

# EXPERIENCE WITH LIBERA BEAM POSITION MONITORS AT DELTA

P. Hartmann\*, J. Fürsch, D. Schirmer, T. Weis, K. Wille

Zentrum für Synchrotronstrahlung DELTA, Universität Dortmund, D-44221 Dortmund

## Abstract

Libera beam position monitor electronics have been installed at the electron storage ring Delta in order to extend the capabilities of the BPM system to turn-by-turn orbit measurements. This report covers the integration of Libereras into the beam diagnostics infrastructure at DELTA and its control system EPICS. Prior to their application in user runs the devices have undergone characterization measurements in a BPM teststand and during machine runs for accelerator physics. The results of these measurements are compared to measurements with DELTA's standard BPM electronics. The necessary clock and trigger signals are provided by a low-cost signal distribution device developed at DELTA.

## INTRODUCTION

The storage ring Delta as well as the booster BoDo are equipped with analog beam position monitor (BPM) electronics<sup>1</sup> which have been working reliably without any problems for roughly ten years. They have proven to be excellent tools for beam orbit measurement up to a maximum bandwidth of 10 kHz.

The advent of off-the-shelf turn-by-turn (TBT) BPM electronics<sup>2</sup> offer the opportunity to acquire TBT orbit data in parallel to 'slow' orbit measurement. Turn-by-turn orbit data open up a new window in beam diagnostics at DELTA. Optics parameters, for example tune and chromaticity, can now be monitored with high temporal resolution. Turn-by-turn data, taken within a fraction of a millisecond, can be obtained during user shifts often even without any beam distortion [1], and not only during dedicated machine shifts.

This report describes the extension of our BPM testbed to incorporate Libera BPMs and the creation of the infrastructure in the Delta storage ring in order to use all features of Libera. First measurements are presented.

## BPM TESTBED

Prior to installation in the ring, new BPM electronics and new firmware versions have to be tested. For this purpose we have set up a BPM testbed (see fig. 1).

The signal from an RF generator running at 499.82 MHz is split by high bandwidth power dividers and is fed into the inputs of a MX-BPM and a Libera. The RF generator can be pulsed in order to simulate a variety of filling patterns.

In addition a Clock Splitter and a trigger generator was installed. On the Libereras we currently use firmware version 1.21 together with the DIAMOND EPICS driver version 0.63. The output signals of both BPMs can be monitored from any PC in the control system.

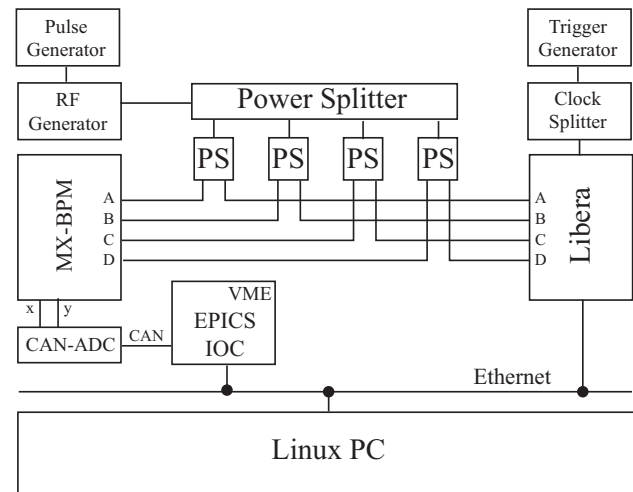


Figure 1: Setup of the BPM testbed.

The Digital Signal Conditioning (DSC) feature of the Libereras, intended to compensate for slow amplifier drifts of the four signal paths of the analog frontend of the Libereras, generates a signal distortion on the turn by turn data which renders TBT measurements unusable. Slow beam orbit measurements, on the other hand, need DSC in order to give reasonable results. Thus a parallel operation of fast and slow data taking is, for the moment, not possible.

The EPICS driver does not support the Automatic Gain Control (AGC) feature of the Libera BPMs thus we do gain switching with a set of EPICS records.

A comparison of the 'slow acquisition' data of the analog and the digital BPM electronics resulted in only small differences at beam currents above 2 mA. Only the vertical component of the slow acquisition data from the Libera shows a deviation in the 10  $\mu\text{m}$  range below 2 mA beam current corresponding to -55 dBm input power. Lowering the beam current to less than 0.8 mA, deviations of more than 100  $\mu\text{m}$  were observed (see fig. 2). The impact on the ring installation is low, since the Delta orbit correction stops operating at its lower beam current limit of 1 mA.

## RING INSTALLATION

The installation of Libereras requires an infrastructure for the distribution of a variety of signals, if all features the

\* hartmann@delta.uni-dortmund.de

<sup>1</sup>Bergoz MX-BPM

<sup>2</sup>I-Tech Libera electron

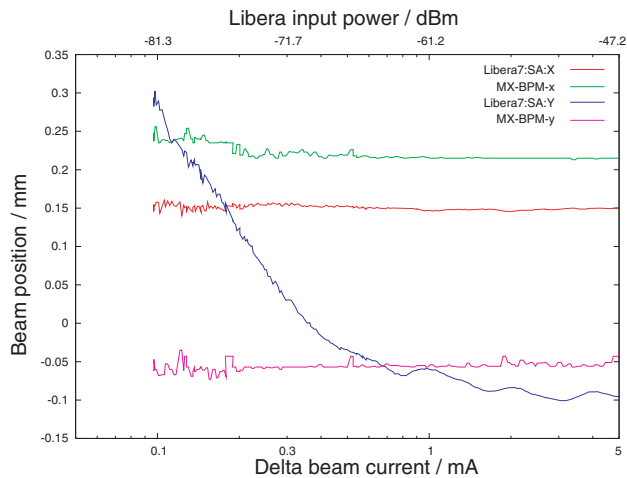


Figure 2: Beam position versus beam current of orbit signals from different BPM electronics.

Liberas provide shall be used. Figure 3 depicts the signal generation and the two-stage distribution network. The first stage (Clock Distributor) resides in a rack on the outside of the ring, accessible during machine runs. Signals will be transported by optical fibers to the inside of the ring where the second stage (Clock Splitter) transforms the optical signals into differential electrical signals required by the LiberAs. Clock Splitters were developed at DELTA based

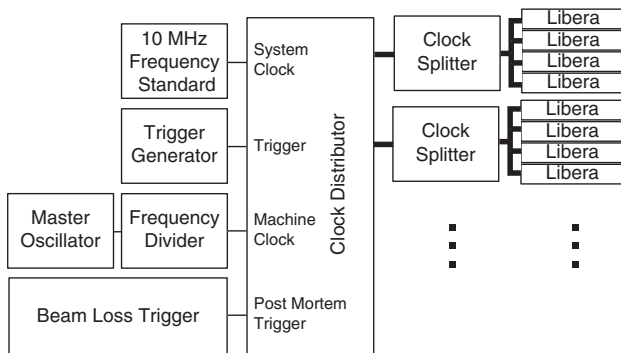


Figure 3: Infrastructure needed by the Libera BPM electronics. All devices except the central Clock Distributor are installed up to now.

on a design provided by the beam diagnostics group of the DIAMOND Light Source. Since at DELTA BPMs are organized in groups of four and signal distribution is planned to be done with optical fibers, a commercially available solution was not an option.

The DELTA Clock Splitter processes four inputs for System Clock, Machine Clock, Trigger and Post Mortem Trigger and has one backward path for the Interlock signal. Parallel to optical fiber inputs, BNC connectors for TTL level signals are available.

Seven LiberAs have been installed in the Delta storage Beam Instrumentation and Feedback

ring up to now. The four mostly used ones are connected to BPM13 - BPM16 (see fig. 4). BPM14 and BPM15 are connected to the pickups via power splitters. BPM13 and BPM16 are connected directly to the pickups. Only BPM14 has the “free run” option of the EPICS driver enabled which is necessary for tune measurement [1].

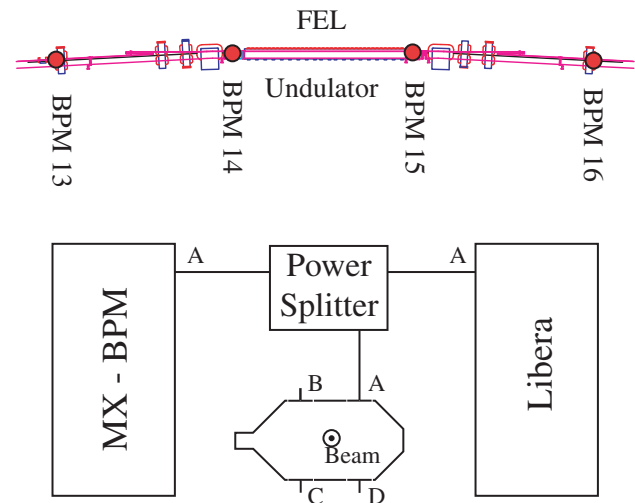


Figure 4: Position of four of the seven LiberAs currently installed in the ring. BPM 14 and 15 are connected to the pickups via four power splitters (only one is shown).

Operating two BPM electronics in parallel on a power divider is not unproblematic as can be seen in fig. 5. Sudden orbit steps were observed on the Libera TBT data having a repetition rate of about 8 kHz. They are attributed to reflections the MX-BPM generates on the RF inputs due to unadapted impedances of the multiplexer. The problem is known to the manufacturer and may be suppressed to negligible level. These orbit steps average out in slow acquisition data. For BPM 14 and 15 MX-BPMs with very low reflections have been chosen.

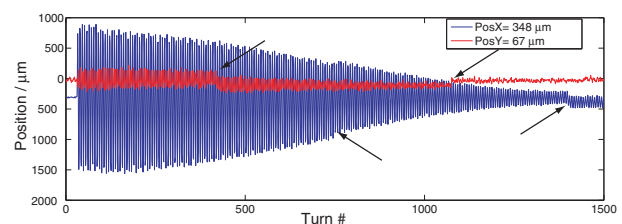


Figure 5: Steps in the turn by turn orbit measurements at 8 kHz repetition rate are attributed to reflections from the MX-BPMs that propagate back through the power splitter.

### Phase space measurement

Besides the measurement of the tune the measurement of the phase space on two successive BPMs is quickly set

BPM related

up, in case the transfer matrix between them is known. The transfer matrix between BPM14 and 15 is that of a simple drift space. The beam was excited using one of the injection kickers. The kick takes place only in the horizontal

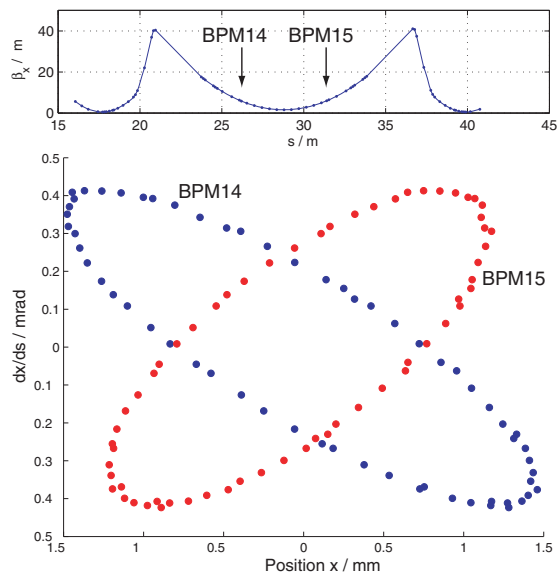


Figure 6: Horizontal beta function from the optics model and measured horizontal phase space at BPM14 and BPM15.

plane and only due to coupling betatron oscillations can be observed in the vertical plane, too (see fig. 5). Plotting the difference of the offsets from the equilibrium orbit divided by the distance between the BPMs versus the offset itself, a phase space ellipse shows up (see fig. 6). A fit to the measured ellipse allows the deduction of the twiss parameters which may serve as a verification for the machine model.

### Analyzing beam loss

The experiment in figure 7 was set up to check the post mortem trigger capability of the Liberass. Turn-by-turn data



Figure 7: Setup for analyzing beam loss 'post mortem'. The beam loss trigger is generated from the differential output of a Parametric Current Transformer (PCT) used for beam current measurement.

are stored in a 16.000 turn ring buffer. Whenever a post mortem trigger occurs, writing to the buffer is stopped. The buffered data can then be analyzed in order to check for reasons of beam loss. We have generated the beam loss trigger from the differential output of the Parametric Current Transformer (PCT) used for beam current measurement. Although this signal is delayed it is still fast enough

to detect 'instantaneous' beam loss caused for example by a kicker (see fig. 8). Beam loss due to RF trips have, presumably due to their low lossrate, not been identified up to now.

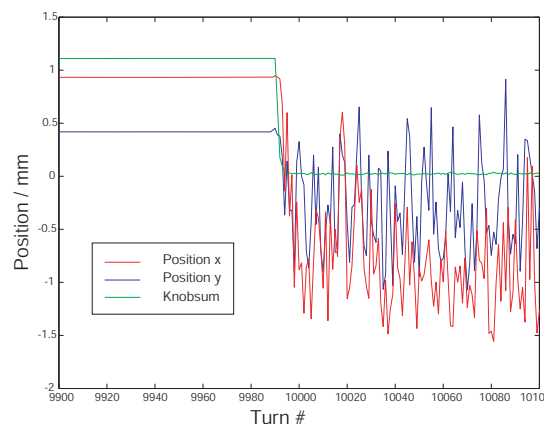


Figure 8: Beamloss within five turns generated by a pulse of one of the injection kickers. These events are extremely rare and can identified and distinguished from RF trips by the analysis of post mortem BPM data.

## CONCLUSION

Within the last year we have, after carefully testing the Libera beam position monitor electronics, installed seven devices in the Delta storage ring. A comparison with the available MX-BPMs in the BPM testbed gave the following results: At beam currents above 2 mA the 'slow acquisition' data from Liberass is of roughly the same quality as the data from the MX-BPMs. At lower beam currents Liberass show a slight deviation in measurements of the vertical component. We have shown in first measurements that TBT orbit data of high quality may serve amongst others as input for machine modelling. The advantage of having this turn-by-turn data justifies under all circumstances the installation of at least a limited number of Libera electronics at suitable positions in the Delta ring.

## ACKNOWLEDGEMENTS

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## REFERENCES

- [1] P. Hartmann et al., Kicker Based Tune Measurement for DELTA, These proceedings.
- [2] <http://www.i-tech.si>, see also Libera workshop 2006
- [3] <http://sourceforge.net/projects/libera-epics>