Experience on the integration of Diamond MBF-2 @ ESRF

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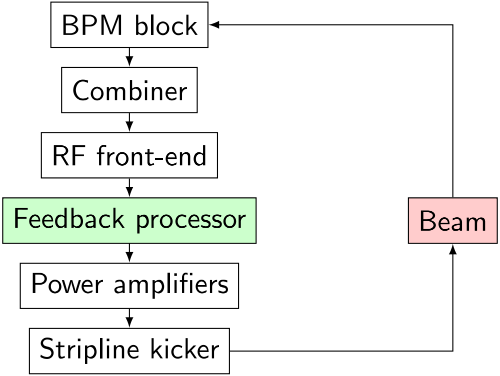
Next Generation Beam Position Acquisition and Feedback Systems
14 Nov 2018, ALBA

Introduction

Layout of a Multi-Bunch Feedback (MBF) system:



→ This presentation is mainly about the feedback processor.

Outline

Multi-bunch feedback at ESRF

- 2006: Longitudinal feedback developed to store up to 300 mA [1].
  → Success! but 300 mA never delivered in user-mode ...
- 2007: Transverse feedback developed to increase current per bunch (4 mA).
- 2014: Chromaticity increased to reach 8 mA in a single bunch.
  → Transverse feedback not (really) needed any-more.

Currently, we don't need a bunch-by-bunch feedback in user-mode.

[1] E. Plouviez *et al.*, "Broadband bunch by bunch feedback for the ESRF using a single high resolution and fast sampling FPGA DSP", in *Proc. EPAC'06*. Link

Previous Multi-bunch feedback (2006-2018)

- Based on a Libera platform[1].
- FPGA was programmed in-house using System Generator (graphical programming).
- Many drawbacks...

Figure : A bunch-by-bunch Libera feedback processor

→ Obsolete Virtex-2 FPGA chip.

→ Needs a precise timing adjustment after each power cycle.

→ No adjustable fine delay available.

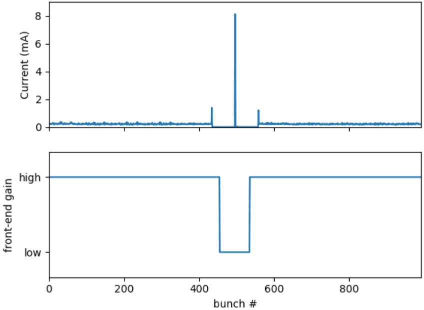
[1] https://www.i-tech.si

ESRF RF front-end

Home-made RF front-end with:

Gain gating:

- Up to a factor 40 between the charge of some bunches.
- RF front-end gain is reduced for the heavily charged bunch to avoid saturation.



And we have a PLL to always be in phase with bunches.

ESRF upgrade: EBS project

ESRF will soon start its upgrade project, the so-called ESRF-EBS (Extremely Brilliant Source).

→ Shutdown starting the 10^{th} of December, 2018.

→ One year for installation.

→ 6 months for commissioning (3 for machine + 3 for beamlines).

Figure : Girders assembled, ready to be installed

Multi-bunch feedback for ESRF-EBS

ESRF-EBS was designed to avoid the need for active beam stabilisation systems:

- HOM-damped RF cavities.
  $\rightarrow$ The longitudinal feedback will not be installed by default on EBS.
- Every vacuum component studied to avoid resonant RF cavities.
- High chromaticity foreseen to increase max current per bunch.
  $\rightarrow$ Not optimal for transverse feedbacks operation.

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So why refurbishing the Transverse MBF?

A bunch-by-bunch feedback for EBS commissioning

So why refurbishing the MBF?

Time schedule for EBS commissioning is very tight.

Ion instabilities will be a limiting factor during vacuum conditioning, it can be speeded up with a transverse MBF.

The new MBF should:

- be quickly available in the early stages of the commissioning,
- have more diagnostics tools in case of unexpected instabilities.

→ It was decided in 2017 to refurbish the MBF.

Candidates for a new MBF

In the little time available to procure this new system, two options were considered:

- Dimtel iGp12 feedback processor[1]

[1] https://www.dimtel.com/products/igp12

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We had 2 years to install it before EBS commissioning.

→ We went for DLS feedback processor.

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Outline

History of MBF at DLS

The first MBF at DLS also relied on the Libera Platform. They started with ESRF's FPGA firmware written using Xilinx System Generator, but it quickly evolved:

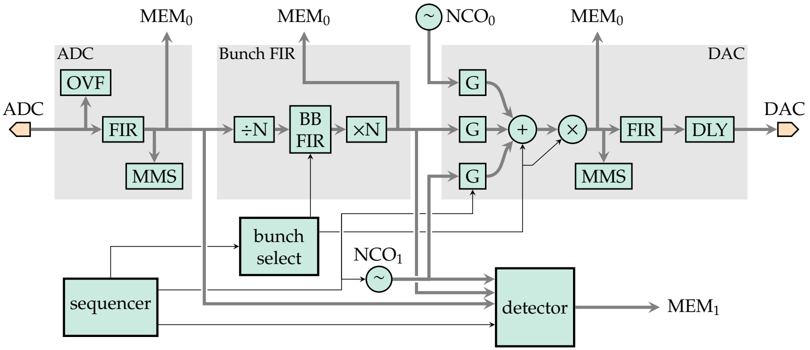
- Converted from System Generator to System Verilog, and tune sweep and individual bunch control added [1].
- Introduction of sequencer and bunch bank control [2].
- Converted to VHDL to avoid licensing problems, adopted by ALBA (2014).
- Rewritten and ported to μTCA hardware [3] (2016 to present).

[1] A.F.D. Morgan, G. Rehm, and I. Uzun, "Performance and features of the Diamond TMBF system", in *Proc. EPAC'08.* Link

[2] M.G. Abbott, G. Rehm, and I.S. Uzun, "Capability upgrade of the Diamond transverse multibunch feedback", in *Proc. IBIC'13.* Link

[3] M.G. Abbott, *et al.*, "A New Transverse and Longitudinal Bunch by Bunch Feedback Processor", in *Proc. ICALEPS'17.* Link

MBF signal processing chain

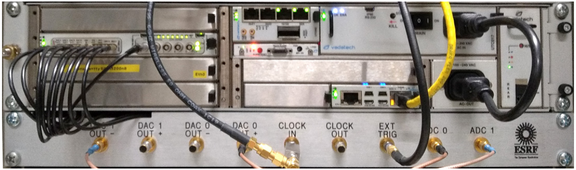


- BB FIR: feedback.
- NCO: bunch cleaning.
- Detector: tune measurement.
- Sequencer: drive-damp experiements.

Hardware

Modular feedback processor based on a μTCA crate (made of commercial components only), with:

- Xilinx Virtex-7 FPGA + 2 GB DDR3 RAM.
- Two ADC (500 MS/s, 14 bits) two DAC (1230 MS/s, 16 bits).
- CPU card with 4 core Xeon 2 GHz, 32 GB RAM
- Two power supplies for redundancy.



For more details, see:

[1] G. Rehm's talk at IBIC'16 ▸ Link

Ring parameters

ESRF and DLS requirements, beam parameters and environment are quite different.

Parameter	ESRF	DLS
Energy (GeV)	6.04	3
Nb of buckets*	992	936
Acc. cavity freq. (MHz)*	352	500
Chromaticity	high	low
Bunch cleaning*	yes	no
Feedback in user mode	no	yes
Control system	Tango	EPICS

* DLS-MBF was designed to take these differences into account.

Hardware assembly and installation

Assembly and installation of DLS MBF @ ESRF went quite smoothly.

- Installed a different OS than DLS (Debian v.s. Red Hat) on the crate.
- Compatible with our timing signals or RF front-end.
- Some little difficulties, now fully documented on the MBF documentation.

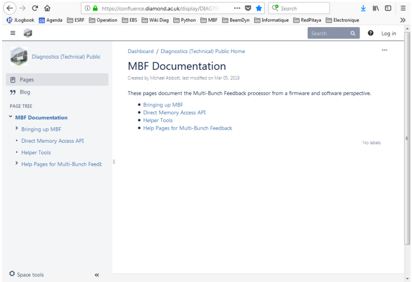


Figure : An unified documentation is provided by DLS

Tango vs EPICS

- We use a EPICS to Tango wrapper (Tango2EPICS Link) to be able to control the MBF with our Tango control system.
- We also made a Java application in order not to rely on EDM (the EPICS graphical user interface).

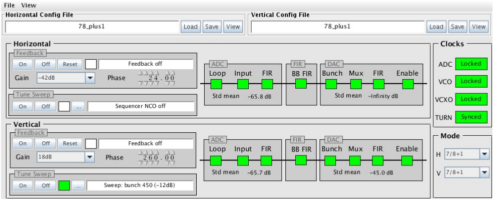


Figure : Tango interface developed at ESRF

→ It could be use with minimal adaptation by any other Tango-based institute.

Outline

Tune Sweep

Tune:

- Measured on an arbitrary group of bunches (from 1 to max.).
- Measure possible on 4 groups at the same time.
- Tune fit work well despite our large chromaticity.
- But, fast tune measurement (tracking) not yet available.

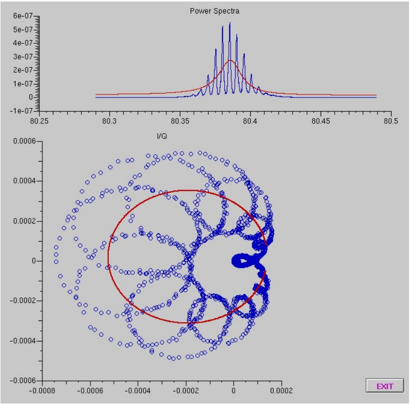


Figure : Tune sweep (blue) and fit (red) from DLS EDM application

Drive-damp experiments

For each mode *n*, we perform the following:

1. stop feedback,
2. excite mode *n* during a short time,
3. stop excitation and measure oscillation amplitude with time (*c.f.* next slide),
4. switch ON feedback to damp residual excitation.

Damping rates measured during phase 2 give information accelerator's impedance.
DLS-MBF can perform this measurement very quickly (a few seconds to scan all modes).

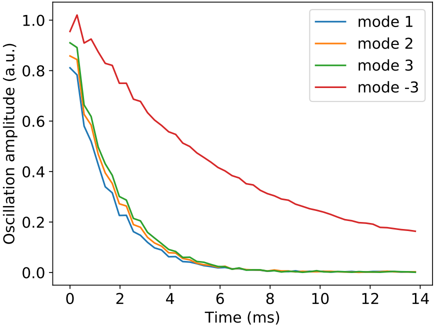
For more details about measurement and result interpretation, see:

[1] G. Rehm's, *et al.*, Proc. of IBIC'14 ▸ Link

[2] R. Bartolini's talk at TWIICE 2 (2016) ▸ Link

Drive-damp experiments

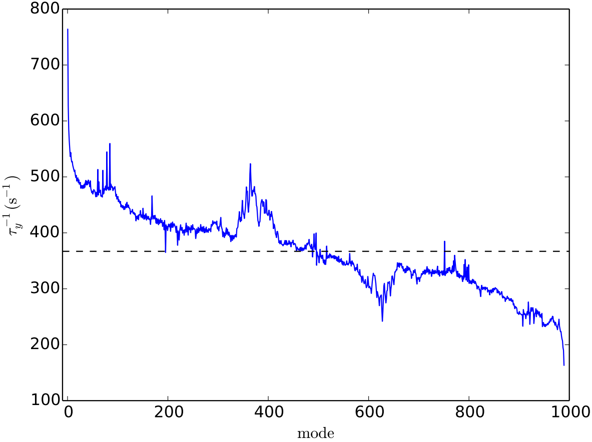
Some drive-damp experiments were performed at ESRF with a low chromaticity. Here is the result for 4 different modes:



Here, mode -3 is less stable than the others (expected from resistive wall impedance).

Drive-damp experiments

Extracting the damping rate for every mode, we get the fingerprint of the machine's impedance.



Drive-damp experiments

At high chromaticity drive-damp experiments are mode difficult to interpret due to fast decoherence.

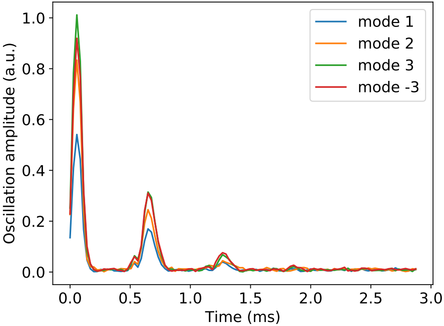
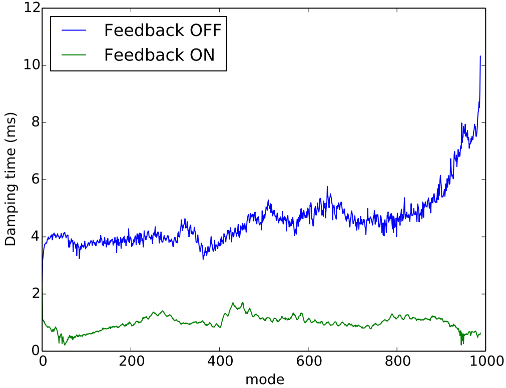


Figure : Drive-damp experiments at ESRF nominal chromaticity

Bunch-by-bunch feedback

Feedback operation is straight-forward and efficient.



Here we see that feedback reduces damping time for all modes substantially.

Conclusion

- Successful integration of DLS-MBF2 @ ESRF!
- Elettra and Bessy are also adopting this system.
- There will be soon a small community of user sharing this system.

Acknowledgements

A big thank to G. Rehm, M. Abbott and A. Morgan from Diamond Light Source for this collaboration!

And also to D. Teytelman from Dimtel for the demo and very interesting discussions.