ACDIV-2013-15
September, 2013

FIRST STEPS TOWARDS A FAST ORBIT FEEDBACK AT ALBA

A. Olmos, J. Moldes, S. Blanch, X. Serra, Z. Martí, R. Petrocelli, M. Muñoz, A. Gutiérrez

Abstract:

An optimum performance of the ALBA facility requires a beam orbit stability on the sub-micron level up to frequencies in the 100 Hz range. The Fast Orbit FeedBack system (FOFB) is designed to achieve such stability. After investigation of possible system architecture, a decision has been taken that exploits the available in-house hardware. This "low-cost" first stage FOFB will be an ideal test-bench to learn about beam stabilization and find possible problems and improvements on it. This report explains the current lay-out and status of the FOFB at ALBA.

Accelerator Division
Alba Synchrotron Light Source
Ctra. BP 1413 Km. 3,3
08290 Cerdanyola del Valles, Spain

FIRST STEPS TOWARDS A FAST ORBIT FEEDBACK AT ALBA

A. Olmos, J. Moldes, S. Blanch, X. Serra, Z. Martí, R. Petrocelli, ALBA-CELLS, Barcelona, Spain
M. Muñoz, European Spallation Source, Lund, Sweden
A. Gutiérrez, Universitat Autònoma de Barcelona, Barcelona, Spain

Abstract

An optimum performance of the ALBA facility requires a beam orbit stability on the sub-micron level up to frequencies in the 100 Hz range. The Fast Orbit FeedBack system (FOFB) is designed to achieve such a stability. After investigation of possible system architecture, a decision has been taken that exploits the available in-house hardware. This "low-cost" first stage FOFB will be an ideal test-bench to learn about beam stabilization and find possible problems and improvements on it. This report explains the current lay-out and status of the FOFB at ALBA.

FOFB LAY-OUT

The ALBA FOFB topology is showed in Figure 1. It is based on a distributed system of the different equipments of it. The ALBA storage ring machine is divided in 16 sectors and so are distributed the different elements of the FOFB.

EQUIPMENTS AND CONNECTIONS

Even though the machine has a grand total of 120 Beam Position Monitors (BPMs), only 88 of these will be used for orbit correction feedbacks, together with 88 horizontal and 88 vertical corrector magnets. Reasons to do that are: a) because the other 16 BPMs are so close to their previous ones that do not give any position extra information (no phase advance), b) using 88 BPMs by 88 Correctors makes the correction matrices square and simpler and c) reduction on the costs of eBPM electronics.

eBPM electronics

Induced signals on the BPM buttons are fed into the widely used Libera Brilliance eBPM electronics [1] for signal treatment and position calculation. These electronics provide a continuous data flow of position values at a 10kHz rate through their high speed serial connection ports. Depending on the connection needs, either copper links or optical links through transceivers are used. eBPM electronics inside each sector share their position data using copper links while the connection between different sectors are done using optical links.

Position data of all BPMs are sent to each FOFB Processing Node (*cPCI* in Figure 1) from one of the eBPM electronics at each sector. The FOFB Processing Node is a cPCI crate hosting the following subsystems: one PMC FPGA board, one Correction Calculation CPU and the Optical Link Interface.

PMC FPGA boards

The PMC FPGA boards receive the position data from all BPMs at a 10kHz rate and make it available for the correction calculation CPU. After analysis of cost, manpower availability and development time, decision was to re-use some Micro-Research EVR-230 boards [2] that we had in-house. These boards were meant for timing system purposes on Beamlines but never installed. The use of such boards has some drawbacks and pros.

The Xilinx Virtex-II FPGA on the board is an already obsolete device and future maintenance of the boards might be a problem. Regarding the needed redundancy on any FOFB system, since these boards do only have one single optical link for position data transfer, the failing of the connected eBPM electronics can lead to a stop of the whole FOFB loop, lowering the FOFB reliability.

On the other hand, the electronics and drivers are well known by ALBA controls staff since they are in-use on the machine Timing System. The overall cost reduction of the FOFB becomes significant since each new FPGA board of similar characteristics can cost up to 9.000€ (times 16 + spares). Same refers to the time-to-succeed, since new boards require delivery times of 7-9 months and a lot of development time. Also similar boards are being used at Diamond on their FOFB system and we got great support from them to make them work.

Analyzing all above, decision to "recycle" and use the EVR-230 boards was taken because it was thought to be the fastest way to have a running operational FOFB, that will stabilize the orbit up to the 100Hz range and it will also be an ideal test-bench to find FOFB system bottlenecks, to understand and improve correction algorithms and to better define possible future upgrades.

Correction Calculation CPU

The Correction Calculation CPU retrieves the position data from the PMC FPGA board and performs the calculation of the needed correction setpoints.

Adlink single, dual and 4-Cores cPCI CPUs have been analyzed. Also different Kernel and Linux OS versions were tested because the handling of the interruptions forced CPU dead-times that were not compatible with the required FOFB timing constrains. Finally the 4-Cores cPCI-3970 CPU running soft real time Linux 2.6.27 was chosen.

Optical Link Interface

Once the correction values are calculated, they are sent to the correctors power converters (PC). This is done by an optical link interface. This interface consists of Transition Boards (Tx) to produce the optical signals,

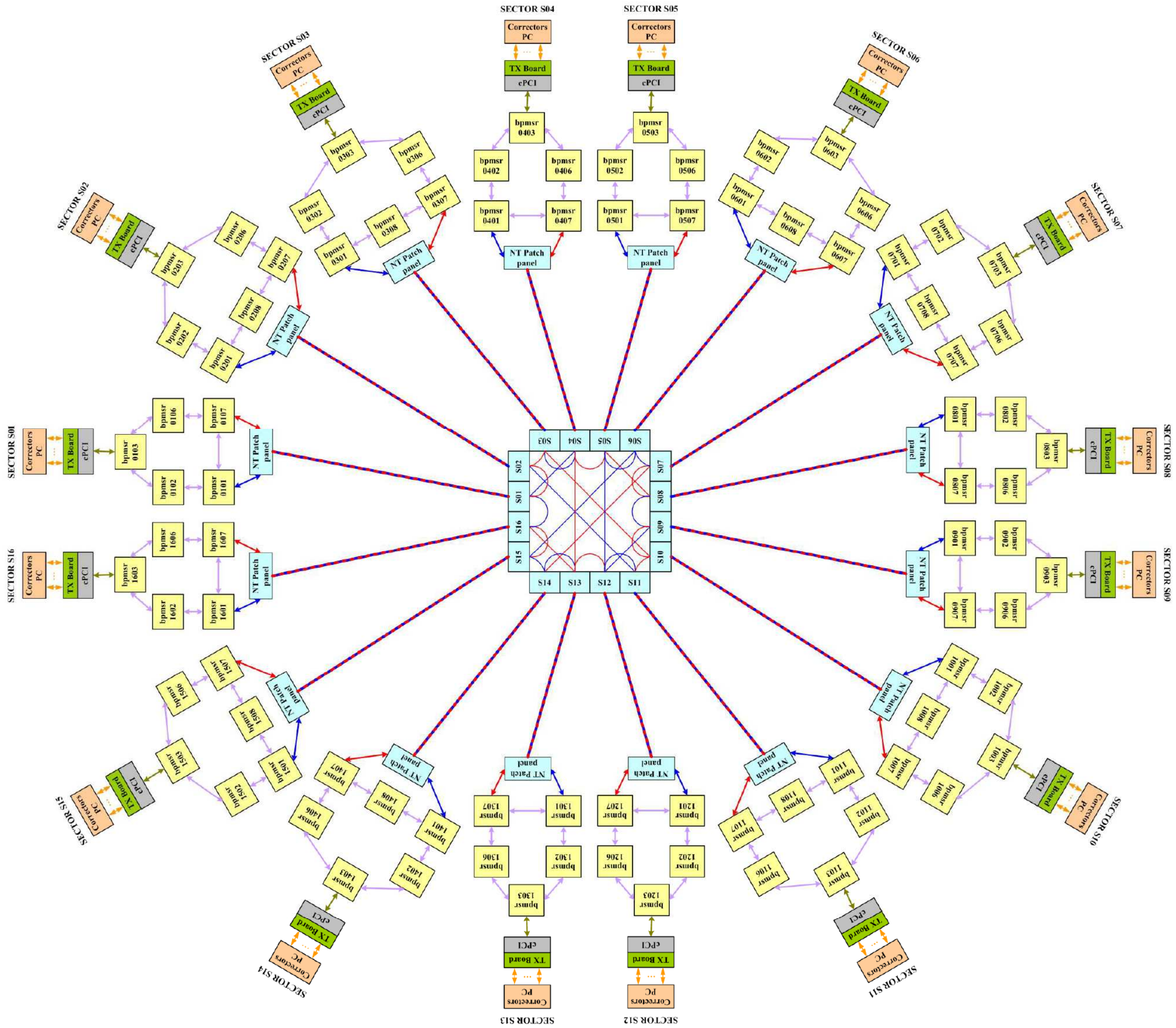

Figure 1: ALBA FOFB topology. Showed elements are: Libera Brilliance eBPM electronics (*bpmsrXXYY*, depending on SR sector and unit), FOFB processing node (*cPCI*), data transition board (*TX Board*), corrector magnets power converters (*Correctors PC*), optical patch panels on Network racks (*NT Patch panel*) and the main interconnection panel in the center.

controllers embedded into IP modules (Industry Pack) and cPCI carriers for the IP modules. Each Transition board handles 4 IP modules and 8 correctors PC.

Power Converters and Correctors Magnets

88 vertical and 88 horizontal corrector magnets are installed for orbit feedback purposes. The correctors coils are extra wirings in the sextupole magnets. To have a more effective penetration field, 1mm thickness reduction on the vacuum chamber where the magnets are has been done.

Power Converters have been provided by OCEM company. Communication protocol from IP modules down to the power converters is based on a PSI protocol and is part of the correctors PC contract with the company.

Data Distribution

As it is showed in Figure 1, position data transfer between sectors is accomplished by building an optical network through the central patch panel. Optical links from two eBPM electronics on each sector are laid to the central panel. In there, routing of each link can be done from-to any other sector. A ring-type topology is used for the time being.

The Communication Controller protocol (CC) is used to handle the position data transfer between units [3]. It has been developed by Diamond and adopted by other institutes like Soleil and ESRF. It is a broadcasting protocol that sends all position values from-to all eBPM electronics every 100us cycle. PMC FPGA boards do also retrieve position data from the eBPMs using the CC protocol. Integration of the CC in the Libera Brilliance units has been done by Instrumentation Technologies company while the integration in the PMC FPGA boards has been done by Diamond.

One dedicated FPGA board for data analysis purposes is also installed (*sniffer board*). It is a VMETRO card borrowed to ESRF that allows data acquisition of all eBPMs into a ~10 seconds buffer. Data can be easily retrieve from the board using a TANGO device server also developed at ESRF. It was already installed on the very early days of the FOFB project and it has been of great help to analyze the machine BPM data, to understand the synchronization process of the eBPM electronics and to determine FOFB noise correction limits.

FOFB CURRENT STATUS

Noise analysis

Using the 10 seconds data from the *sniffer board*, we managed to make first noise analysis of the machine. A comparison of integrated beam motion between different machines was done by G. Rehm [4] and is showed in Figure 2.

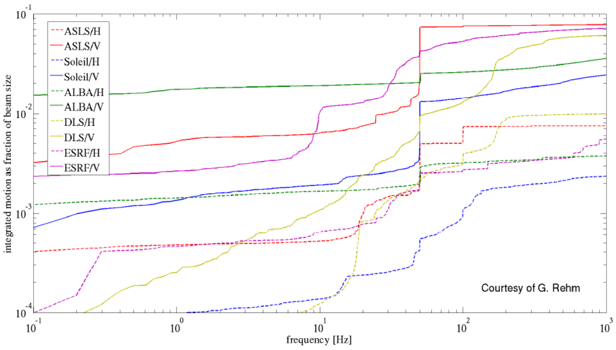

Figure 2: Comparison of integrated motion as fraction of beam size.

Data for ALBA and ASLS refer to machines without FOFB while the others refer to machines with FOFB on. So ALBA SR turns out to be a very “quiet” machine. The data does not take into account neither the noise induced by the Booster in future top-up operation nor the one due to opening and closing of IDs. According to experience of similar machines, motion of a few µm will be induced at the 5-20 Hz range when moving the IDs.

Correction simulation

First correction simulations have been done in Simulink. The model uses a measured response matrix as well as real 10kHz position data from the eBPMs. Position data was acquired while Booster was ramping (big 3Hz injection contribution). ID movements and RF trips have not been analyzed yet. The ID perturbations up to 20Hz should be easily removed by the FOFB. The RF trips usually induce perturbations at frequencies above 1kHz and hence are out of the FOFB scope.

A simple backward integrator with only gain parameter Kp has been used for the first simulations.

$$H(z^{-1}) = \frac{Kp}{1 - z^{-1}} \qquad (1)$$

Figures 3 and 4 show the RMS beam displacement at each BPM before and after correction using a Kp=0.085. The blue line corresponds to the input data while the green line corresponds to the corrected one.

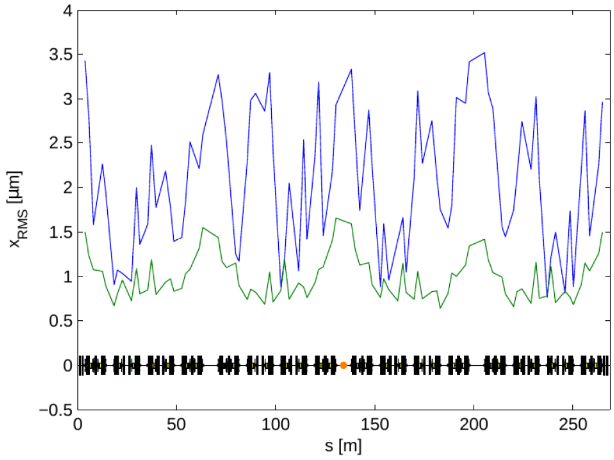

Figure 3: Horizontal RMS beam displacement.

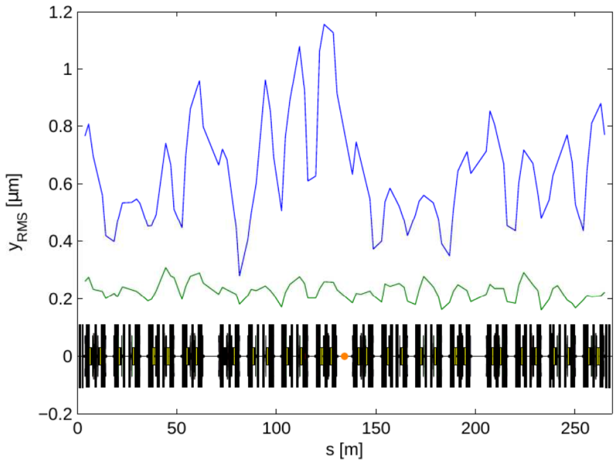

Figure 4: Vertical RMS beam displacement.

Typically, any FOFB has to ensure 10% beam size stability at source point. At ALBA this implies being below 10µm in horizontal and 0.5µm in vertical. As seen, in the figures, the specifications are fulfilled at the medium straight sections even without correction (and no ID movements).

NEXT STEPS AND FUTURE PLANS

Storage ring correction

The main FOFB limiting parameters at ALBA are the vacuum chamber cut-off frequency and the loop total latency. The first has been theoretically determined to be 230Hz for horizontal plane and 2.3kHz for vertical. The loop latency parameter depends on the whole elements of the loop, from the eBPM electronics to the correctors PC. Regarding this, possible bottlenecks have been identified on the data transmission between the PMC FPGA boards and the correction CPUs, as well as between the CPUs and the correctors PC.

In order to properly determine it, a correction test in only one sector of the machine will be performed by the end of September. After that, the plan is to test the correction of the whole machine until end of the year and to have an operational FOFB by the beginning of 2014.

Integration of xBPM

The integration of the photon monitor (xBPM) of MISTRAL beamline is already implemented in the SOFB. In order to have the possibility to also include it in the FOFB loop, we have purchased a Libera Photon electronics, although the real improvement of such integration is not yet proved. With that, we will be able to easily integrate the xBPM since it uses the same interfaces and communication protocols as the other 88 eBPMs.

New PMC FPGA Boards

As already mentioned, an identified possible bottleneck of the FOFB performance can be the PMC FPGA boards since the fulfilling of the correction timing constrains is still to be proved. Nevertheless we're confident about that because of the relatively low frequency correction needs. The already analyzed data of the ALBA machine shows low noise at high frequencies and the expected perturbations when moving IDs will remain in a relatively low frequency range.

An issue that can put into troubles the long term maintenance of the FOFB is the obsolescence of the PMC FPGA boards and the no-support at all from the correctors PC manufacturing company OCEM (went into bankrupt)

The future of the ALBA FOFB will include an upgrade of the PMC FPGA boards. Main reasons for that are:

- Change obsolete electronics by new ones, more powerful and with longer lifetime.
- Integrate in the new electronics the position data reading, the correction calculation and the interfacing with the correctors PC.
- Have the possibility to synchronize the correction.
- Improve the redundancy and reliability of the loop with more data links between FPGA board and the eBPM electronics.

What has been presented in this paper is a *part-I* beam orbit correction loop for ALBA, based on the use of already existing in-house electronics and assuming some performance limitations. The commissioning of it and the routine operation will teach us how to improve and upgrade it for the near future.

ACKNOWLEDGMENT

Guenther Rehm, Michael Abbott and Isa Uzun (Diamond) for the integration of the Communication Controller in our PMC FPGA boards and Jean-Marc Koch (ESRF) for lending us the *sniffer board* and for many fruitful discussions about feedback.

REFERENCES

[1] http://www.i-tech.si

[2] http://www.mrf.fi

[3] I.S. Uzun, R. Bartolini, G. Rehm, J.A. Dobbing, M.T. Heron, J. Rowland, "Initial Design of the Fast Orbit Feedback System for Diamond Light Source", 10th ICALEPCS 2005

[4] G. Rehm, "Achieving and Measuring Sub-Micrometer Beam Stability at 3rd Generation Light Sources", 11th International Conference on Synchrotron Radiation Instrumentation SRI 2012