FAST ORBIT FEEDBACK AT DELTA*

P. Hartmann, A. Althaus, D. Rohde, D. Schirmer, G. Schuenemann†, P. Towalski†, T. Weis, S. Khan
DELTA, TU Dortmund University, Germany

Abstract

At the electron storage ring DELTA, studies of a fast orbit feedback integrating Libera Electron and Bergoz MX-BPM electronics were conducted. A review of the project and its results is given.

INTRODUCTION

Global orbit feedback systems that correct orbit distortion in a frequency range between 1 and 500 Hz have become a standard at modern synchrotron light sources [1]. They are typically based on FPGA-driven beam position monitoring (BPM) electronics as for example the I-Tech Libera Brilliance [2].

At the 1.5 GeV synchrotron light source DELTA [3] at the TU Dortmund University, the storage ring as well as the booster synchrotron are mainly equipped with Bergoz MX-Beam Position Monitors [4]. At strategic positions in the storage ring, ten MX-BPMs have been replaced by I-Tech Libera Electron/Brilliance BPM electronics which are capable of measuring the beam position turn-by-turn. The Libera BPM electronics are shipped with a digital interface that intergrates seemlessly into DELTA's control system EPICS [5] while the MX-BPMs provide the measured beam position as an analog voltage that is at present digitized by 12-bit analog-to-digital converters (ADC) and fed over CAN bus into the EPICS control system of the accelerator. A slow control system based global orbit feedback (latency > 1 s) compensates for slow beam motion caused by insertion device drifts and thermal drifts.

Fast beam motion

Beam motion at frequencies above 1 Hz has been identified by turn-by-turn measurements from Libera BPM Electronics (see Fig. 1). While high-frequency distortion is mainly caused by the line frequency and its harmonics, distortions at 5.3 Hz, 10.6 Hz and 12.5 Hz were identified as girder resonances using acceleration sensors on top of magnets and on the floor (see Fig. 2) [6].

LOCAL ORBIT FEEDBACK

Suppression of fast beam motion has been investigated in a first step with a fast local orbit feedback based on two I-Tech Libera BPMs and four correctors (see Figs. 3 to 5) [6]. The Libera devices use a code developed at the Diamond Light Source called the Diamond Communication Controller (DCC) [7]. This code runs on a Virtex-II-Pro FPGA contained in the Libera BPM electronics. It distributes measured

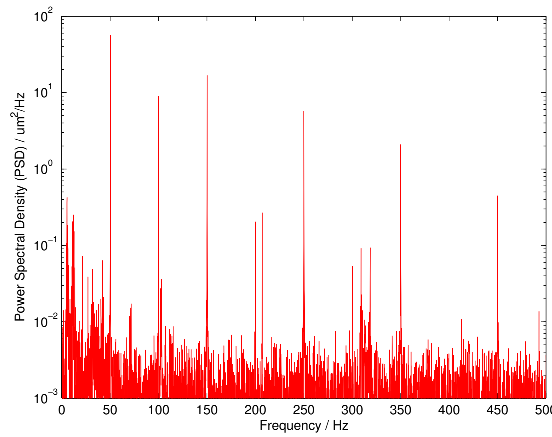

Figure 1: Vertical beam motion at BPM42.

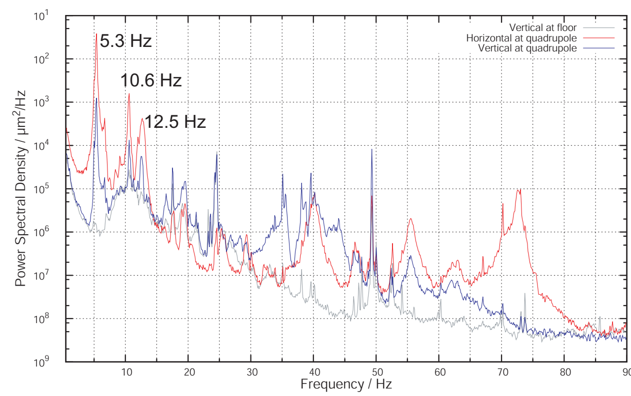

Figure 2: Magnet motion due to girder resonances.

BPM position data at a rate of 10 kHz between all participants linked to a dedicated optical fiber network.

In order to compute orbit corrections and to apply them to fast power supplies and corrector magnets, we implemented the DCC on a Virtex-II-Pro FPGA mounted on the Digilent XUP-Virtex II Pro evaluation board (XUPV2P) [8]. This board was connected to the fiber network and was thus able to receive BPM data at a 10 kHz data rate. In addition, we developed software for orbit correction based on a PI regulator and a driver for fast magnet power supplies (see Fig. 4).

With an optimum set of parameters we were able to reach an upper frequency limit for orbit correction slightly above 350 Hz (see Fig. 5). Distortion at higher frequencies is amplified instead of being damped. This frequency limit is attributed to latency of the beam measurement and regulation process. Beam motion at 50 Hz was damped to -20 dB of the original amplitude, while at 150 Hz the damping still was -10 dB.

* Work supported by BMBF, FKZ 05P09PERB5 and Forschungszentrum Jülich, contract no. COSY/FAIR-114
† Affiliation changed

ISBN 978-3-95450-189-2

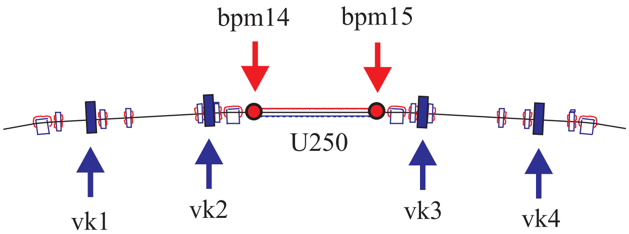

Figure 3: Local orbit feedback for the FEL undulator (U250).

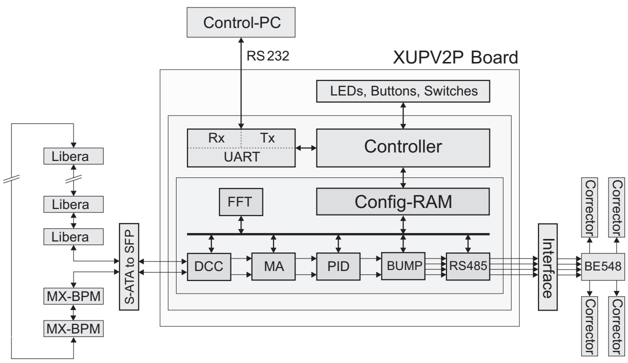

Figure 4: Schematic of the software running on the XUPV2P for the local orbit feedback.

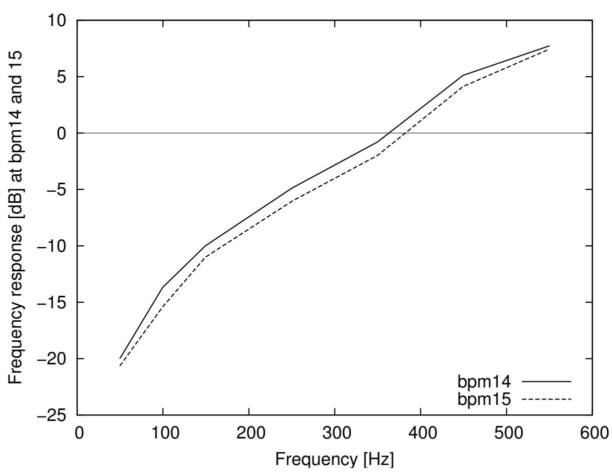

Figure 5: With an optimized set of parameters a frequency limit of about 350 Hz was reached.

BPM EXTENDER

At the same time, we developed the 'BPM Extender 3000', a digital frontend for up to four Bergoz BPMs (see Fig. 6) [9]. The Extender is also based on the XUPV2P evaluation board. An ADC board and other peripheral electronics were added (see Fig. 7). The four Bergoz BPMs are clocked at the highest specified rate of 40 kHz, resulting in position information at a rate of 10 kHz.

This fast data stream is passed to the DCC that distributes it over the DCC network. The link of the XUPV2P to the fiber network was established by connecting the three SATA ports and one extension port of the XUPV2P to SFP jack connectors. The SFP connectors are equipped with fiber connectors. An Extender 3000 is thus capable of having at maximum 4 neighbours in the DCC optical fiber network.

The original DCC had to be modified to match the requirements of the XUPV2P. For example, the XUP-DCC serves four BPMs while the original DCC serves only one. In addition, the on-board SATA clock of the XUPV2P running at 75 MHz had to be replaced by a 106.25 MHz clock in order to integrate the XUPV2P into the Libera DCC network.

Besides the distribution of this BPM data over the DCC, the data is downconverted to a data rate of about 10 Hz by averaging over 1024 samples. We implemented Linux on one of the internal PowerPC-405 processors of the Virtex II Pro FPGA. A kernel driver was developed that makes the 10 Hz data stream from the FPGA core available through a linux device file. The control system software EPICS including ASYN- and StreamDevice drivers [10], [11] was then compiled and installed. ASYN device support reads data from the linux device file and provides it as EPICS records in the control system network. We were able to achieve a statistical error of less than 0.5 µm for the horizontal and vertical position data of all four Bergoz MX-BPMs [9].

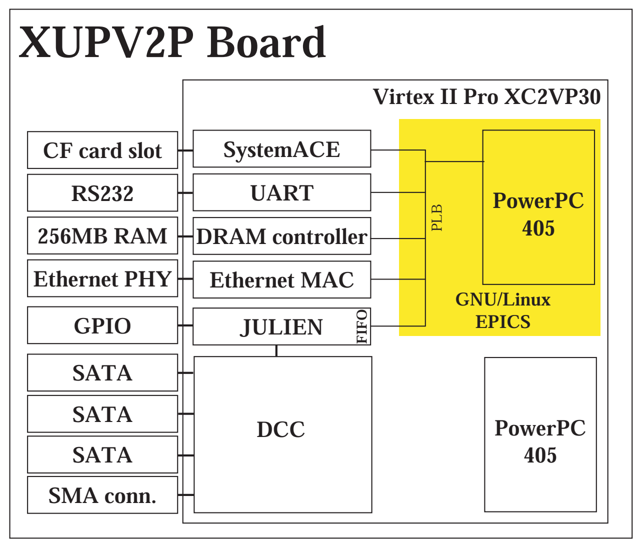

Figure 6: Schematic of the soft- and hardware on the XUPV2P board in the Extender 3000.

GLOBAL ORBIT FEEDBACK

In order to set up a fast global orbit feedback, all MX-BPMs were connected to BPM Extenders using their debug connectors. This way they were still able to provide data in parallel on the 'classical' data path for standard beam operation. The initial network topology was chosen as a ring with one diagonal connection. The time window for the DCC was chosen to be 60 microseconds. Within this window, all BPM data has to be distributed to all participants of the fiber network.

A few 20 years old MX-BPMs were not able to be clocked at 40 kHz. We were able to return them to the manufacturer for hardware upgrade and recalibration.

ISBN 978-3-95450-189-2

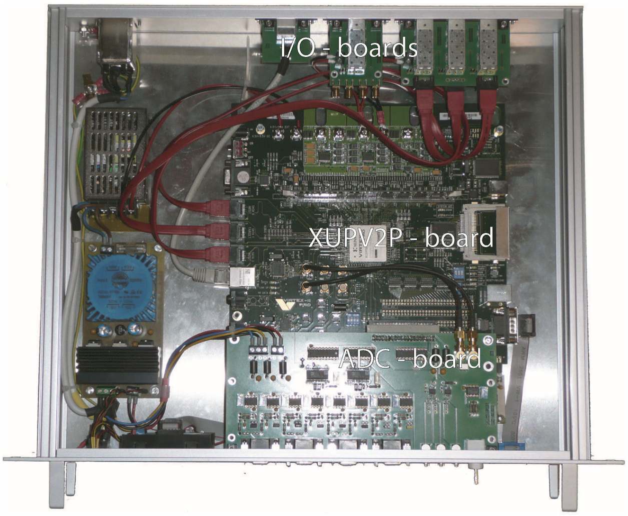

Figure 7: View of the XUPV2P board, the ADC board and the I/O boards inside the Extender 3000.

For orbit correction, several Extender boxes, distributed around the ring, were connected to fast power supplies using RS485 links (see Fig. 8). Horizontal and vertical correctors magnets were developed and installed at strategic positions, based on the ring optics. Promising first tests took place. The main problem turned out to be the synchronization of the DCC data between the Extended MX-BPMs and the Libera BPMs, especially when the Libera sample clock was tuned [12]. Also some Extender boxes had synchronization problems among themselves. Currently, the code for the Extenders ist being rewritten from scratch.

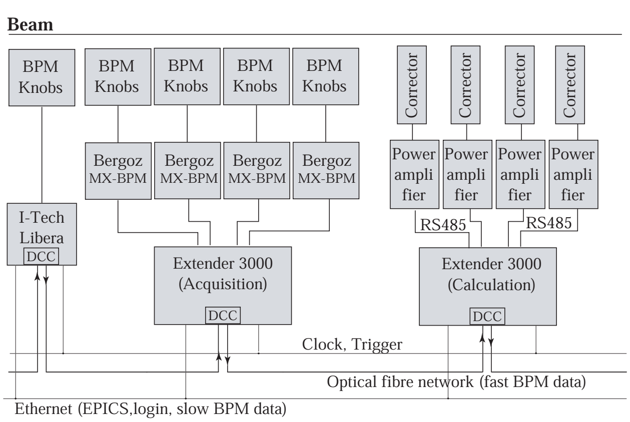

Figure 8: Functional groups of the fast orbit feedback at DELTA. Bergoz MX-BPMs, equipped with BPM-Extenders, deliver fast orbit data in parallel to Libera BPMs. The data are picked up by BPM-Extenders that calculate and apply orbit corrections to the electron beam.

CONCLUSION

At DELTA we have set up a local orbit feedback that allows us to damp orbit distortion up to a frequency of 350 Hz. The development of the Extender 3000 integrates Bergoz BPMs into the DCC communication network. A global orbit feedback was set up but showed synchronization problems between the Extender boxes and the Libera BPMs. The FPGA code is currently being rewritten.

ACKNOWLEDGEMENT

We appreciate help from N. Koch and B. Krumm from the electronics department of the Faculty of Physics, G. Rehm, M. Abbott and I. Uzun (Diamond Light Source), N. Hubert (Synchrotron SOLEIL) and D. Zimoch (PSI).

REFERENCES

[1] N. Hubert, in *Proc. IPAC'16*, Busan, Korea, p. 3139.

[2] `http://www.i-tech.si`

[3] T. Weis *et al.*, in *Proc. RuPAC'06*, Novosibirsk, Russia, p. 138.

[4] Bergoz Instrumentation, "Multiplexed Beam Position Monitor User's Manual", St. Genis Pouilly, France.

[5] Leo R. Dalesio *et al.*, *Nuclear Instr. Meth.* A 352, p. 179

[6] P. Towalski, Master Thesis, TU Dortmund, Germany, 2009.

[7] I. S. Uzun *et al.*, in *Proc. ICALEPCS'05*, Geneva, Switzerland, P02.030-2.

[8] `https://reference.digilentinc.com/_media/virtex-ii:xupv2p_user_guide.pdf`

[9] G. Schünemann, Master Thesis, TU Dortmund, Germany, 2008.

[10] `http://www.aps.anl.gov/epics/modules/soft/asyn/ASYN`

[11] `http://epics.web.psi.ch/software/streamdevice/`.

[12] M.G. Abbott *et al.*, in *Proc. ICALEPCS'09*, Kobe, Japan, p. 694.

ISBN 978-3-95450-189-2