EXPERIENCE WITH THE COMMISSIONING OF THE LIBERA BRILLIANCE BPM ELECTRONICS AT PETRA III

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Abstract

PETRA III, a new 3rd generation synchrotron radiation source, is presently under commissioning at DESY. Its beam position measurement system is based on the Libera Brilliance electronics. The BPM system is used for the machine start up and development. Later on, the system will be used for the orbit monitoring and orbit feedback. This paper presents the infrastructure and features of the BPM system together with the commissioning experience of the BPM electronics.

INTRODUCTION

In 2004 DESY decided to reconstruct its storage ring PETRA II into a new 3rd generation synchrotron radiation source PETRA III [1]. After two-years upgrade, one eighth of the 2.3-kilometer long ring was completely rebuilt and equipped with 14 undulator beamlines. The remaining seven eighth were completely removed, modernized and reinstalled. The electron beam position monitor (BPM) system that was installed in PETRA II did not meet the resolution and stability requirements of PETRA III. A simple upgrade was not possible; therefore it was decided to equip PETRA III with a completely new BPM-system. The BPM pickup stations, cables, BPM read-out electronics and all related infrastructure were renewed. Installation of the BPM system began in summer 2008 and commissioning with beam started in the end of March 2009.

BEAM POSITON MONITORS AND READ-OUT ELECTRONICS

PETRA III is equipped with 227 BPMs for the orbit measurement. There are 8 different types of electrostatic button pickup stations because the vacuum system of PETRA III has various types of vacuum chamber cross sections. Commercial RF button feedthroughs from PMB and Meggitt are used as pickups for the BPM blocks. All feedthroughs were individually tested and grouped together per BPM by similar test pulse response.

The requirements for the readout electronics are quite tight for new light sources. The BPM system for PETRA III has to support the machine commissioning as well as orbit feedback and the beam position observation. All of the BPMs have to be equipped with single turn and single pass, i.e. Turn-by-Turn (TbT) capabilities with the resolution of 50…100 μm (rms) in this operation mode. For standard user operation the orbit of the stored beam has to be kept constant with high accuracy: the beam should be stabilized to 1/10th of the beam width σ. For the BPMs located near the undulators required vertical resolution is 0.3μm (rms), i.e. the BPM system must have very high accuracy. Additionally, position data with TbT frequency about 130 kHz and resolution not worse than 50μm (rms) are needed for the Fast Orbit Feedback (FOFB) system. Other important requirements are the temperature drift (≤ 0.2 μm/°C) and 8-hours stability (1 μm peak to peak).

Libera Brilliance BPM electronics from Instrumentation Technologies was chosen as BPM read-out electronics. This beam position processor meets all technical requirements of the BPM electronics. Additionally it is an all-in-one solution that allows simplifying the infrastructure, and therefore the reliability of the system. Liberas were successfully used at other light sources like Soleil, Diamond, Elettra and ESRF.

In the beginning, the Libera Electron version was comprehensively tested in the laboratory and during a beam test at the ESRF [2]. Later on it was estimated that the monitor signals from the buttons might be higher than allowable input signal level of the Libera Electron [3]. Libera Brilliance, the next version of the beam position processor, has different characteristics of the input RF chain and allows operating with higher input signal levels. In addition the Brilliance version has better TbT resolution, temperature drift, beam current and bunch pattern dependency. Finally it was decided to equip PETRA III with the Libera Brilliance. The functional block diagram of Libera Brilliance together with the input chain is shown in Fig. 1.

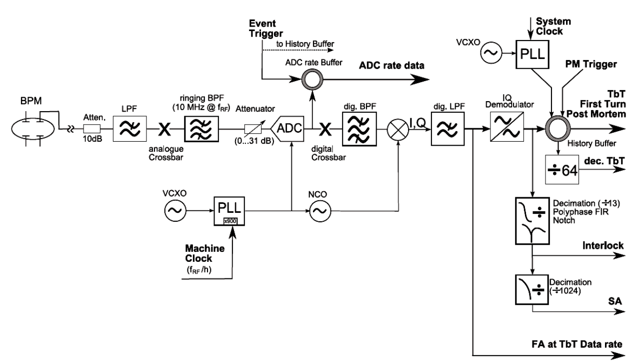

Figure 1: Functional block diagram of one channel of the Libera Brilliance BPM read-out electronics at PETRA III.

There are five data paths: ADC raw data, TbT data, decimated TbT data (factor 64), slow acquisition (SA) data for closed orbit measurement at approx. 10 Hz and fast acquisition (FA) data. External 10 dB attenuators are placed on each input in order to avoid damage of the

Libera's input circuit by high peak voltage. The performance of the attenuators was tested and meets the resolution requirements of the BPM system as well as the temperature stability using thermally-coupled mounting. The Libera Clock Splitter from Instrumentation Technologies is used to apply clock and trigger signals to each Libera device. Orbit interlock signals are directed to the Machine Protection System. The fast data stream with TbT update rate is used to collect the beam position at each BPM location for the FOFB system. Fast acquisition data from all BPM electronics located into the same rack are streamed via Libera's Rocked IO to the signal combiner and then towards the FOFB system. One BPM rack has up to 14 BPM electronics. Communication with the control system and feeding the slow acquisition data for closed orbit observation as well as slow orbit feedback are accomplished via Fast Ethernet switches.

BPM SYSTEM INFRASTRUCTURE

In order to achieve the required BPM resolution and stability, the BPM system must have proper environment and infrastructure. Important points are cables, pickup support and movement, temperature control and stabilization. High performance cables are used for the BPM-signal cabling. There are 3 types of cables depending on the distance between the pickups and the location of the read-out electronics. The maximal cable length is about 160m. A set of four cables should provide the signals with equal phases to the inputs of the electronics in order to fulfill beam current dependency requirements [4]. Therefore the cables have been precisely cut to equal lengths within 3-4 cm for each set. All of the input signal cables are additionally fixed in order to avoid unwanted vibrations that can affect the resolution of the system. All button pickups located in the new octant are joined to a High Frequency Movement Monitor in order to measure their position and movement with respect to the girder or ground floor. The resolution of this measurement system is better than 0.01 µm.

The BPM electronics are housed in 24 racks. 10 of them are placed in the new experimental hall. Temperature stabilization of the electronic racks is necessary in order to improve the reproducibility of the system. The hall has its own air conditioning system that provides temperature stabilization within ± 0.1 °C. Each rack has a fan-driven panel placed on the top in order to get proper ventilation. 14 BPM electronics rack are positioned in 8 halls around the remaining seven eighth of the ring. The BPM together with the FOFB racks are located into special air-conditioned huts as these halls have no temperature stabilization. The requirement to the beam stability is not too tight in these locations. The temperature inside the huts can be varied within ± 1°C. An absolute value of this temperature is important and should not exceed a certain value. Therefore the temperature and the speed of the fan rotations inside the Libera are monitored by software.

COMMISSIONING OF THE BPM ELECTRONICS

Site acceptance tests of each unit have been performed after delivery of the BPM electronics. The results of the tests were within specifications [5]. After finishing the hardware installation and before beam start up, all BPM electronics have been verified together with the input signal cables to avoid wrong cabling. Server, client and dedicated MATLAB® application programs, required for the commissioning, were developed.

Turn by Turn Measurements

After first beam injection, the sum signal from the four buttons was used at the first stage of the commissioning for guiding the beam around the ring. TbT data together with the ADC raw data were used for the position measurements. It allowed to proceed with the injection improvement and to correct the beam position. Figure 2 shows the first sum signal from the beam at PETRA III.

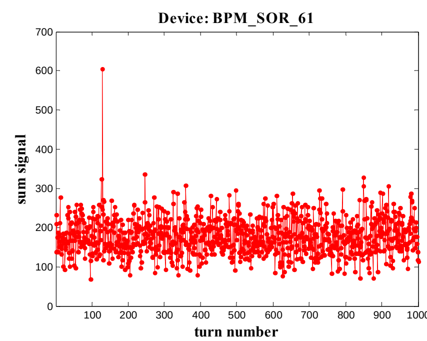

Figure 2: First beam at PETRA III. Response of a single BPM near injection. Due to an adjusted timing offset the first turn appears in turn no. 129.

After obtaining the position information from several BPMs one of the priorities became synchronization of the acquisition of all Liberas in the ring, i.e. first-turn sum signal should be observed at the same turn with respect to the acquisition trigger for all devices. Correct synchronization was set by finding proper external trigger, adjusting the hardware trigger delay inside Libera (available in the software release 1.80), and looking to the ADC data. Bunch signals have to be seen on the same position in the ADC samples for all BPMs. Additionally the phase of the Machine Clock (MC), coming with the revolution frequency, was adjusted in order to get correct beam phase with respect to the MC. Figure 3 shows first turn sum signals from all BPMs in the ring with the correct synchronization.

ADC raw data are very useful for finding certain hardware failures (e.g. noisy channels) in the beginning of the commissioning when the beam current is small and therefore the signals from the buttons are difficult to see. An essential application of the TbT data is the tune measurements. The tune measurements have been done as soon as a few hundreds turns were injected (Fig. 4).

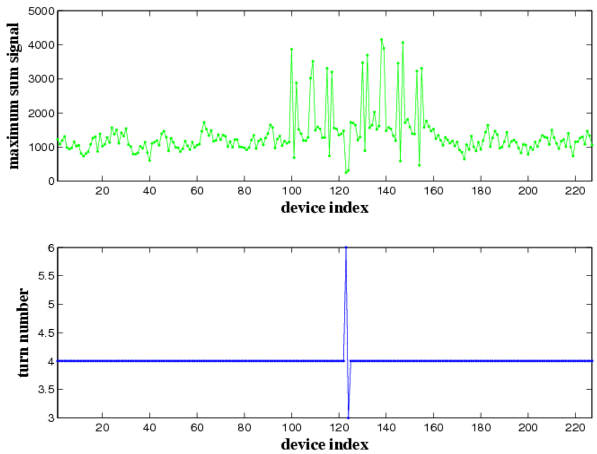

Figure 3: First turn sum signals from 227 BPMs observed at the same turn. Top: un-normalized sum signal. The narrow gap BPMs near the undulators are clearly visible. Bottom: Due to a readjusted delay the first turn appears in turn no. 4 now. BPM no. 121 and 122 are not installed.

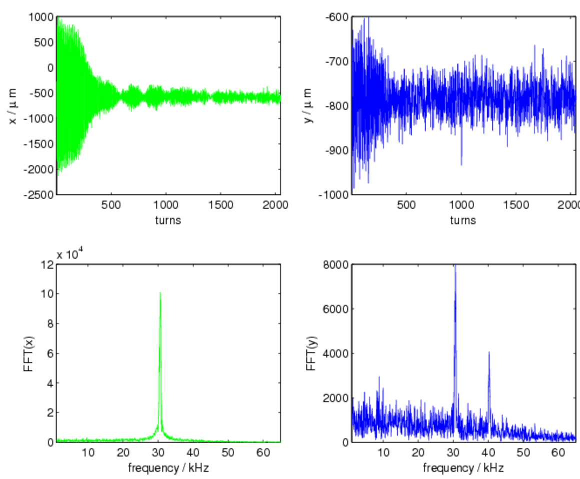

Figure 4: Horizontal and vertical turn by turn data together with FFT for tune measurement.

Slow Acquisition

The first stored beam was obtained shortly after the start of PETRA III commissioning [6]. Slow acquisition data have since been used for monitoring the closed orbit (Fig. 5). The SA data streams from all Liberas should be synchronized. Therefore their internal system and machine times had to be set simultaneously in advance for all devices. Automatic gain control was used to find the proper level for the attenuators in the Libera inputs. The resolution of dedicated monitors close to the undulators was better than 1µm in horizontal and about 0.5 µm in vertical plane at input signal levels of -45 dBm (1.9 mA; 6 GeV; 40 bunches) in SA mode. Interlock and post mortem functionality were successfully tested with beam.

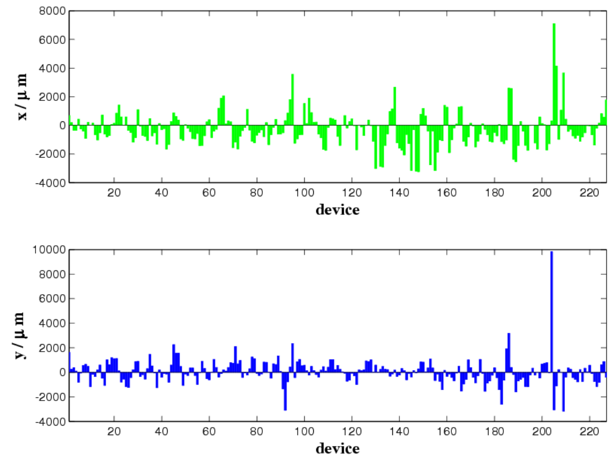

Figure 5: Orbit of the stored beam.

CONCLUSIONS

The PETRA III BPM system was completely renewed after reconstruction. Substantial effort was put into design, installation and testing of the system. As a result, the BPM system was put into operation in time and without any trouble. It enabled a successful start to the commissioning of PETRA III. Some features of Libera Brilliance BPM-readout electronics like trigger delays, possibility to use ADC data etc. helped a lot during the commissioning.

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