COMMISSIONING OF A NEW BEAM-POSITION MONITORING SYSTEM AT ANKA

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Abstract

A new beam-position monitoring (BPM) and diagnostic system is being commissioned at ANKA, the synchrotron light source of the Karlsruhe Institute of Technology (KIT). This system is based on 40 Libera Brilliance devices from Instrumentation Technologies. It provides turn-by-turn information about the beam position. This information can be used for beam diagnostics (e.g. finding the position where the beam is lost during injection phase) and can also form the base of a fast orbit-correction scheme. We have performed studies to assess the performance of the new BPM system in comparison to the old system being replaced. In order to optimize the commissioning process we have developed a scheme for switching to the new system gradually by integrating it with the MATLAB Middle-Layer using EPICS control software. In this contribution we present the results of our comparison of the two BPM systems and provide an insight into the experience gained during the commissioning process.

INTRODUCTION

Synchrotron light sources have become an important tool in many different sectors of science. The stability of the photon beams used at the various beamlines directly depends on the stability of the electron beam orbit. Therefore, a stable electron beam orbit is an important goal for the operation of a synchrotron light source.

In order to provide such a stable orbit, an orbit feedback system is needed: The beam position is tightly monitored at many locations around the storage ring and corrections are applied to the electron beam using small dipole magnets. Thus, the orbit of the beam can be kept within the specified limits.

At ANKA we upgraded our orbit feedback system by replacing the beam-position monitor (BPM) electronics with Libera Brilliance devices from Instrumentation Technologies [1]. Tests showed that the new electronics provide data with equal or less noise than the old electronics. The new electronics have successfully been in operation since January 2012.

The new BPM electronics provide enhanced diagnostic tools. We are looking into using these BPMs for upgrading our slow orbit-correction scheme to a fast orbit-feedback system in order to improve the orbit stability.

DECISION FOR NEW ELECTRONICS

At ANKA we faced the challenge that an increasing number of BPM electronics was showing aging effects. Besides, being in use since the start of accelerator operation in 2000, these electronics were rather slow compared to the electronics available today: As they averaged the BPM signal over a period of ten seconds, they had a limited use for diagnostics (e.g. during injection).

For these reasons, we made the decision to replace the old BPM electronics with new Libera Brilliance devices from Instrumentation Technologies. Each Libera Brilliance can provide per-turn information about the beam position. This data is useful for discovering fast oscillations of the beam and can be used for studies of the injection process, as well as detailed optics studies. Moreover, fast BPM electronics are crucial for a fast orbit-correction scheme.

COMPARATIVE EVALUATION

Before installing the new BPM electronics we had to make sure their accuracy matched or exceeded the accuracy of the old electronics. At the same time, we wanted to test whether we could connect the old and the new electronics to the same set of BPM buttons in parallel, using T-pieces or splitters. Being able to use both electronics in parallel would ease the transition.

Testing with a Signal Generator

For testing the long-term stability and dependance on the signal power-level (wich is proportional to the beam current in the accelerator), we used an Instrumentation Technologies RF & Clock Generator [2]. This signal generator can provide a signal at the RF frequency of the accelerator (500 MHz for ANKA), which is similar to the signal from a BPM button if every bucket is filled and has the same bunch charge. It also provides the revolution clock trigger (about 2.7159 MHz for ANKA) for the BPMs. The 500 MHz signal was split into four signals in order to simulate all four button signals for the BPM electronics.

We tested three different setups: old electronics alone, new electronics alone and old and new electronics in parallel, by splitting the signal of each (virtual) button. We set the signal generator to two different power levels to see how strong the noise depends on the simulated beam current. For each power level and setup we recorded the measured “beam position” for about 2.5 hours.

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While this method does not yield the absolute noise of the electronics due to the noise from the signal generator, it presents a comparison of how much the noise changes for the different setups. We can see from Table 1 that the new electronics always perform better than the old ones and that splitting the signal increases the noise.

Table 1: Noise measurement for different setups. The values represent the peak-to-peak noise for for a measurement of 2.5 hours at a sampling rate of 1 sample per 3 seconds, using scaling factors of $K_X = K_Y = 13$ mm for the assumed button geometry.

Power Level	**-5 dBm**		**-20 dBm**	
Plane	**X**	**Y**	**X**	**Y**
Electronics				
Old (alone)	1.6 µm	1.3 µm	1.0 µm	0.9 µm
New (alone)	0.6 µm	0.4 µm	0.5 µm	0.3 µm
Old (split)	1.8 µm	1.9 µm	1.6 µm	1.4 µm
New (split)	0.9 µm	0.6 µm	0.6 µm	0.7 µm

Testing with the Electron Beam

For determining the change of the beam position offset when changing the electronics, we used the same BPM combinations as in table 1. This time however, we used the signals from real BPM buttons installed in the accelerator. We performed a beam-based alignment (BBA) [3] for each of the four setups in order to determine the change in the position offset. The results showed, that when changing from the old to the new electronics or from either of them to a parallel setup, we had to expect an offset change of up to several millimeters. That meant that each time the setup for a set of buttons was changed, we would need to perform a BBA.

For this reason and because of the increased noise when using the split setup, we decided not to use old and new electronics in parallel as an intermediate solution, but change from old to new electronics directly.

CONTROL-SYSTEM INTEGRATION

We had to integrate the new BPM electronics into the accelerator control-system. However, we did not want to use the existing control-system framework, because we already had a project running for gradually replacing this system. Therefore, we were looking for control-system drivers with a common, standardized interface.

We decided to use the Libera EPICS Driver from Diamond [4], because it provided a simple, reliable and yet comprehensive solution for configuring the devices, retrieving data for slow-orbit feedback, and accessing the diagnostics features. In particular, the ready-to-use EDM panels, which come with the driver, proved to be very useful in the commissioning phase.

The existing orbit-correction code was changed to use the new EPICS interface and a software was installed that made the components still using the old control system (the old BPM electronics and the corrector magnets) available through an EPICS interface. Thus, the new orbit-correction code is a pure EPICS client.

COMMISSIONING OF THE NEW ELECTRONICS

Due to a tight operation schedule, the final installation of the new BPM electronics was performed during the shutdown at the end of 2011 and we had only the first week of operation in 2012 to get the new system running. After this week the system had to be ready for user operation.

If all BPMs had been switched to the new electronics at once, we would not have been able to measure and correct the beam orbit until all offsets had been determined. However, as the orbit-correction code was designed in a way, so that it could use old and new BPM electronics at the same time, we could use an iterative scheme.

First we switched over a few BPMs (usually one per sector) and then performed orbit correction using the remaining BPMs. Next, we measured the new offsets using BBA. Subsequently, we could then change the next group of BPMs. Using this strategy, we were able to migrate from a setup using the old electronics to a setup completely using the new electronics within less than three days. Thus, the accelerator could go back to normal user operation after only one week as planned.

By the time of writing, the new system has been successfully running for several months.

BENEFITS

Besides the obvious benefit of having a more reliabe BPM system for the accelerator operation, there are a some benefits from a diagnostics point of view. In addition to the "slow" orbit data provided at an update rate of 10 Hz, there are two kinds of fast orbit data:

A continous stream of the beam position sampled at a rate of 10 kHz is provided through a special, 1 GBit network interface. This data is useful for monitoring fast orbit instabilities and can also be used for a fast orbit-correction scheme.

Furthermore, each device can provide orbit data for each individual turn. This data is stored in a special buffer in each device and can comprise up to a few hundred thousand turns (depending on the revolution frequency of the accelerator). This data is useful for investigating details of the injection process and can also be used for tune measurements by kicking the beam and calculating the Fourier transform of the resulting beam oscillations.

Another important benefit is the significant decrease in time for BBA runs and orbit-response-matrix measurements: With the old electronis a complete BBA run took about 8 hours and a response matrix measurement about 30 minutes, due to the long time until the BPM electronics supplied all new data. Using the new electronics, with their 10 Hz update rate for slow data, these times have decreased to about 40 minutes for the BBA and about 5 minutes for the response-matrix measurement.

BOOSTER SYNCHROTRON

Recently, we installed four Libera Brilliance devices in the booster synchrotron. While we always had BPM buttons at several positions in the booster synchrotron, their use was limited because the old BPM electronics were very slow.

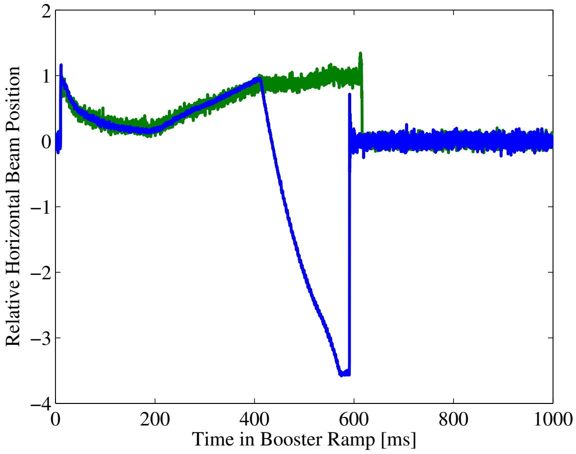

Figure 1: Orbit in the ANKA booster synchrotron during one cycle. The blue line shows the orbit when the beam is kicked and subsequently extracted at about 600 ms. The green line however represents the orbit when the pulsed magnets have been switched off. In this case, the beam is stored a few milliseconds longer, until the magnets are cycled for the next injection.

Using the new electronics, we can now monitor the orbit as it changes during the energy ramp from 53 MeV to 505 MeV. Fig. 1 show the horizontal orbit at BPM 01 with and without the magnets used for extracting the beam being pulsed. This data was retrieved using the fast 10 kHz readout channel. As we can see from the plot, the orbit is quite stable until the beam is deliberately kicked for extraction.

In addition to that, we measured the horizontal betatron tune at various points in the booster ramp. We gained the results shown in Fig. 2 by kicking the beam with the extraction kicker and simultaneously triggering the BPM electronics to record turn-by-turn data. By repeating this measurement for multiple cycles, we could determine that the tune at a certain point in the ramp is constant over many cycles. Thus, the main contribution to the uncertainty of the tune is from the binning of the Fast Fourier Transform (FFT), which contributes an uncertainty of about $5 \cdot 10^{-4}$.

FAST ORBIT FEEDBACK

In the near future, we plan to install the fast 10 kHz readout channel for all BPMs (at the moment it can only be used on one BPM at any time). This will eventually lead to the integration into a fast orbit-correction scheme. As such a system will also require an exchange of all corrector magnets and their power supplies, this task is on the long-term roadmap.

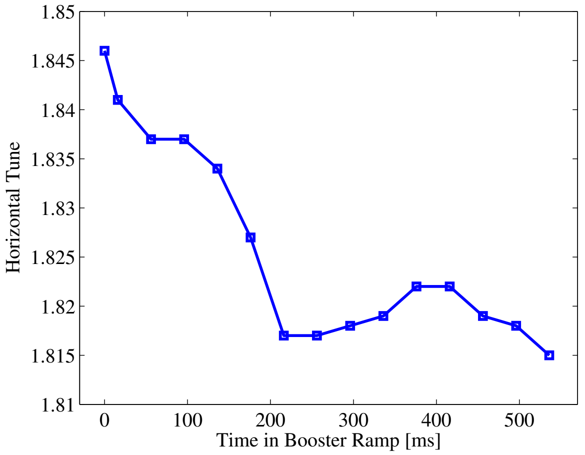

Figure 2: Horizontal betatron tune in the booster ramp.

CONCLUSION

The orbit-feedback system at ANKA was upgraded by installing new BPM electronics. Due to good preparation and using a well planned transition scheme, the commissioning of the new electronics could be performed within a few days. The new system has successfully been in operation since January 2012.

We have started to explore the wide range of diagnostic tools offered by the new BPM electronics. For the future we are planning to extend the upgrade by adding a fast orbit-correction scheme.

ACKNOWLEDGEMENTS

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