Orbit Correction System for the Brazilian Synchrotron Light Laboratory (LNLS)

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Topics

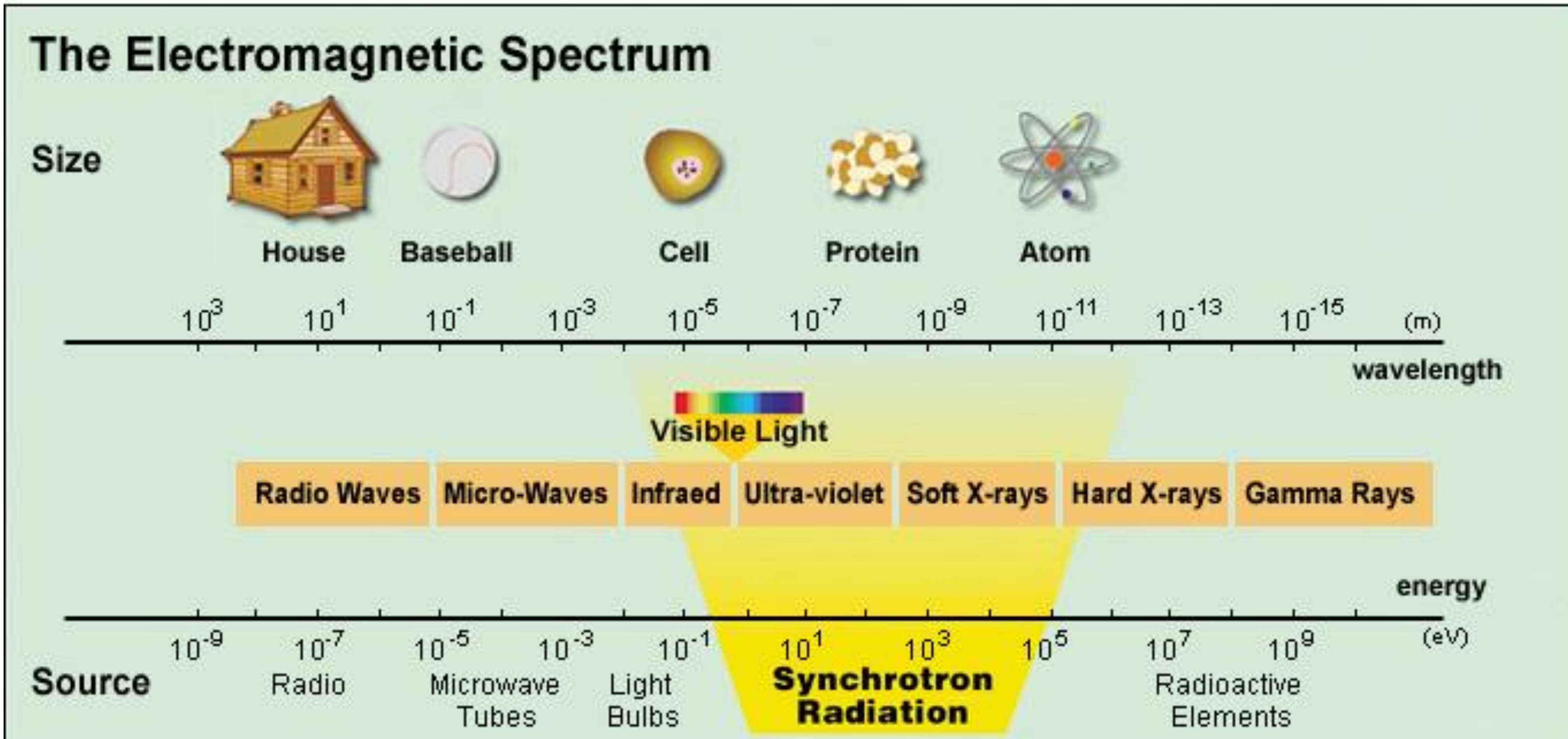
- *What is Synchrotron Radiation?*
- *LNLS storage ring and beamlines*
- *Beam stability requirements*

- *Orbit correction system previously in operation*
- *New system proposed by NI*
- *Software architecture*

- *System performance*
- *Future steps*

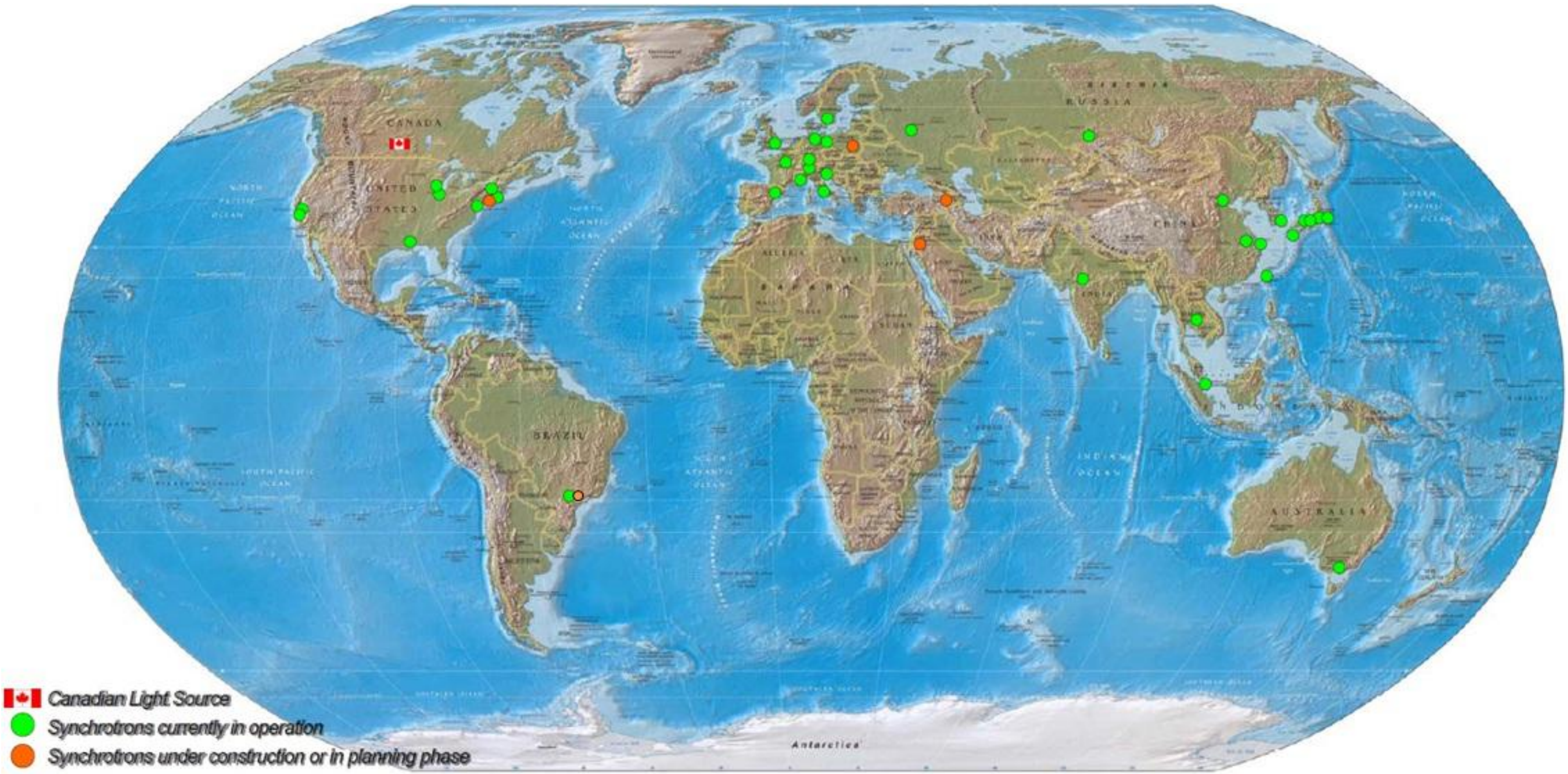
- *Final remarks*

What is Synchrotron Radiation ?



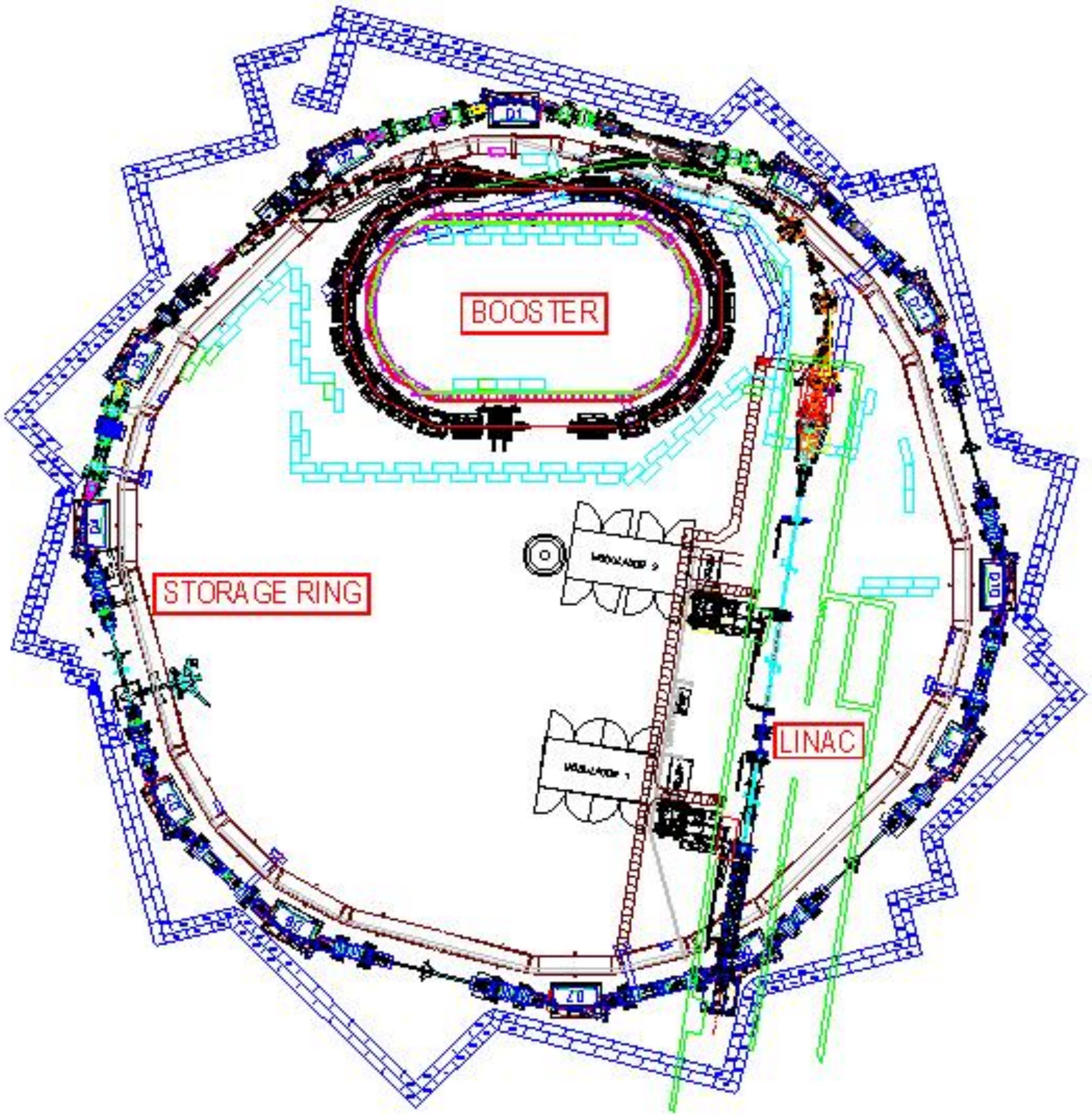
Pictures from Taiwan National Synchrotron Radiation Research Center (NSRRC) website

Synchrotrons around the world



Pictures from Canadian Light Source (CLS) website

The LNLS UVX storage ring



LNLS Storage Ring Main Parameters		
Operating energy	1.37	GeV
Current	250	mA
Injection energy	500	MeV
Circumference	93.2	m
Revolution frequency	3.22	MHz
Revolution period	311	ns
RF frequency	476	MHz

LNLS storage ring and beamlines

The LNLS UVX storage ring

UV/Soft X-Ray beamlines

- 4 operating
- 1 for diagnostic

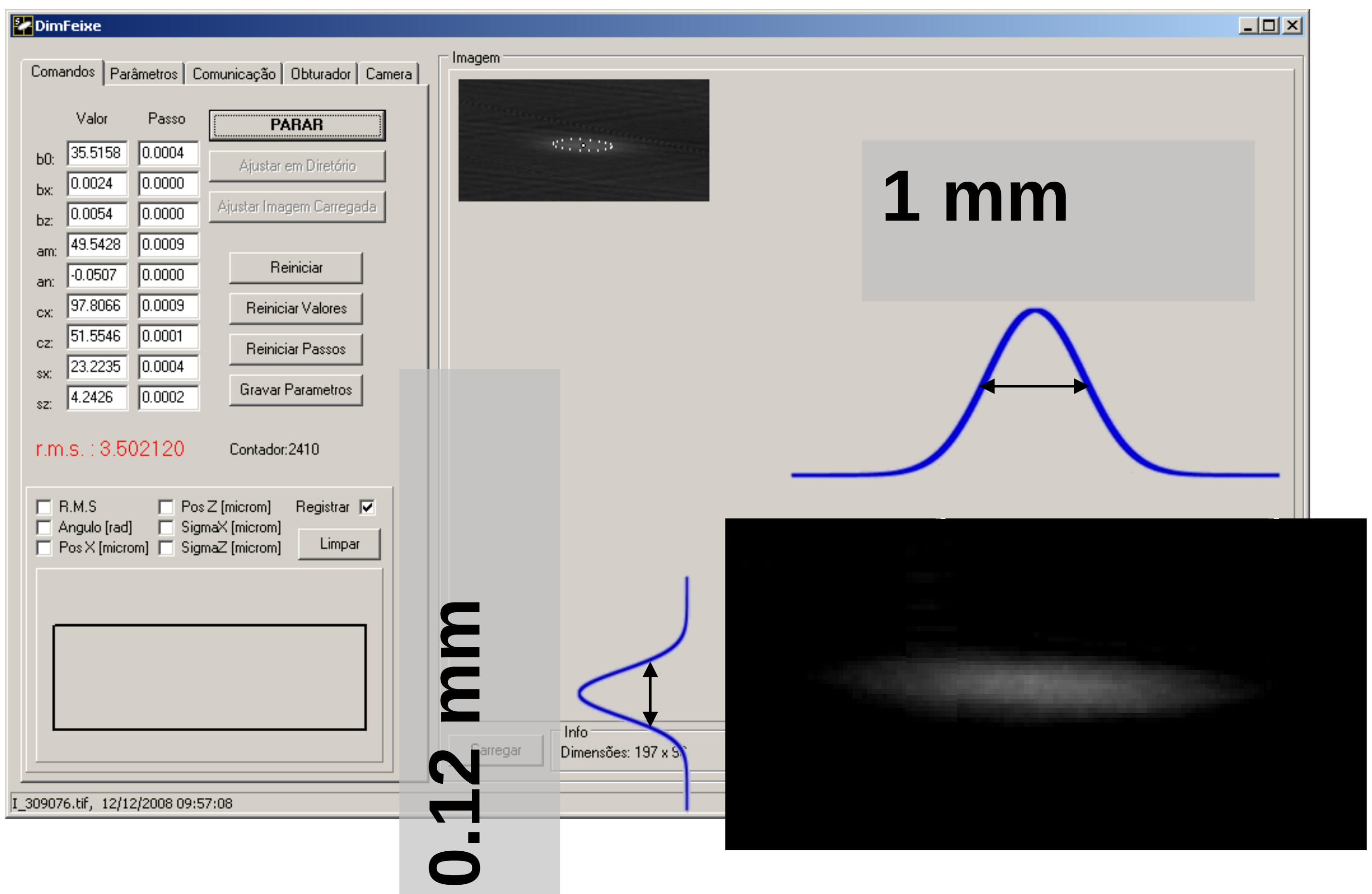
Hard X-Ray beamlines

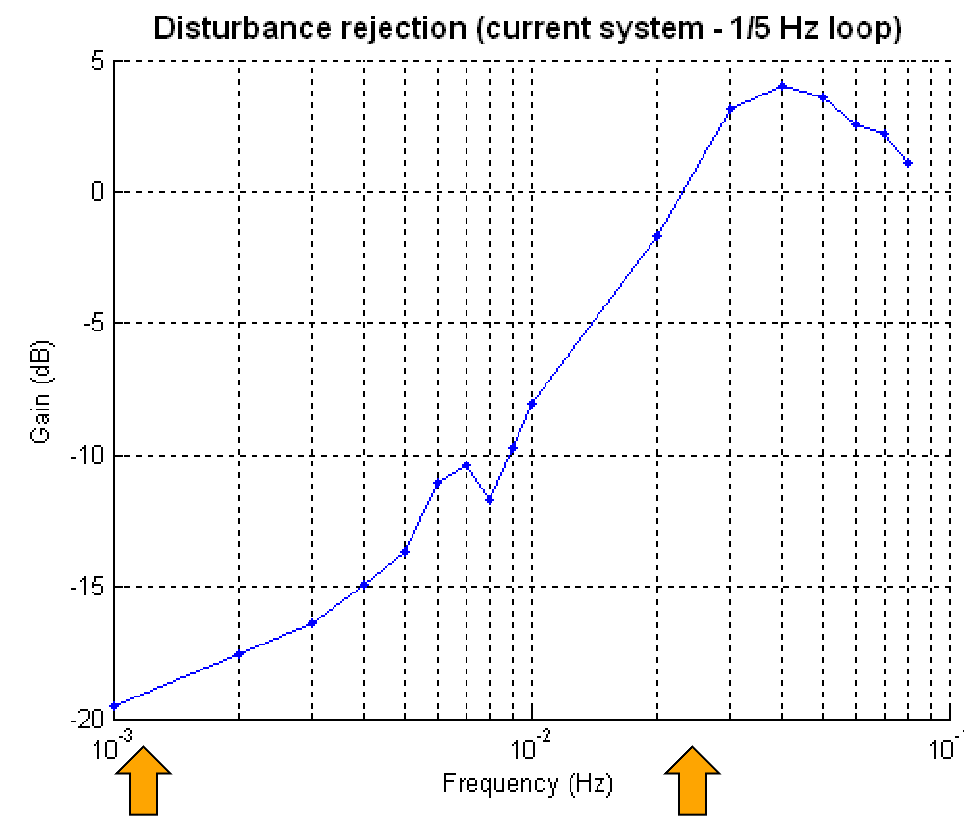
- 11 operating
- 1 under construction
- 1 for diagnostic

BEAM STABILITY

Beam stability requirements

The LNLS UVX storage ring beam size





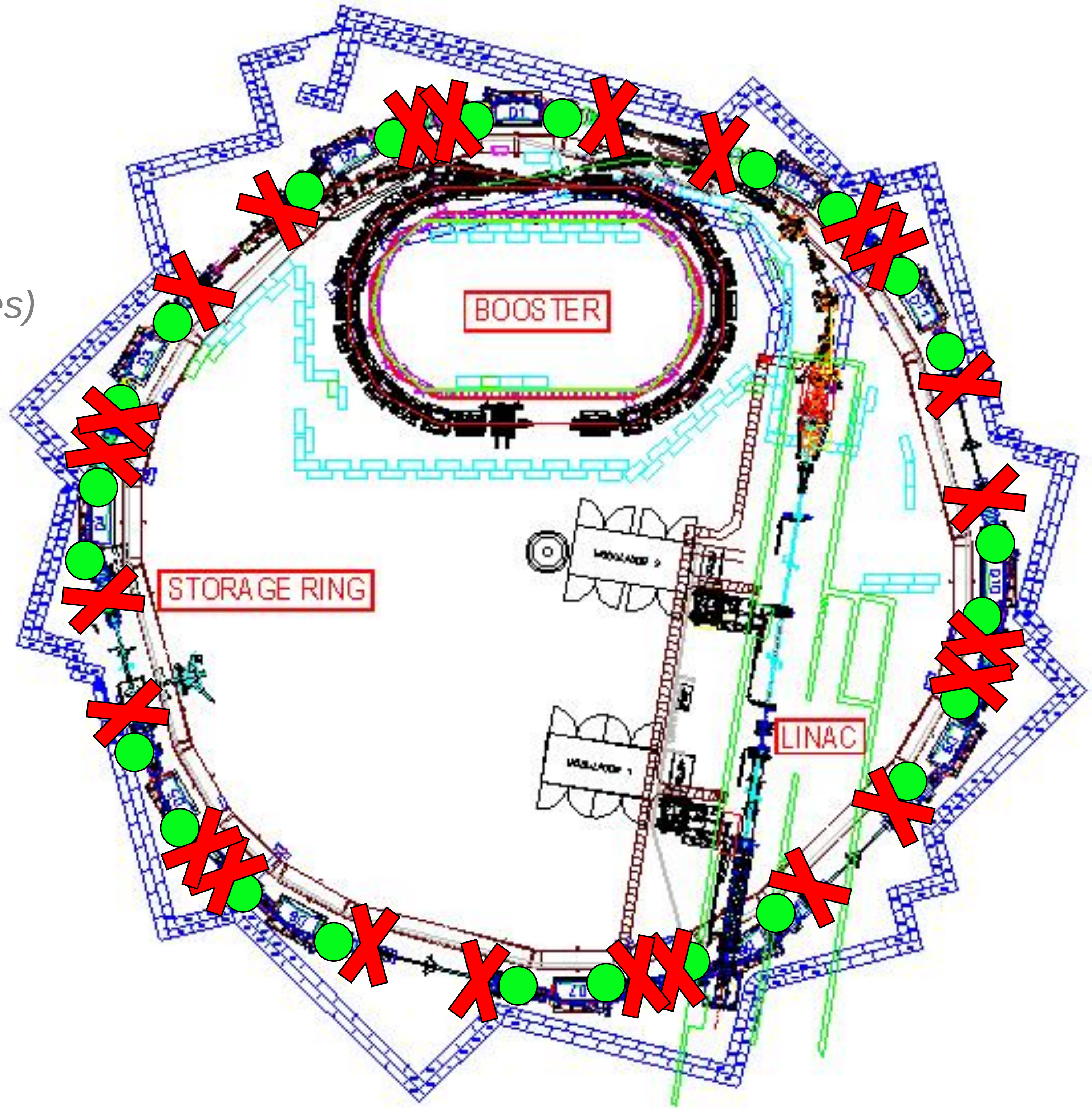
99% attenuation @ 1 mHz

No effect @ 20 mHz

Orbit correction system

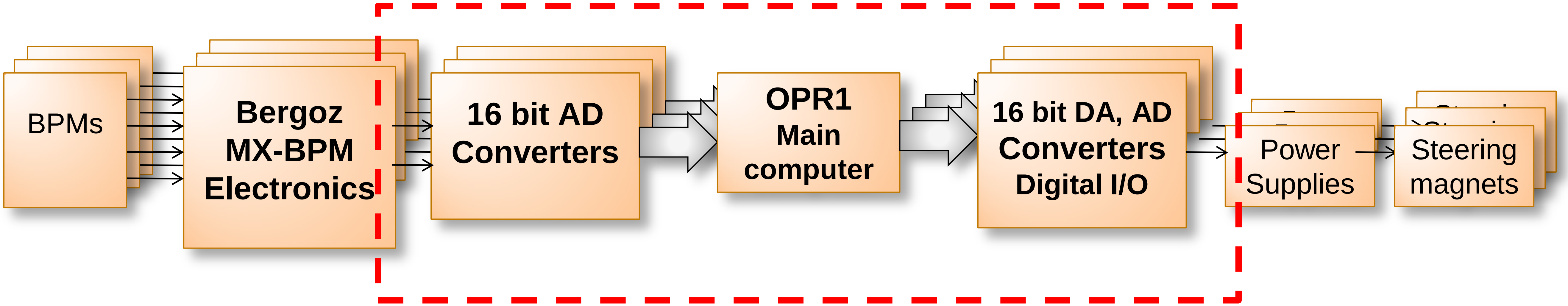
Beam Position Monitors
(horizontal and vertical planes)

steering magnets
(for horizontal and vertical planes)



Orbit correction system: current architecture

Replacing with National Instruments hardware/software



Main Requirements

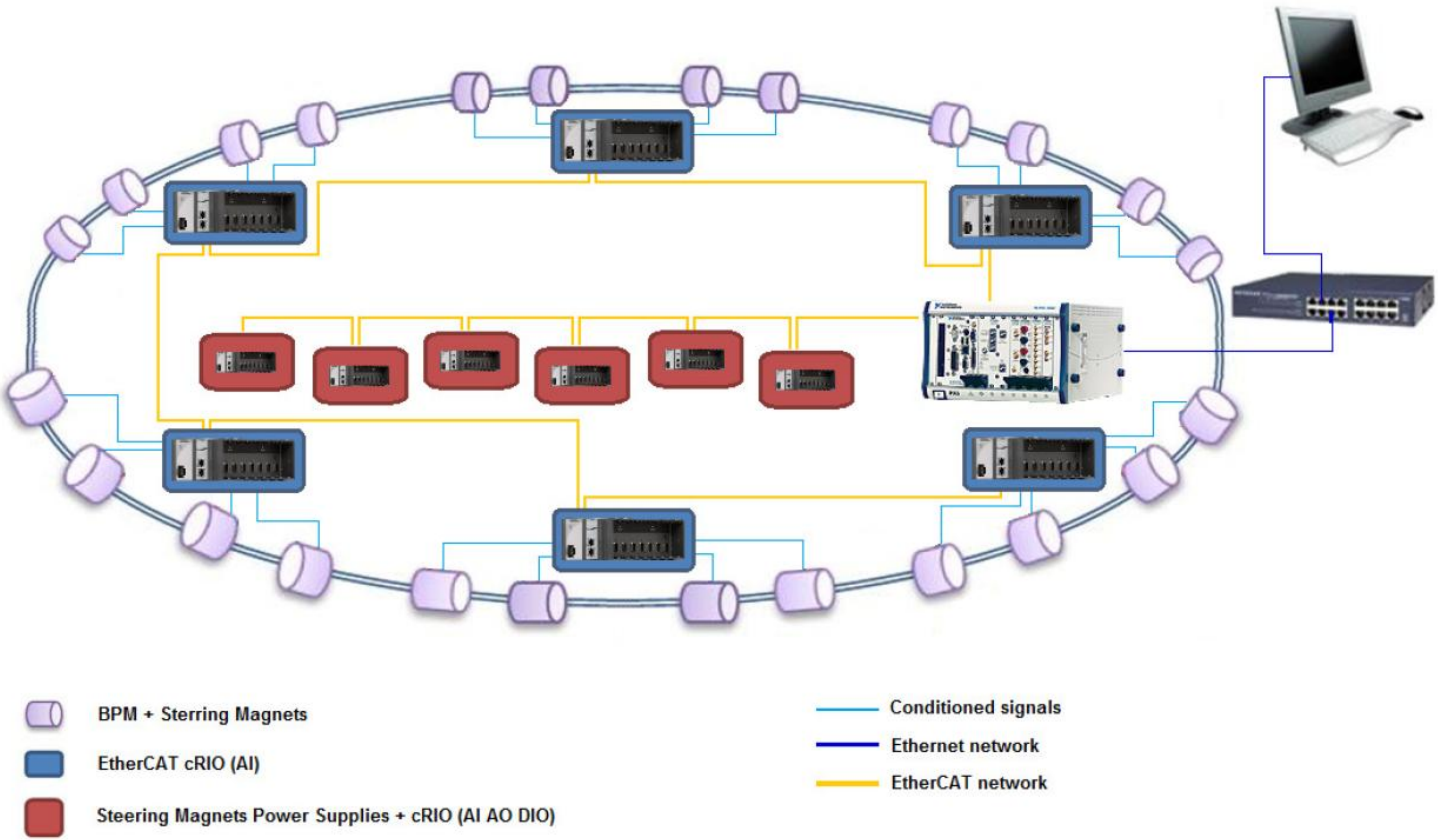
Analog Inputs	> 50
Analog Output	> 42
I/O Resolution	≥16 bits
Analog I/O Range	±10V
I/O Sampling Rate	>> 1 KS/s
Correction Speed	> 1 kHz
Control Algorithm Complexity Matrix Size (MIMO)	50 x 48 (maximum)*
Available Budget	R$ 50k

Table 1*- Main control system features.*

**The matrix dimension can change depending on how many sensors and actuators are being used in the orbit control. A typical dimension is 50 x 42.*

New system proposed by National Instruments

New orbit control system topology: 2 EtherCAT loops with 6 cRIO chassis each and 1 PXI Real-Time Controller



PERFORMANCE AND RESULTS

New orbit correction system requirements

3 characteristics are essential to FOFB systems:

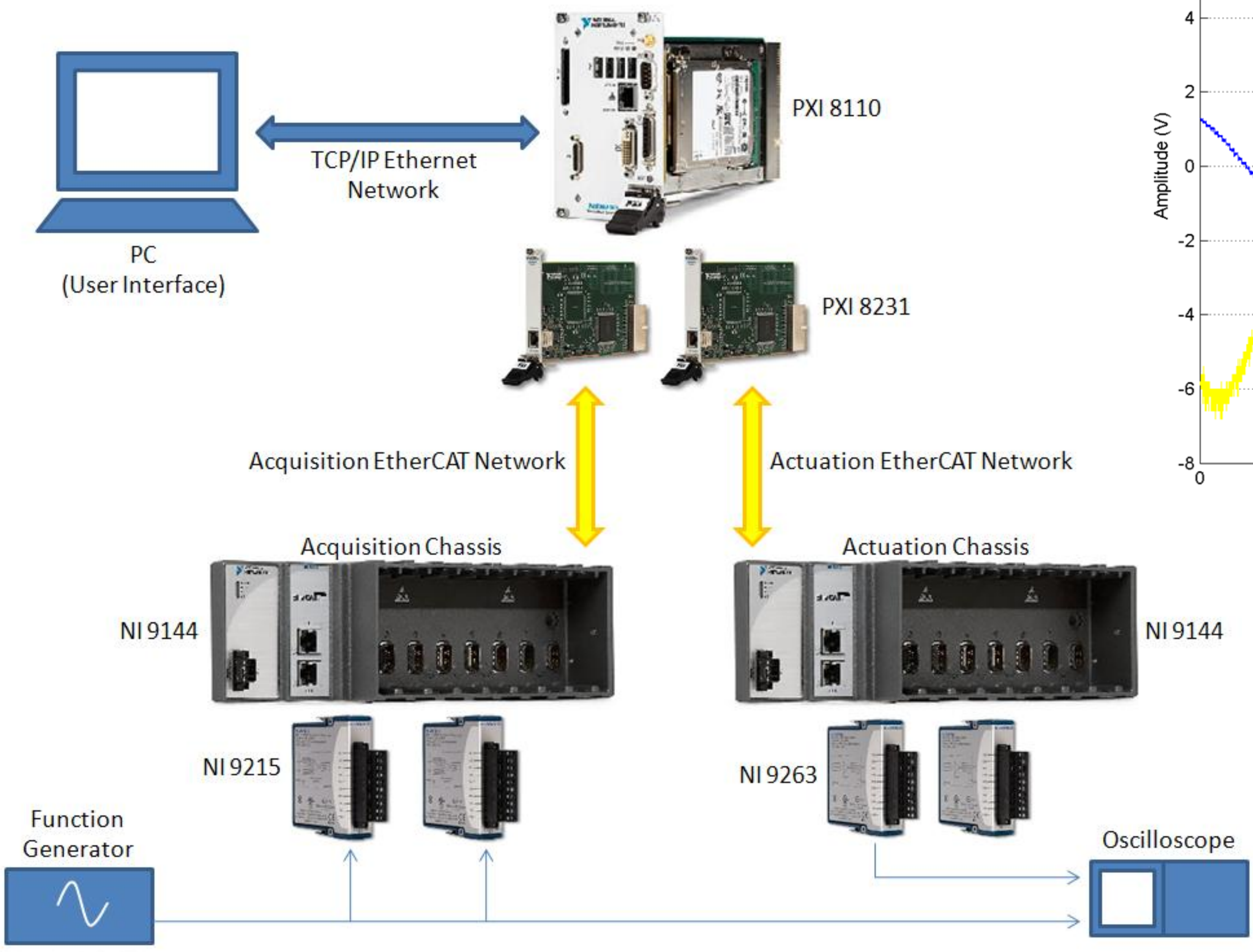
- **Overall speed:** the state-of-the-art fast orbit feedback systems operate @ 10 k readings/writings per second

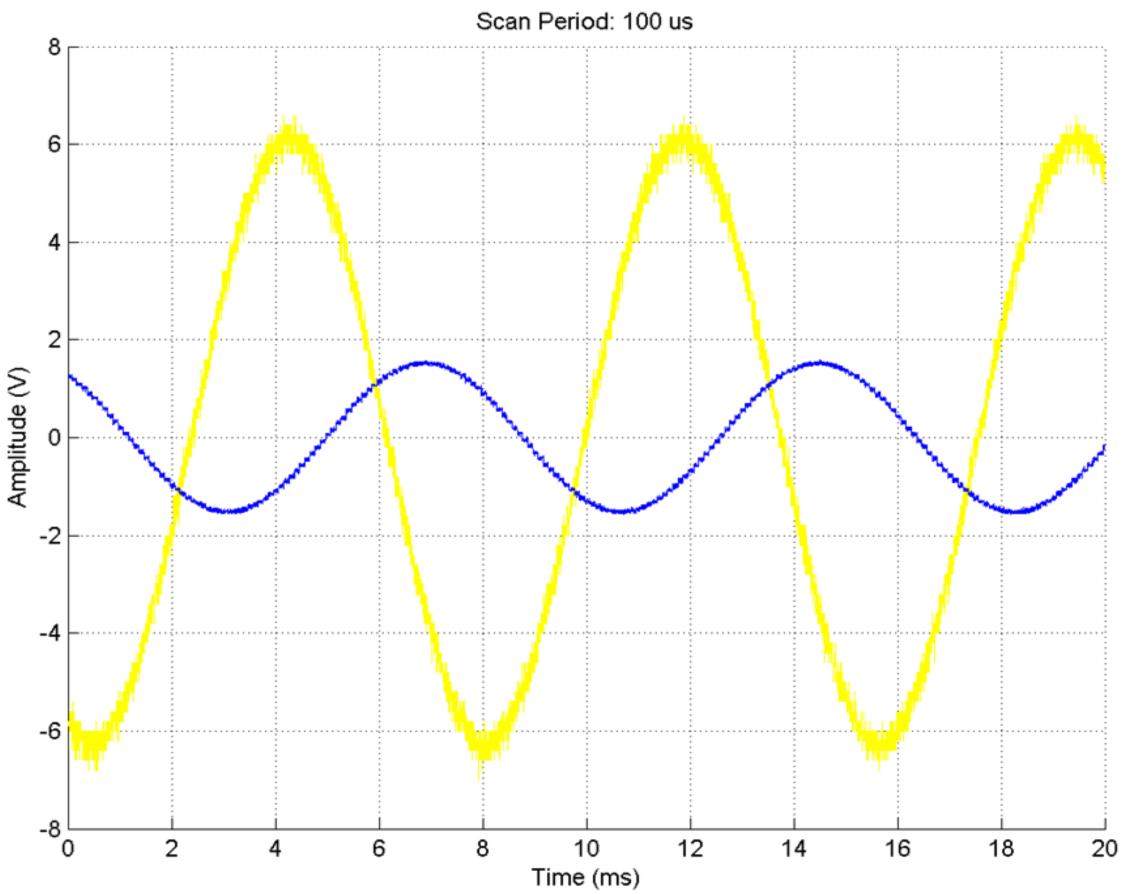
- **Time synchronization:** among input readings and output writing operations

- **Reliability**

Overall speed

Experimental setup for the feedback loop rate and real-time execution.



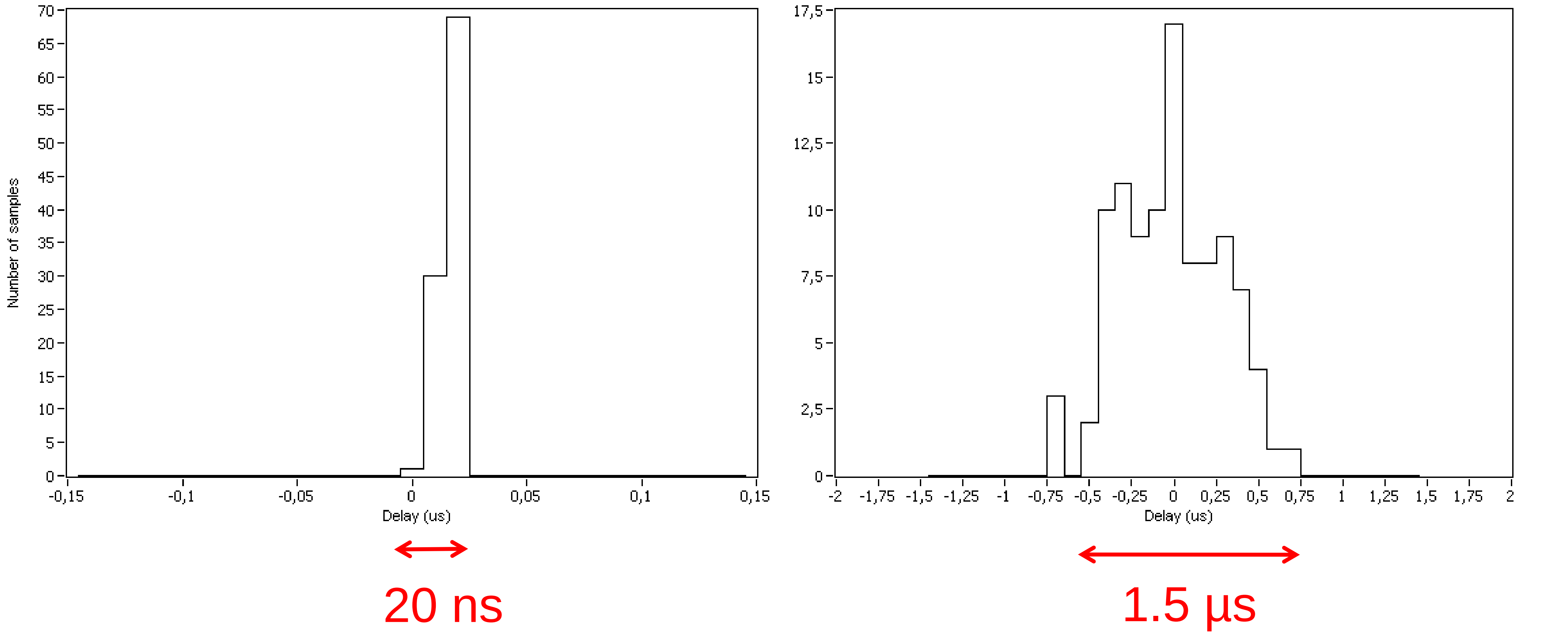


MIMO system @ 5KHz

15x improvement !

FOFB Time synchronization

Sample jitter histograms



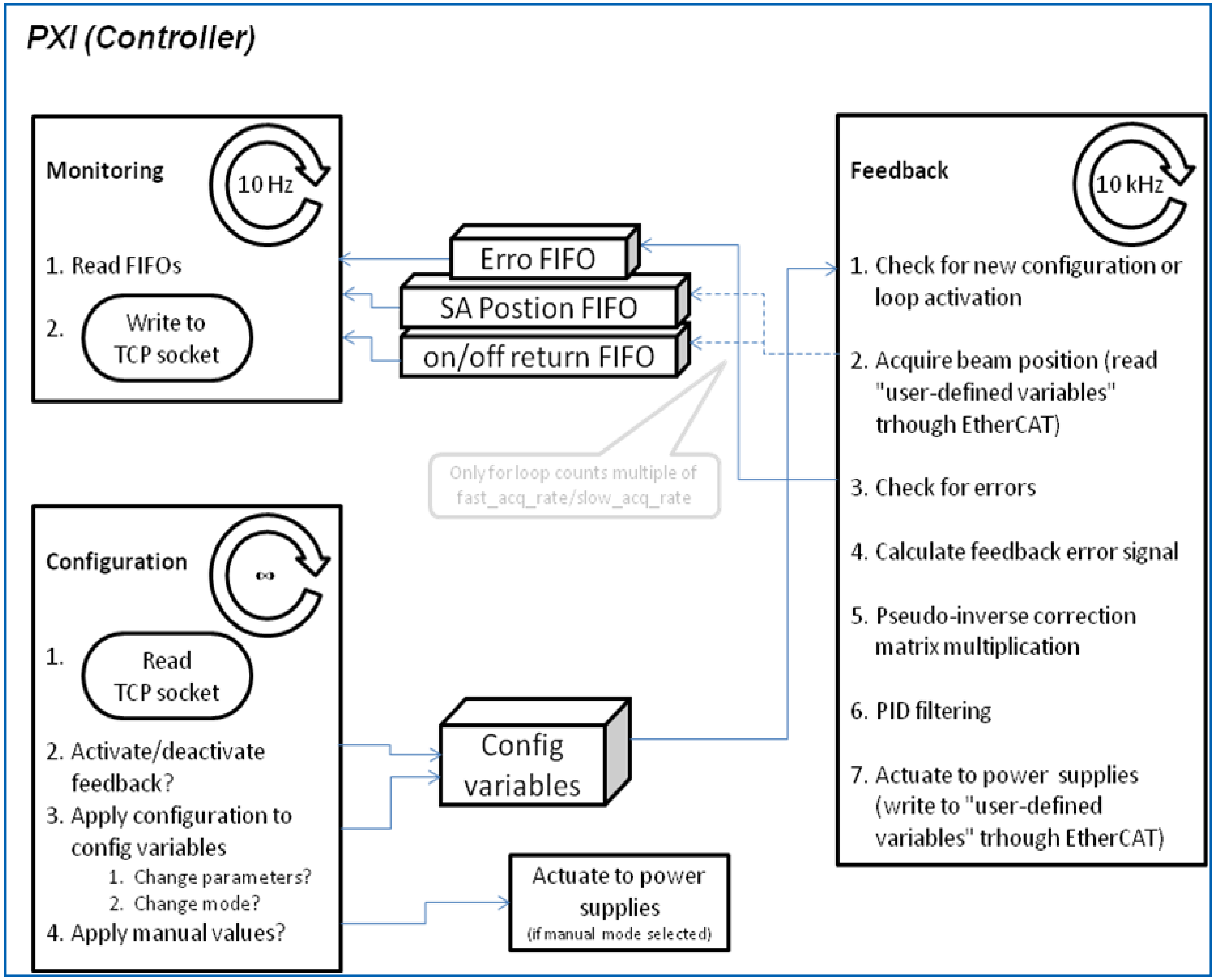
Delay histograms for channels acquired from same chassis (left) and for channels acquired from different chassis over EtherCAT (right)

10,000x improvement !

SOFTWARE

Example of software architecture *(Controller)*

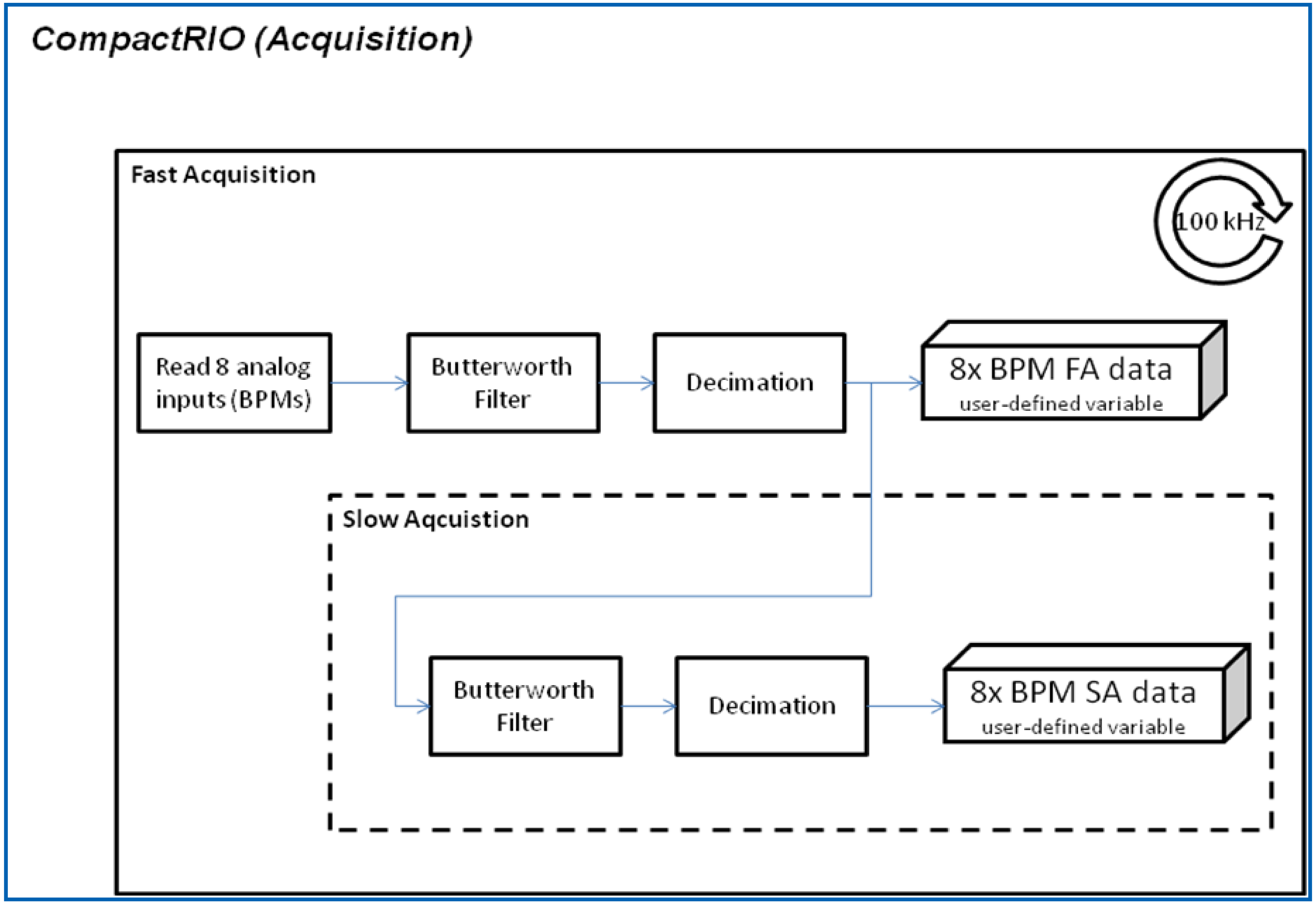
Several loops with different priorities run simultaneously in the controller. The 3 main loops are described below.



Example of software architecture
(Fast acquisition of position data)

LNLS

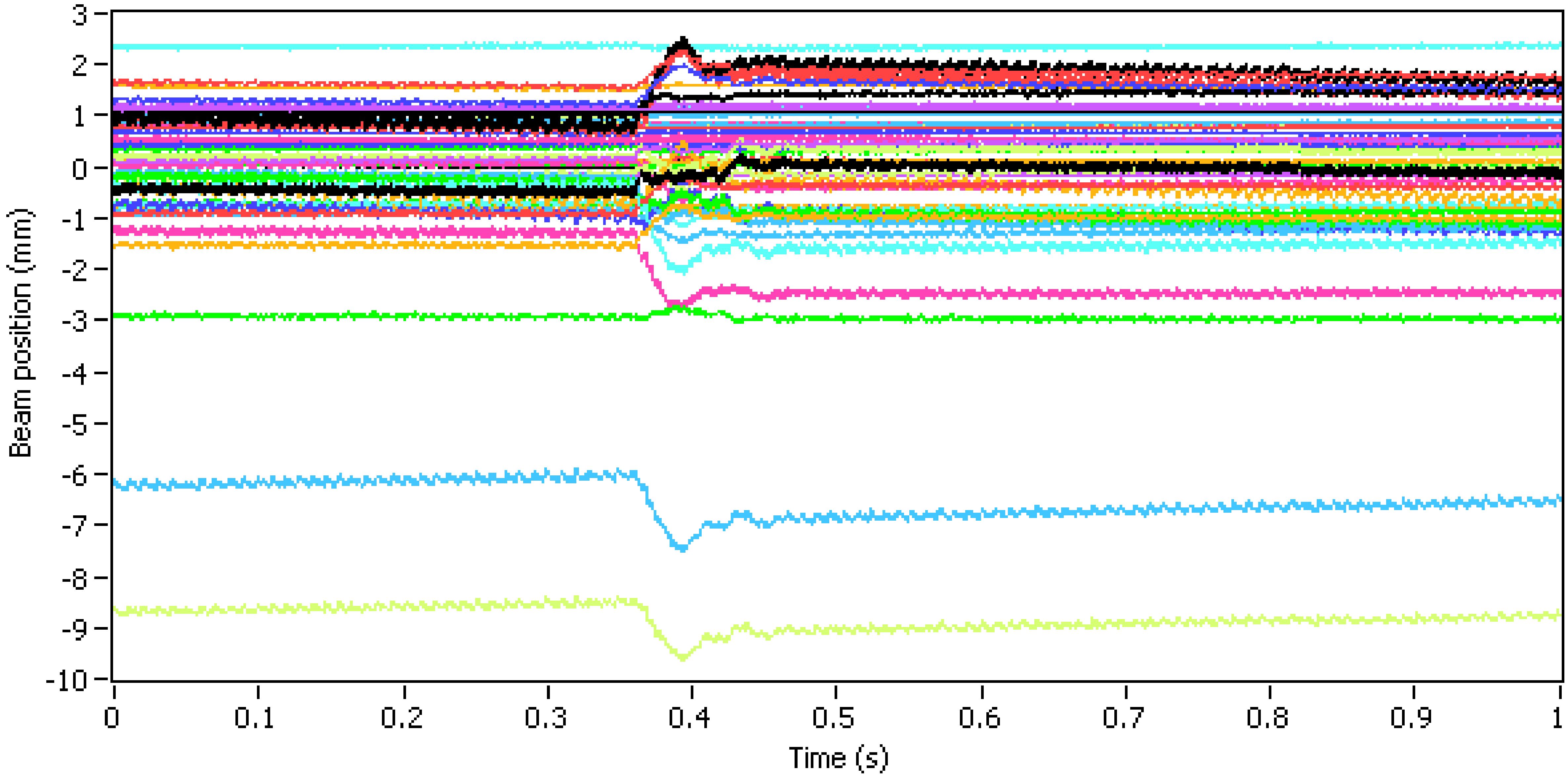
The 100 kS/s data are filtered and decimated before sending to the controller trough the EtherCAT network



New orbit correction system performance

Example of fast acquisition (3KS/s) during energy ramp.

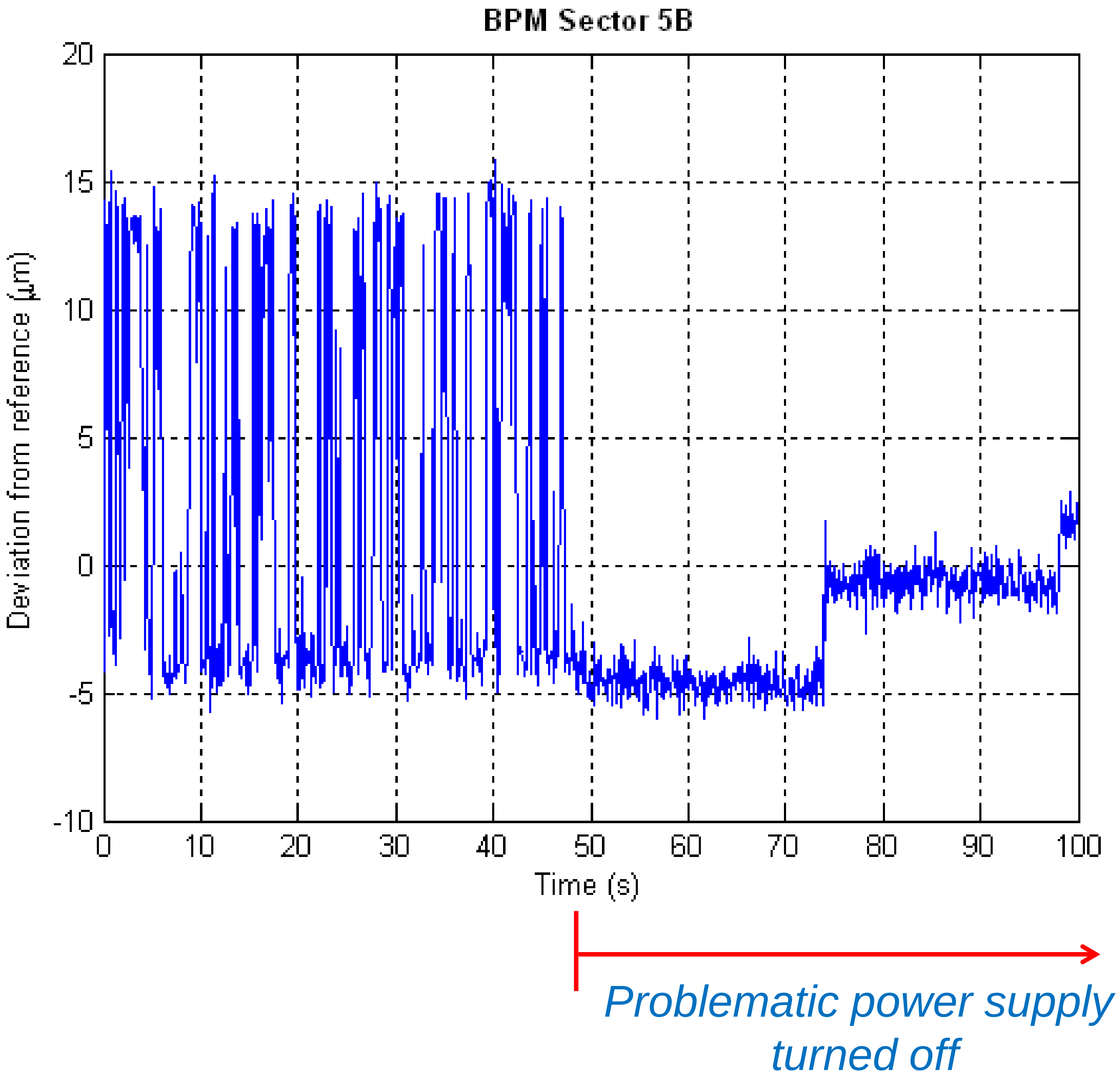
(The previous current system would provide only 3 values for this time frame.)



New orbit correction system performance

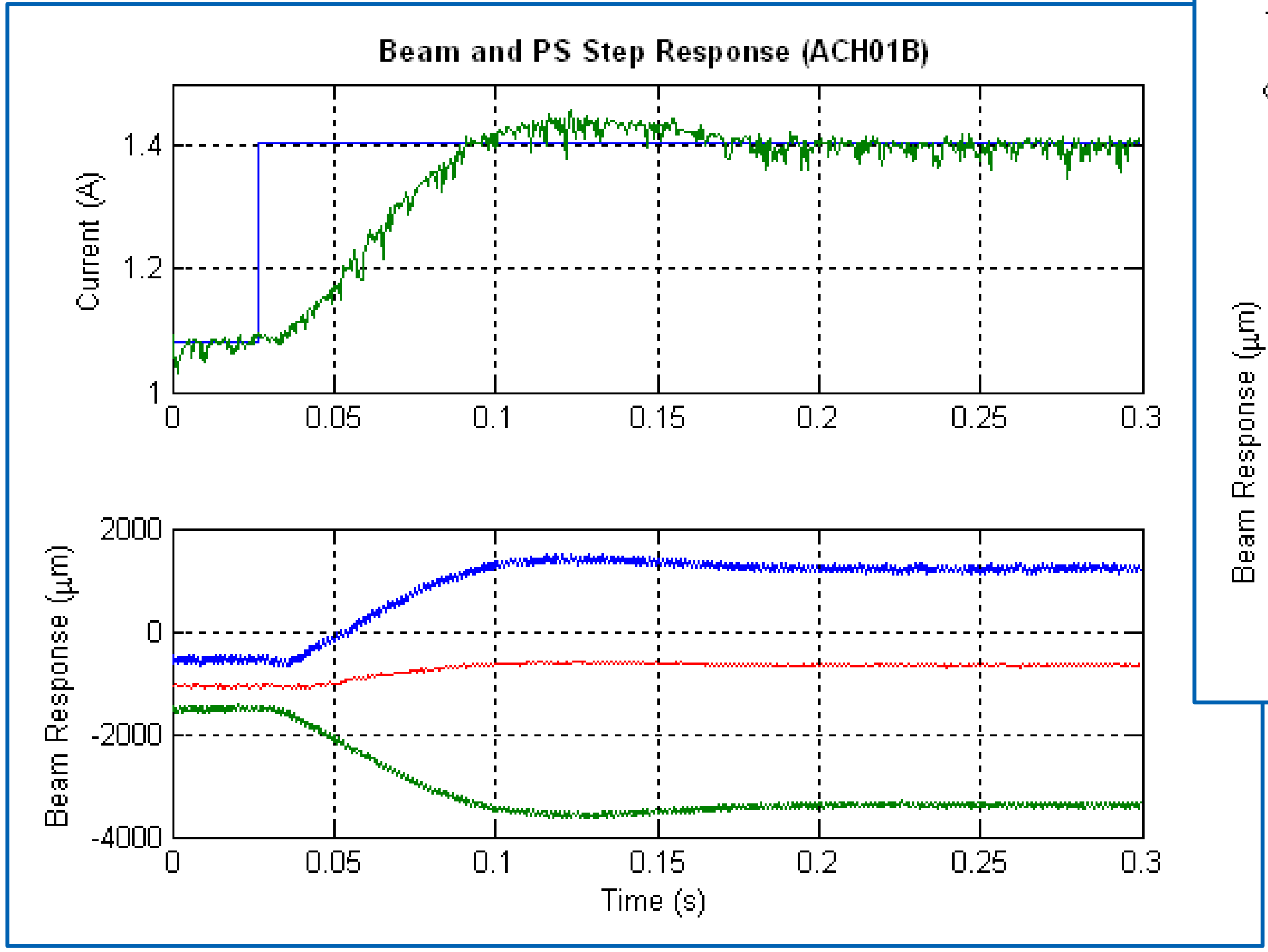
Example of problem detected by the fast continuous acquisition

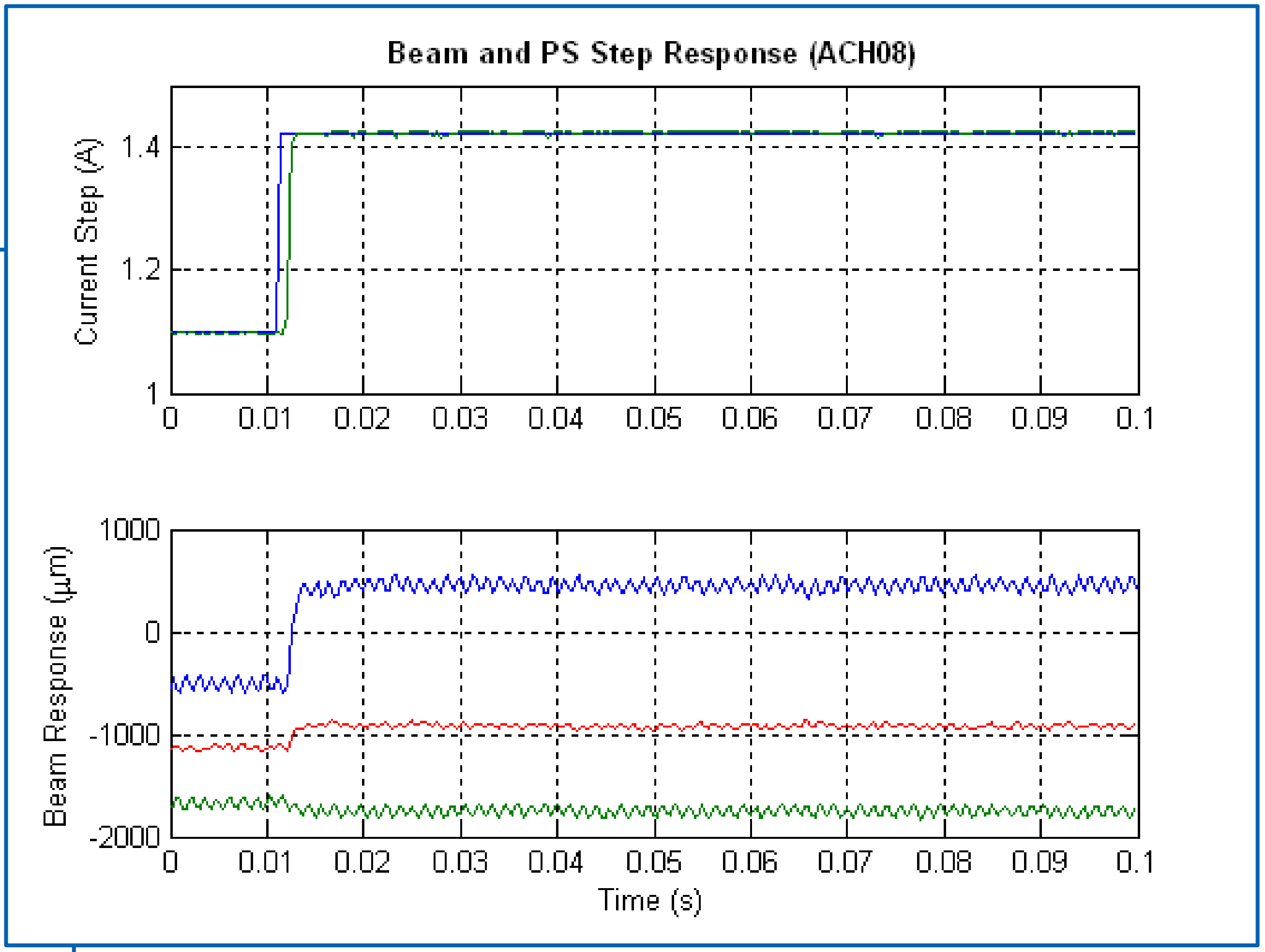
(the system in operation filters out the fast phenomena and did not see the problem)



New orbit correction system performance

Fast acquisition showing the difference between a slow and fast power supply





New orbit correction system: future steps

Besides response matrix and fast acquisition experiments, we closed the feedback loop and tested the orbit correction algorithm. Currently we are limited to ~ 10 corrections per second due to the power supplies “asymmetries”. In the near future we intend to:

- Optimize the pre-filtering parameters (FPGA acquisition at NI 9215)
- Verify the performance of the system running at full speed (5 kHz?)
- Improve the graphical interface of the system and implement tools for beam diagnostics (this will allow the definitive replacement of the old system by the new one!)
- Push the limits of the feedback controller testing more shophisticated algorithms for orbit correction taking in account the dynamics and limitations of the power supplies

FINAL REMARKS

•Software developments in LabVIEW proved to be simple and relatively not time-consuming. 1,5 engineer worked during 7 months on the project. In this period they took LabVIEW courses, designed the system, performed a proof of concept, finished the physical installation and started the commissioning;

•The major software tasks (fast orbit feedback loop, feedback configuration and process variables monitoring) as well as FPGA pre- and post-processing (oversampling and filtered acquisition for inputs and PID control for outputs) were quickly implemented with a robust architecture;

•The simultaneity of acquisitions, within ~ 1 μs between adjacent EtherCAT slaves, is perfectly acceptable for the fast orbit feedback application;

•The system represents an important achievement in beam control and monitoring for the LNLS instrumentation team.

Thank you

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