentioned has been obtained from measurements in the commissioning phase. As the injection conditions, in terms of stability and current, are not yet optimal [1] it is anticipated that the accuracy will improve in the near future.

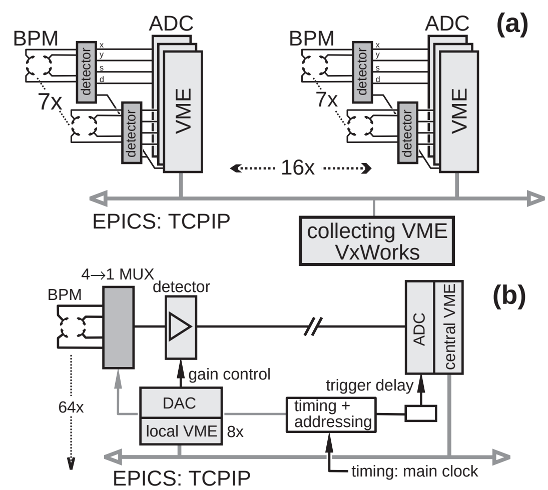

Figure 4. Overview of the SR BPM setup for closed orbit mode (a) and for single-turn (b).

3. USER INTERFACE

An overview of the user-interface is given in Fig. 2. A GUI running on a UNIX platform gives control over 1) the BPM-hardware and data-storage, 2) display of the present closed orbit, and 3) manipulation steerers for orbit- and bump-control. Behind the graphics separate software monitors and controls the BPM-hardware and the settings of power-supplies used for the optical components (quadrupoles, steerers, etc.) of BESSY. This is established with the aid of EPICS tools [4], i.e., CA and CDEV [5] communication protocols. The software is also linked to the Goemon modeling toolkit [6] for on-line orbit-calculation and control [7]. Database (ORACLE) entries provide a unique conversion between the power-supply settings and the model parameters of Goemon [3]. The user-interface is made such that the GUI and the control software can run on separate computers where multiple sessions may run simultaneously.

4. COMMISSIONING RESULTS

4.1 The injector

At present the injection system is fully operational. During its commissioning phase the BPM system has proven to be a valuable tool for correction of the orbit at injection energy and to monitor the closed orbit during the acceleration period [2]. As an example Fig. 5 shows a recording of the extraction bump. The control software [3,7] successfully predicted the settings of the bumper power supplies based on the ring model Goemon [6].

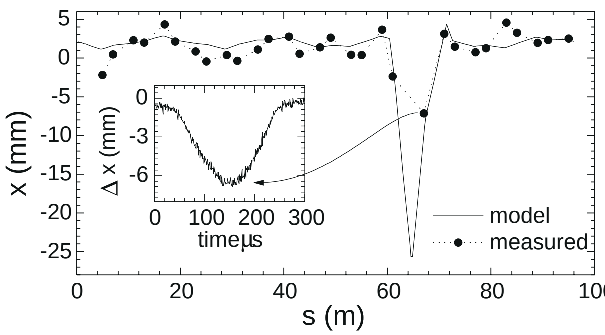

Figure 5: Measurement of the extraction bump of the booster compared with the optics model Goemon [6]. The inset shows the evolution of the marked BPM while the bumpers are fired.

4.2 The Storage Ring

Recently, the storage ring entered the commissioning phase. Some first results obtained with the BPM system are presented in Fig. 6 and Fig. 7. The former depicts the first efforts to correct the closed orbit. The dashed lines are the original closed-orbit without correction. The solid lines are the recorded after computer-aided correction. It was difficult to make adequate orbit corrections by hand as there were too many parameters. With the computer all the 144 steerers were used to correct by using the theoretically calculated sensitivity of each steering-coil as input. Prior the model was carefully tuned to match the experimental situation [7]. As a result a reduction of a factor of 3 of the orbit deviation was obtained. For the next step it is anticipated that the orbit can be improved, as more information on the ring becomes available. The remaining vertical bump around *s*=100 m, for example, suggest that more refined optimization schemes give room to further improve the orbit.

In single turn modes the recording of successive turns can be used to determine the integer and fractional part of the tune. At present this has been the most important use of these measurements as it enables tune-measurements before beam is actually stored. In the example shown in Fig. 7, the tune was found to be exactly on a third order resonance. Consequently the beam could only be stored for a period of 180 μs, more than sufficient for accurate tune measurements. The additional spikes in the spectrum are a result of the 8-fold symmetry of the BESSY II design, see Fig. 1. For the near future it is anticipated to use the single turn modes of the BPM system to optimize the injection in the ring.

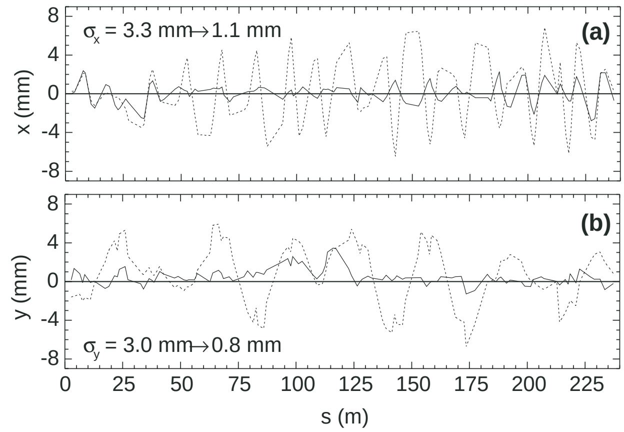

Figure 6. First results of horizontal (a) and vertical (b) orbit correction in the storage ring.

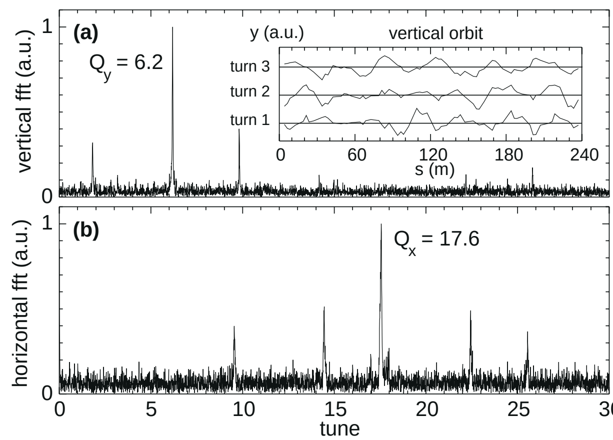

Figure 7. Tune-measurement obtained from 64 individual single-turn recordings (e.g., see inset).

5. SUMMARY

The BESSY II BPM systems are operational. During the commissioning of both the injection system and the systems for the main ring have proven to be a valuable tool to understand and optimize the machine. As more information on the machine becomes available, it is anticipated that the performance of the available tools will improve further.

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