

INSTRUMENTATION
TECHNOLOGIES



LIBERA



Beam position monitoring challenges and techniques for recent and future lightsources

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Agenda

- 🔍 New synchrotron machines
- 🔍 Requirements
- 🔍 Stabilization techniques
- 🔍 Hardware and software upgrades



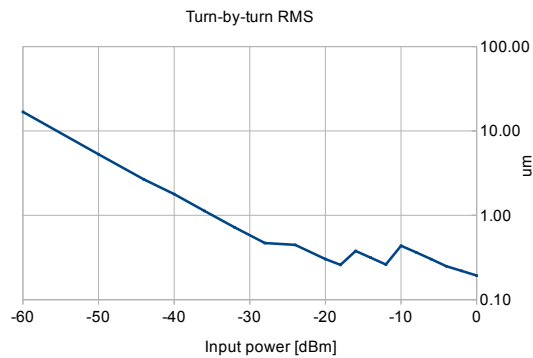
New synchrotron machines



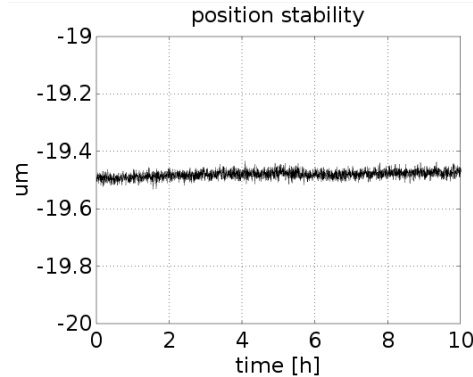
Requirements for BPM

- Turn-by-turn measurement performance
- Longterm stability
- (Much) faster orbit feedback (>10 kHz, >100 kHz)
- High quality production (“all instruments as one”)
- Support service

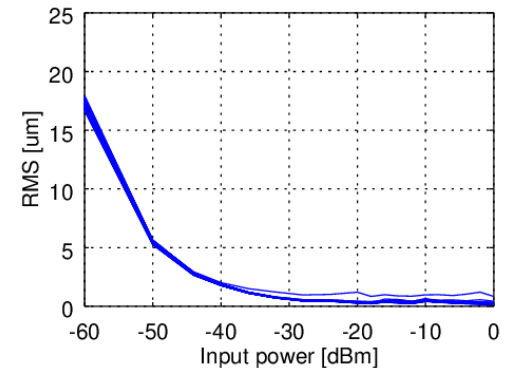
$< 1 \mu\text{m}$ RMS over large dynamic range



$< 1 \mu\text{m}$ longterm drift



Production statistics over 600 BPMs



BPMs (r)evolution

X,Y position information

Data rate

10000000 S/s

1000000 S/s

100000 S/s

10000 S/s

1000 S/s

100 S/s

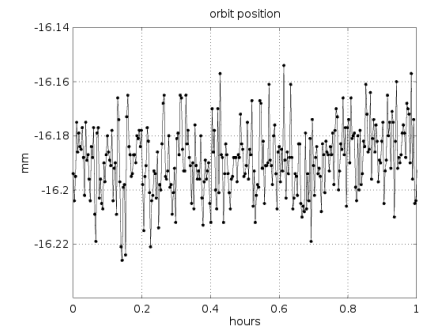
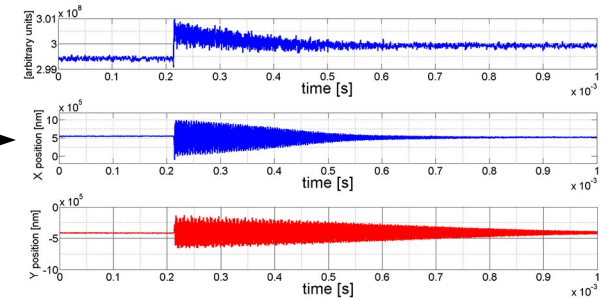
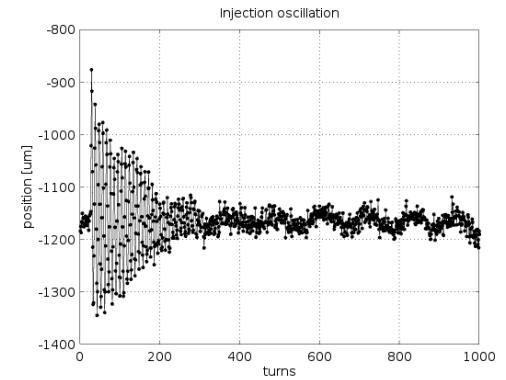
10 S/s

1 S/s

Digital systems, Libera

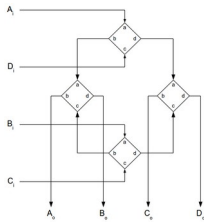
Analog + digital systems

Analog systems



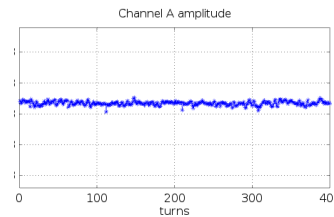
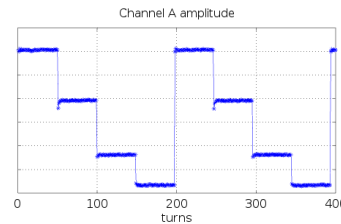
Stabilization techniques

Cross-bar switch



Switching the channels every $\sim 77 \mu\text{s}$ (13 kHz)

Signal reconstruction in **time domain**

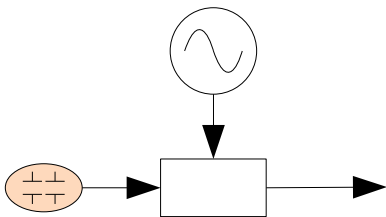


Digital Signal Conditioning adjusts the compensation coefficients

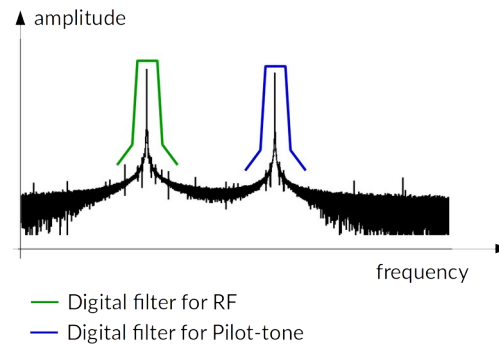
Typical results

- 50 – 100 nm position stability over several days
- $\sim 100 \text{ nm}/^\circ\text{C}$ drift

Pilot signal

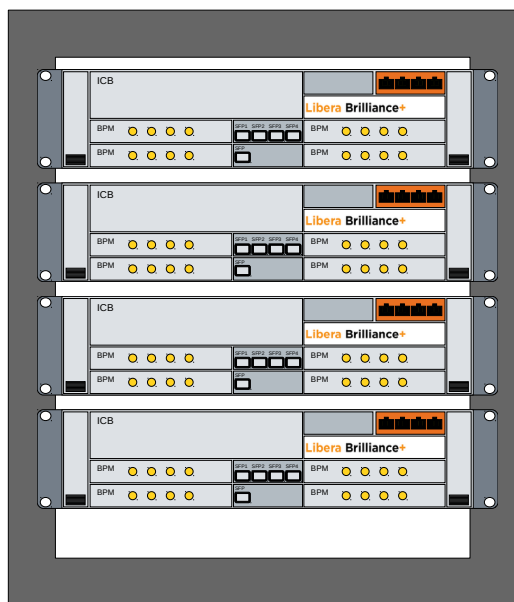


Signal reconstruction in **frequency domain**



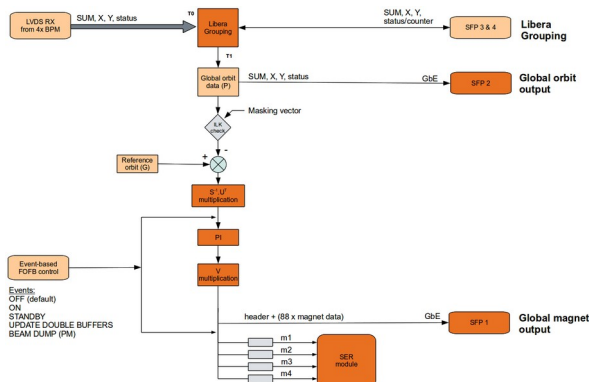
New project in Russia: (BINP)

BPM electronics



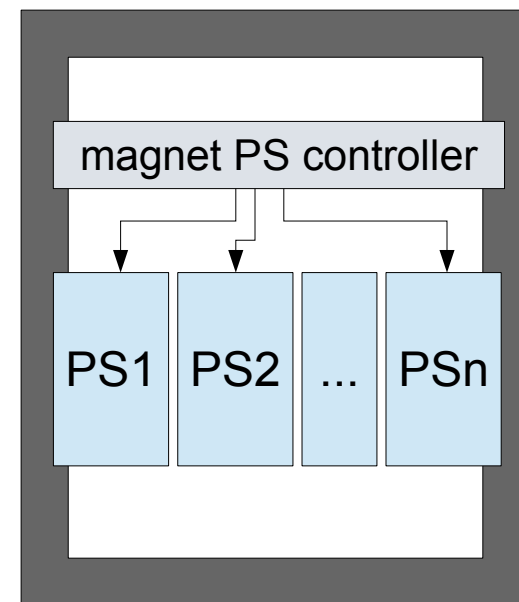
224 BPMs in 16 sectors

Fast Orbit Feedback Application



25 μ s for data concentration
1.5 μ s calculation time

Fast power supplies



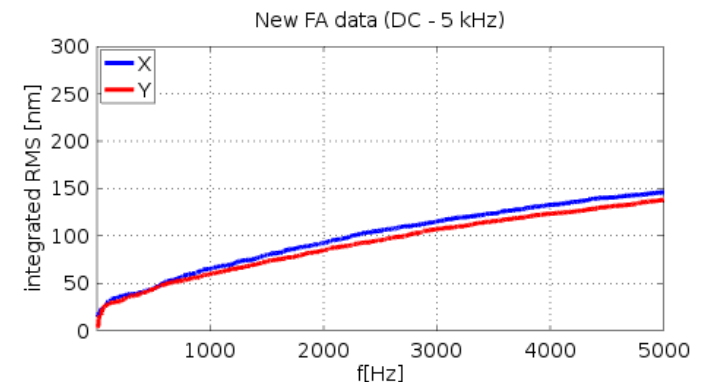
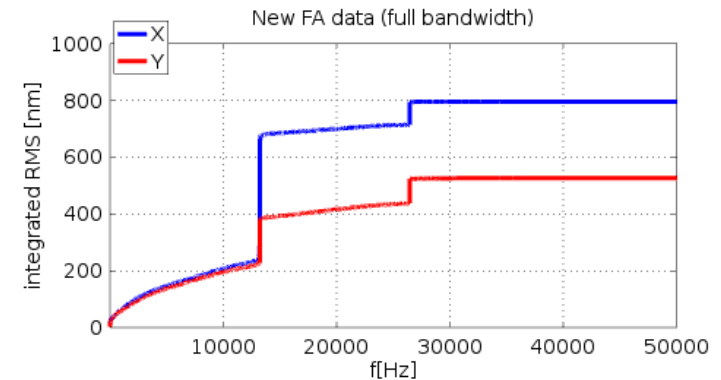
128 fast corrector power supplies

Ongoing software upgrades

- Variable cross-bar switching frequency
- FOFB running with 100 kS/s data rate
- Adjustable turn-by-turn digital filtering

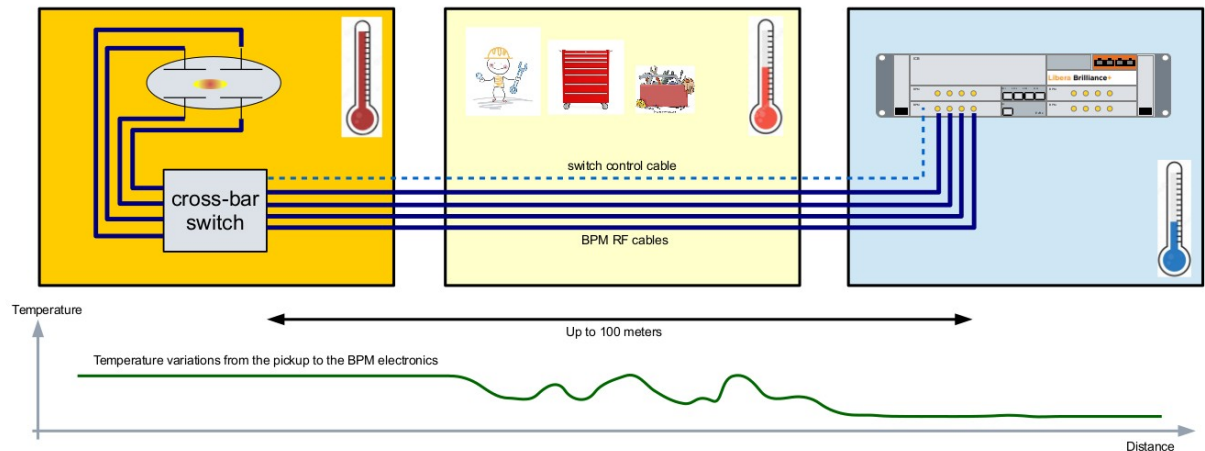
Benefits:

- Low latency FOFB response ($<20 \mu\text{s}$)
- Clean bandwidth from DC to 5 kHz



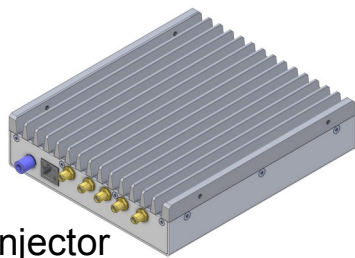
Ongoing hardware upgrades

- Idea: compensate the cable path
- Move the switching from the BPM module to **external switching matrix**
- Backward compatible Digital Signal Conditioning
- Tested at DESY Petra-3; ~30 nm longterm drift over 1 week

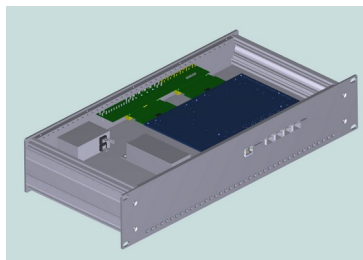


Other collaborations: Industrialization

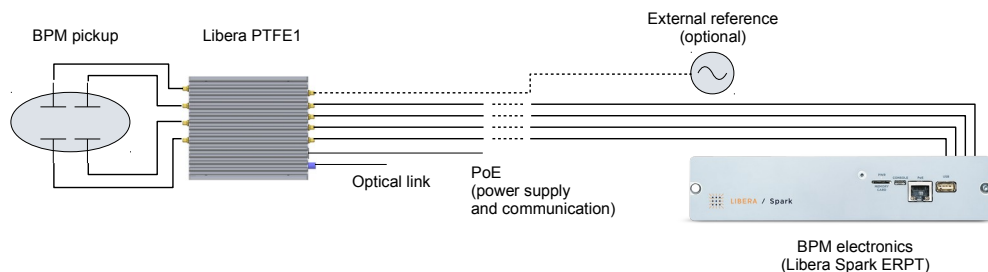
- Collaborative project with Elettra Sincrotrone Trieste
- Optimization and industrialization of the pilot tone generator
- Industrialization of the digital readout system
- Production of >200 systems



Pilot tone injector



Data acquisition electronics



Elettra Sincrotrone Trieste



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Ready for the future?

- Multi-bunch turn-by-turn position calculation
- Real-time FOFB with turn-by-turn data
- Sub-micrometer turn-by-turn RMS
- 1-week longterm stability $< 1\mu\text{m}$
- What is the next challenge? New electronics? New algorithms? BPM pickups? Ground stability, etc.?

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BPM Electronics



- Libera Brilliance+
- Libera Single Pass E/H
- Libera Hadron



- Libera Spark
- Libera Photon



- Libera CavityBPM

Beam Loss Monitor System



- Libera BLM



- Beam Loss Detector

Digitizers



- Libera Digit



- Libera Digit 500

Clock Transfer System



- Libera Sync 3
- Reference Master Oscillator

Digital LLRF



- Libera LLRF

Current Meter



- Libera Current Meter

Wide Dynamic Range Amplifier



- Amplifier 110



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