Commissioning of SOLEIL Fast Orbit Feedback System

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Summary

- SOLEIL characteristics
- Fast Orbit Feedback principle
  - Beam Position Monitors
  - Correctors
- Architecture
  - Algorithm computation
  - Data Distribution
  - Power-supplies control
- Data Processing
- First results
  - Commissioning
  - FOFB efficiency
  - Future improvements
- Conclusion

SOLEIL Main Characteristics

- Storage Ring circumference: 354 m
- Energy: 2.75 Gev
- Nominal current: 500 mA (fall 2008, presently 300 mA)
- 3rd generation => 29 % of circumference for Insertion devices)
- Extended photon spectral range :
    - From UV (5 eV) up to hard X-rays (30 keV)

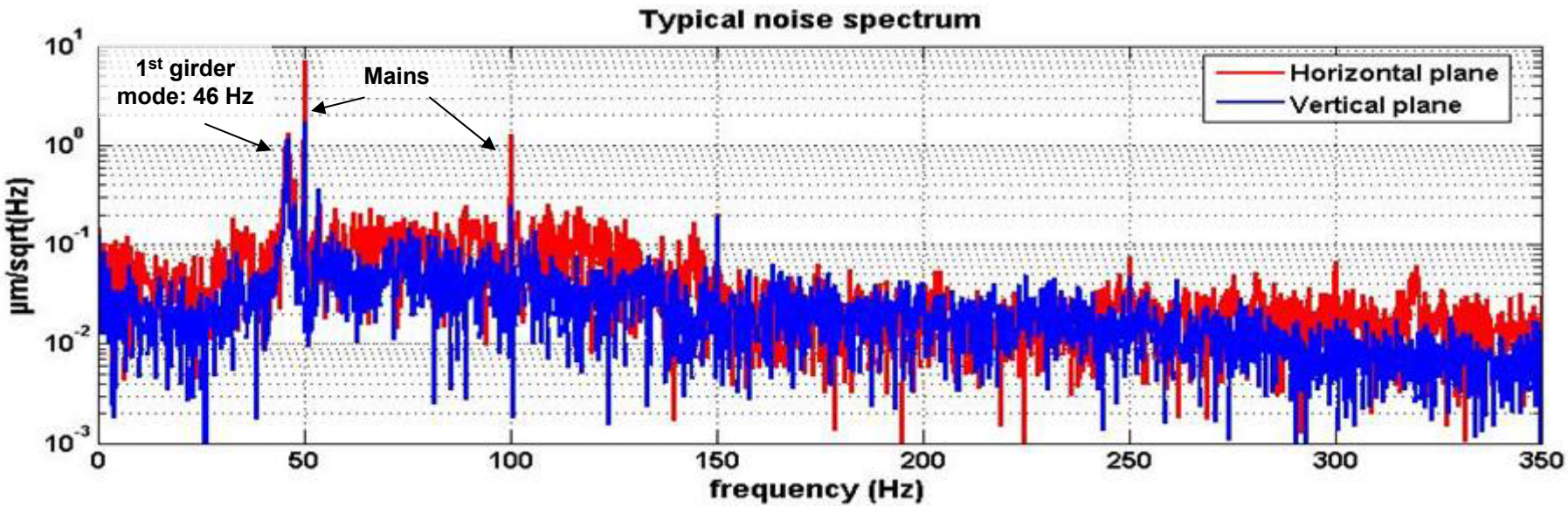
- First beam in 2006
- 14 beam lines take beam
- +12 beam lines under construction
- 800 A.h integrated current (today)

Beam Stability

- Great care has been taken in the design of the machine to improve its stability:
  - Long term (year):
    - Foundations:
      - Slab of the ring and experimental hall on ~600 15 meters long piles
  - Medium term (24 hours):
    - Temperature is regulated:
      - Experimental hall 21° C ± 1° C
      - Storage ring (air and water cooling) 21° C ± 0.1° C
    - BPMs blocks are bolted to girders and mechanically isolated (bellows)
    - A Slow Orbit Feedback System (since May 07)
      - Correction rate 0.1 Hz
    - Top-up (end 2008)
  - Short term:
    - Girder design (lowest ringing frequency: 46 Hz)
    - Fast Orbit Feedback System

Fast Orbit Feedback Principle

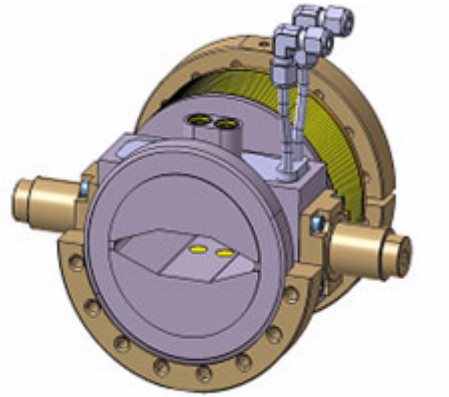
- Purpose of the system
  - Stabilizing the beam position in the high frequencies (>0.1 Hz)
- Perturbation sources in this frequency range:
  - Ground vibrations (girder modes)
  - Mains frequency (50 Hz)
  - Overhead cranes of the Experimental Hall
  - Insertion devices (transitions of the feedforward correction during gap changes)



=> Fast orbit feedback system should have its cut-off frequency above 150 Hz

Fast Orbit Feedback Principle:
Beam Position Monitors

- BPM blocks:
  - 120 units
    - 48 on the straight sections
    - 72 in the arcs



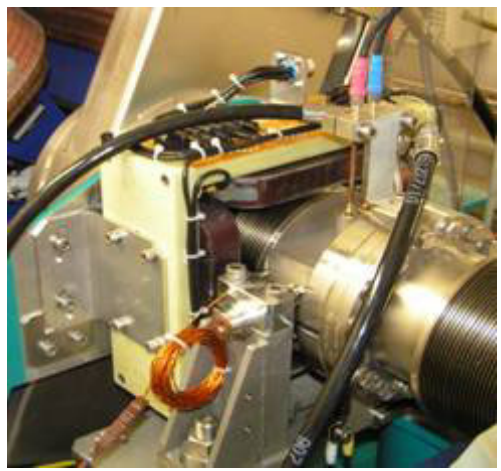
- BPM electronics:
  - 120 “LIBERA” modules
    - Developed by Instrumentation Technologies and SOLEIL
    - Subsequently used and improved by most storage ring in the world
    - Based on an FPGA
    - Data stream for the Fast Orbit Feedback:
      - Frequency rate: 10 kHz
      - Resolution in 100 Hz BW: 200 nm

Fast Orbit Feedback Principle:
Correctors

- Choice of the correctors:
  - 56 Slow correctors for slow orbit feedback are located inside the sextupoles.
  - Vacuum chambers are in Aluminum for low vacuum chamber impedance with NEG coating
  - Eddy currents in Al prevents high frequency corrections

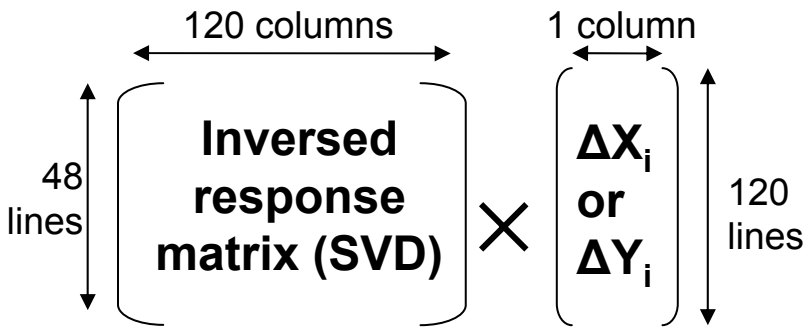
=> Necessity to have different correctors for the Fast Orbit Feedback

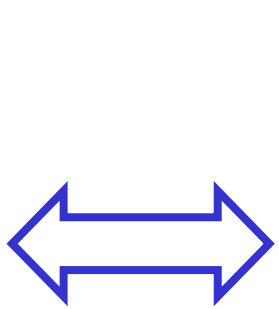
- Air-coil correctors
- Over stainless steel bellows
- Located on each side of the 24 straight sections => 48 units
- 20 µrad maximum strength
- Cut-off frequency: 2.5 kHz

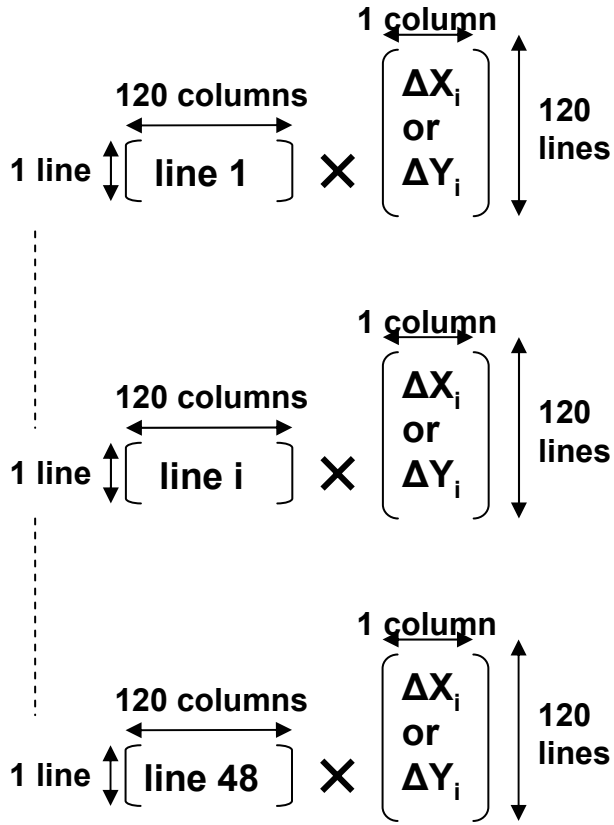


FOFB Architecture

- The most demanding part for computing resources is a matrix multiplication
  - Inversed response matrix (SVD computation is done offline)
  - Difference between current orbit and golden orbit





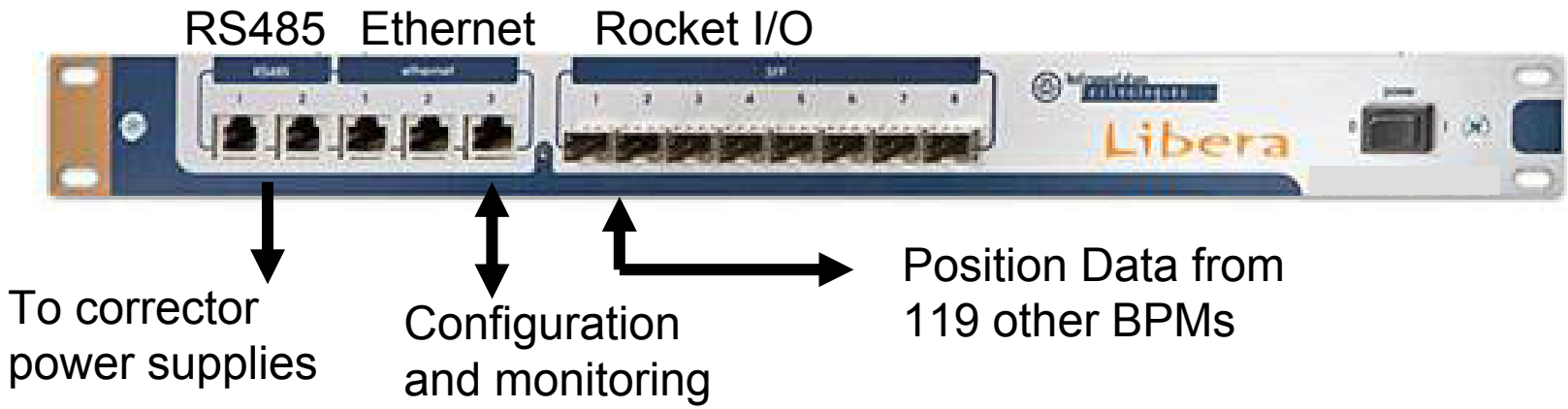


- Matrix multiplication is split and distributed:
  - Processing of one line of the matrix is done in one Libera FPGA

  => 48 Liberas (out of 120) are calculating correction data for FOFB

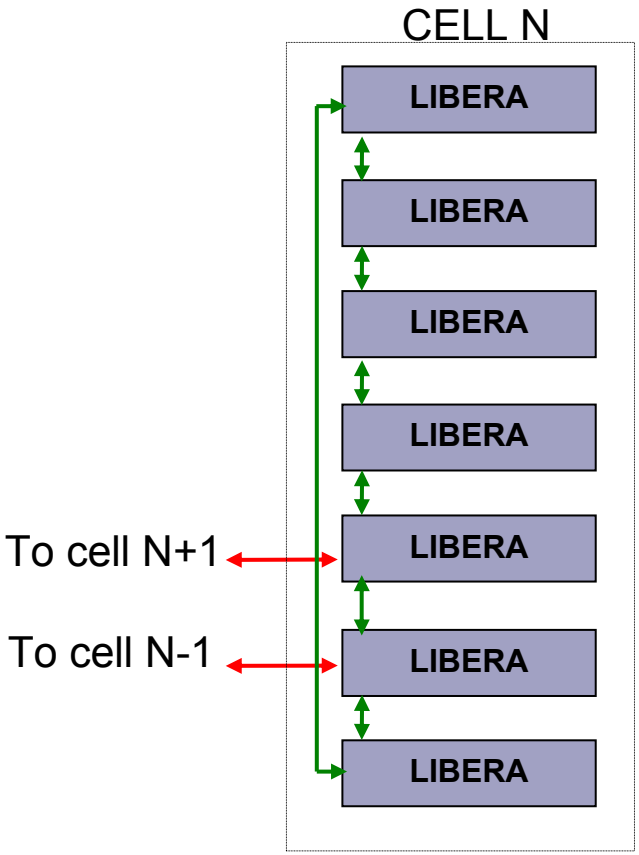
FOFB Architecture

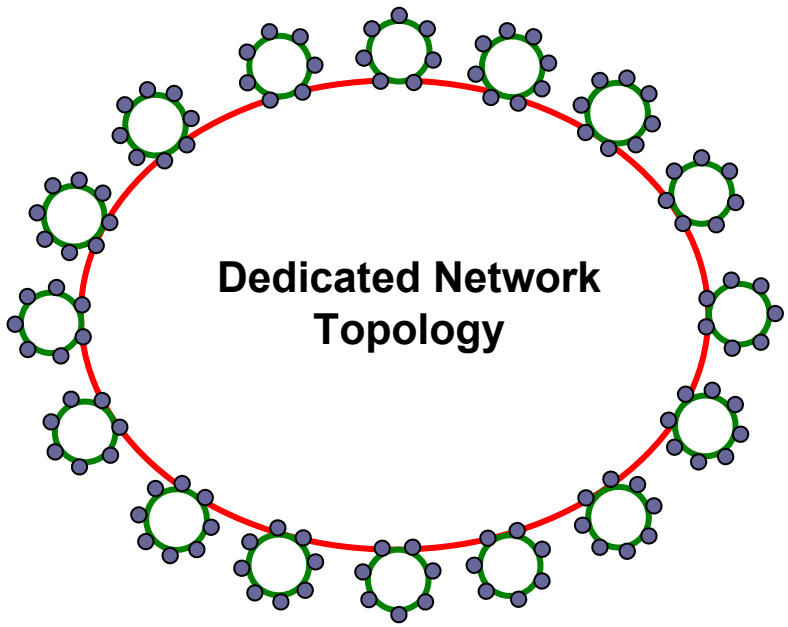
- An ‘all embedded’ solution
  - All the processing of the FOFB is done in the LIBERA FPGA, on top of the position calculation provided by Instrumentation Technologies
  - Different interfaces for data exchanges are built in the LIBERA.



FOFB Architecture:
Fast Dedicated Network (10 kHz)

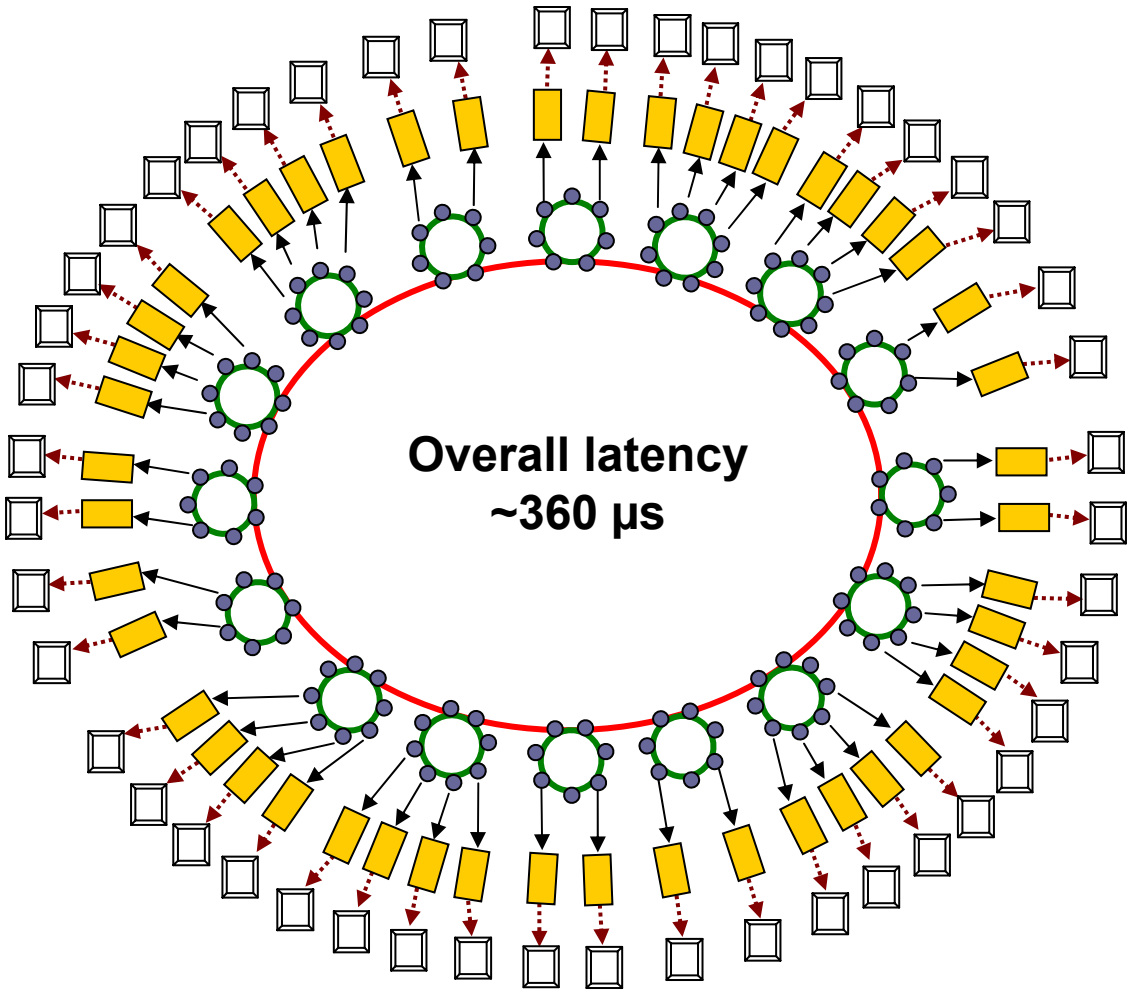
- Global Feedback:
  - All position data have to be delivered to all BPM modules





Copper link Optic link

FOFB Architecture:
Power Supply Control



Libera rack (7 or 8 units)

Power supply rack (2 planes)

Air-coil magnet (2 planes)

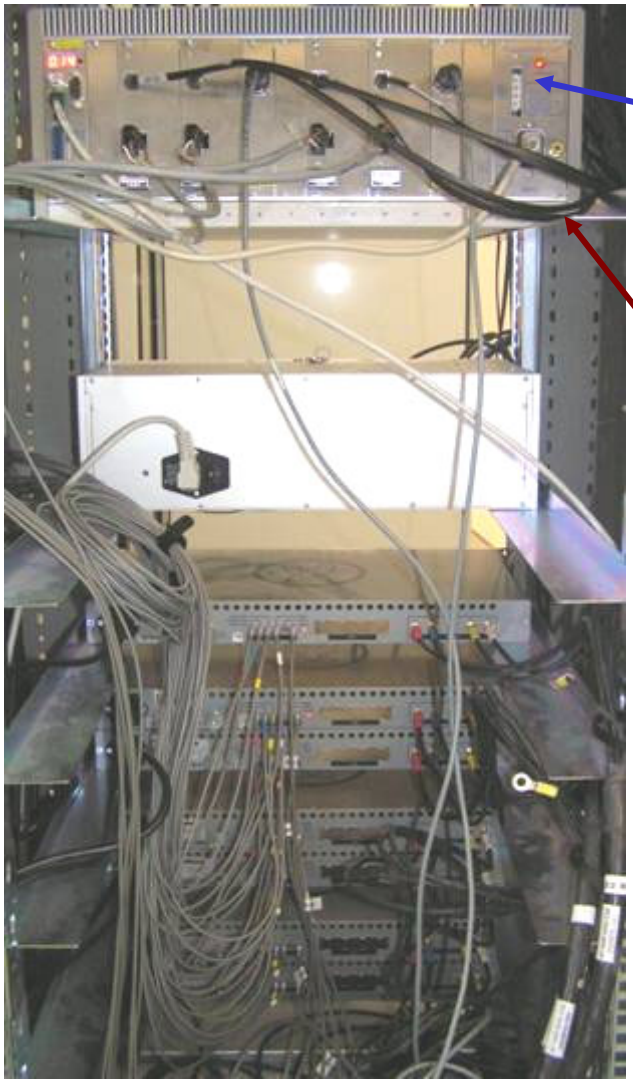
Copper link

Optic link

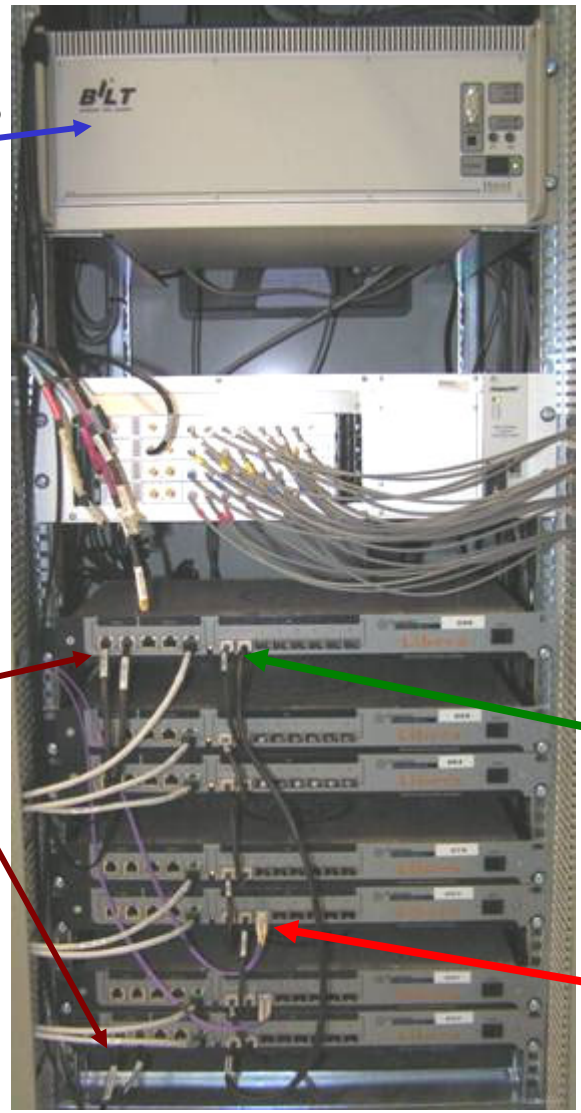
RS 485 link

2 conductor copper cable

FOFB Architecture:



4 power supplies
=> 2 correctors

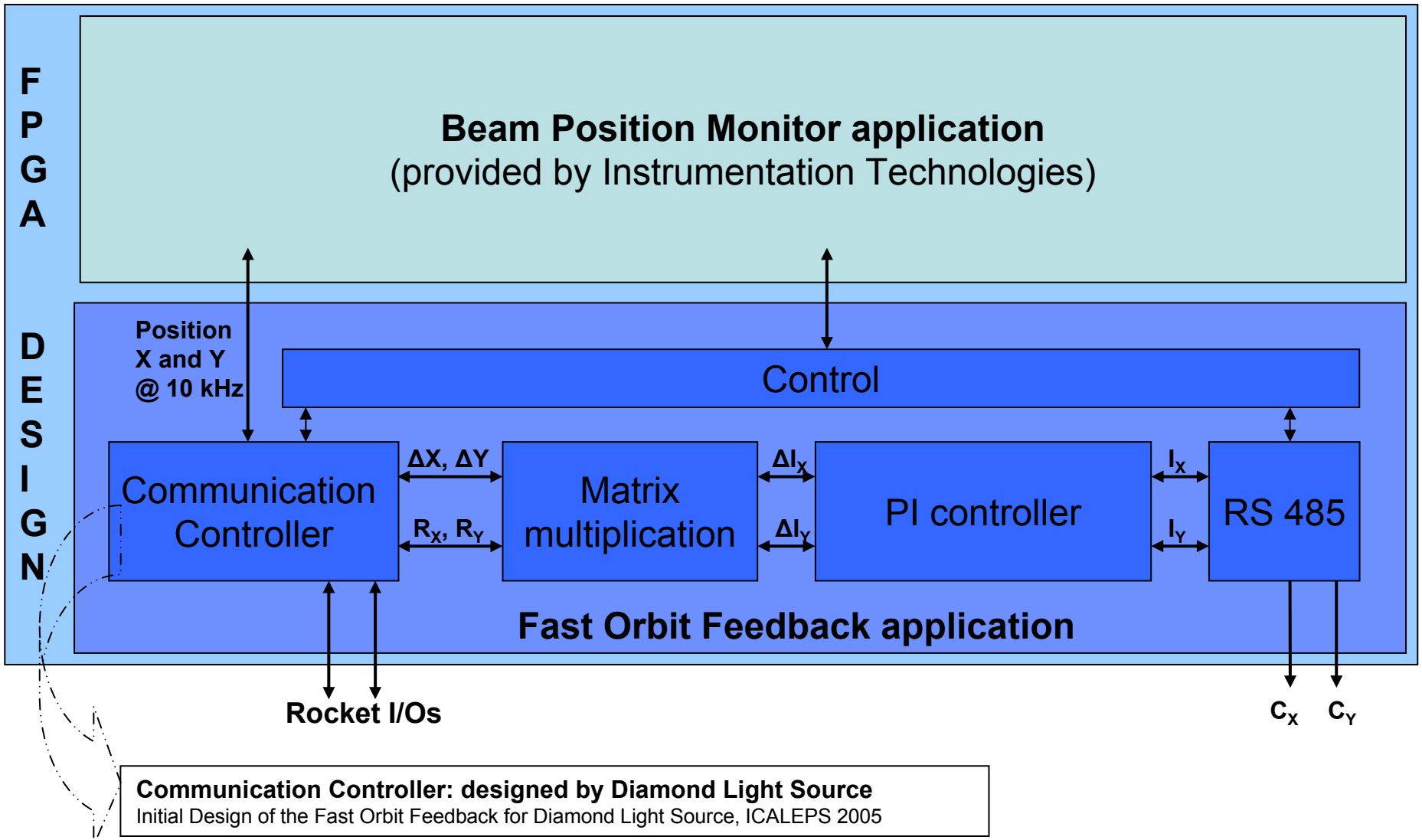


RS 485
links

Copper
links

Optic
fibers

Data Processing



Communication Controller: designed by Diamond Light Source
Initial Design of the Fast Orbit Feedback for Diamond Light Source, ICALEPS 2005

FOFB Commissioning

- Schedule:
  - October 2007: Data distribution is operational
  - December 2007: Feedback loop is closed
  - January -> July 2008: Optimization of the system
  - September 2008: FOFB to be available for operation

- 2 configurations tested:
  - 48 BPMs and 48 correctors
  - 120 BPMs and 48 correctors

- FOFB is efficient from DC to ~100 Hz (cut-off frequency:~400 Hz)

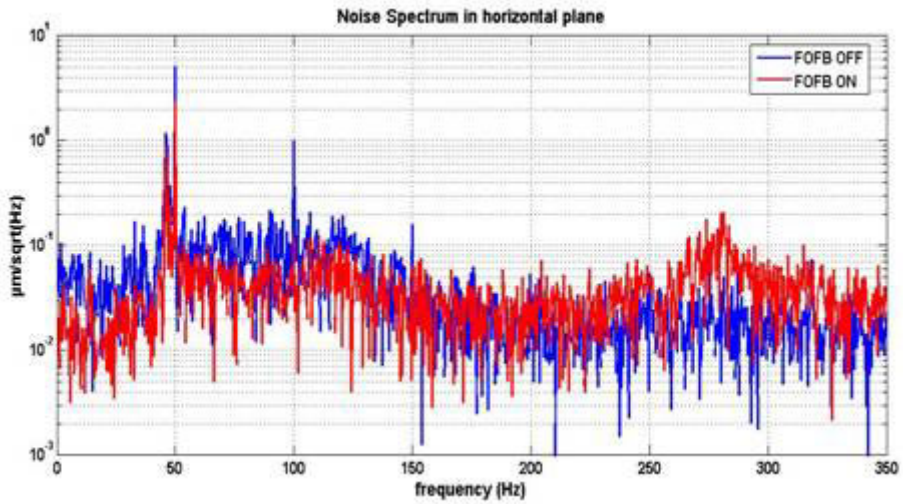
- System efficiency:
  - The frequency range where the FOFB has an influence can be divided in 3 area:

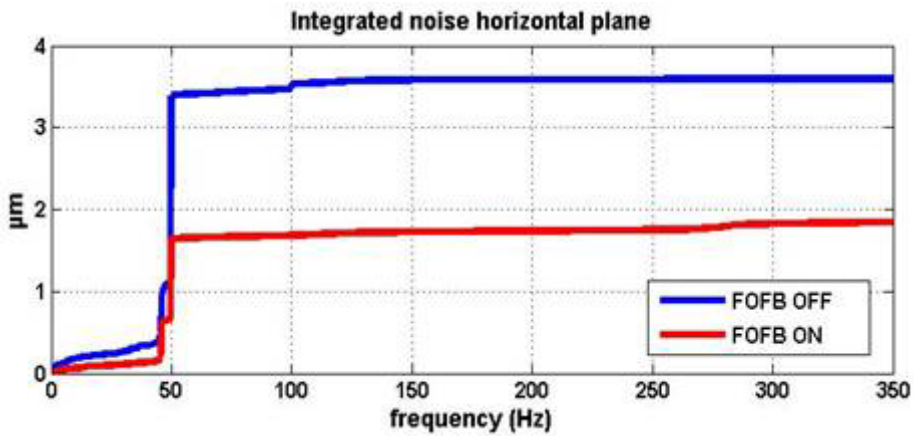
    - 1 Hz to 350 Hz : Ground vibrations, mains,…
    - 0.01 Hz to 1 Hz : Insertion devices, crane
    - DC to 0.01 Hz : Drifts (thermal effects)

FOFB Efficiency (1-350 Hz)

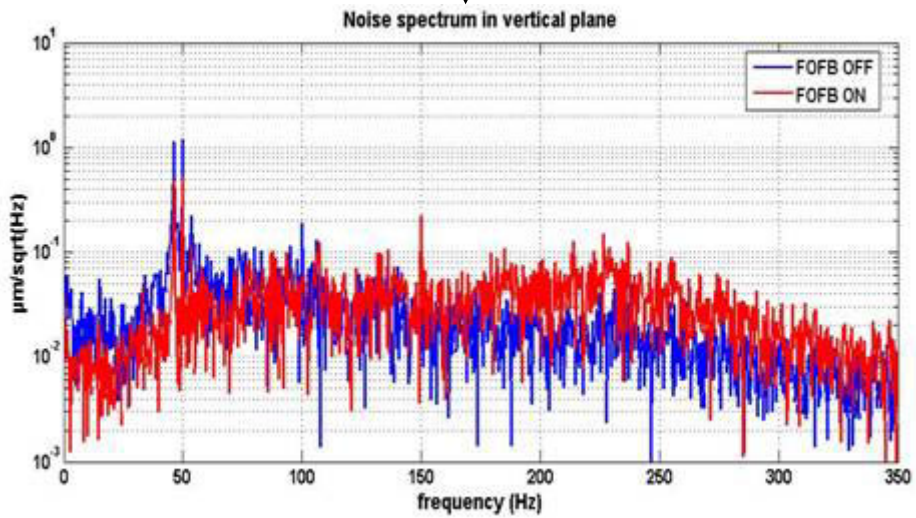
Measurement on a BPM outside the feedback loop

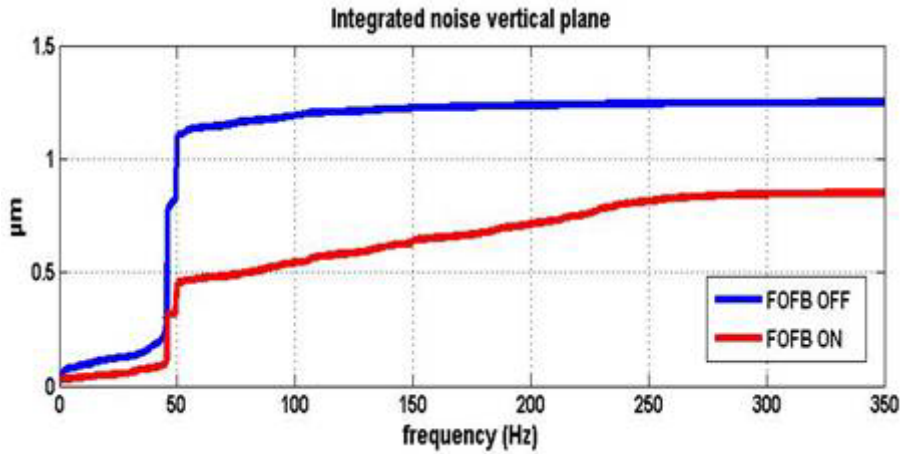
HORIZONTAL





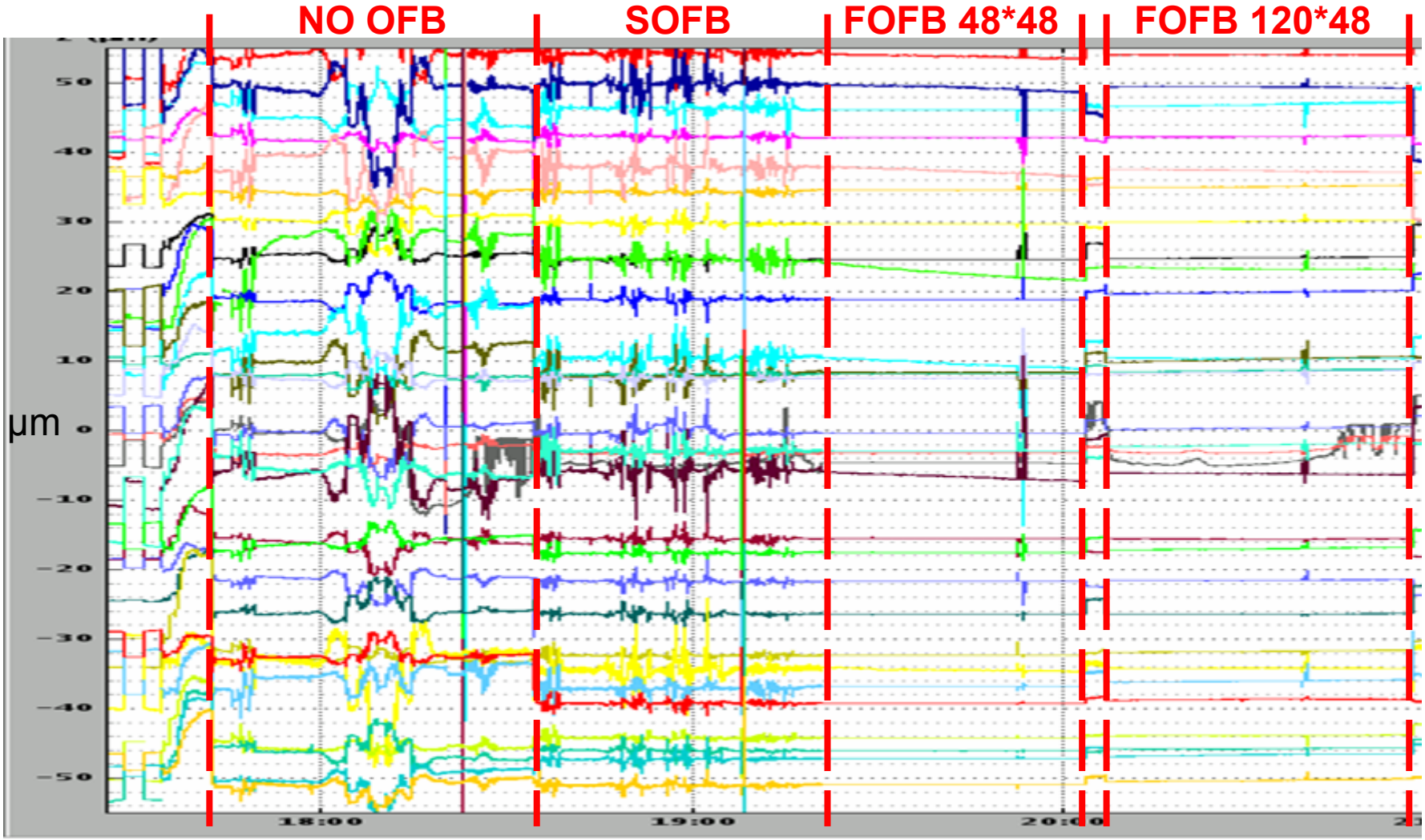
VERTICAL





FOFB Efficiency (0.01 Hz – 1 Hz)

Effect on the perturbations caused by the insertion devices (vertical position at source points)

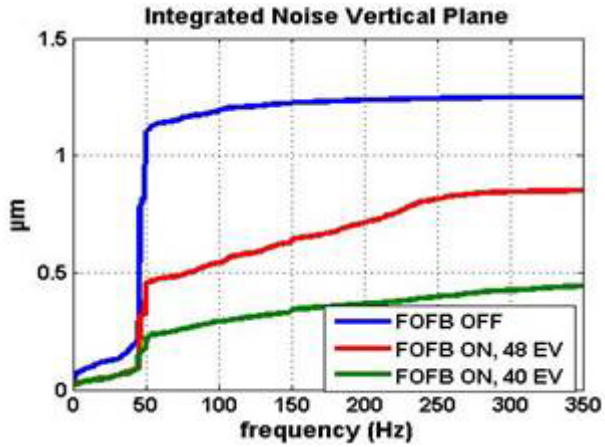


FOFB efficiency (DC to 0.01 Hz): slow drifts (thermal effects)

		UV	Soft X ray	Hard X ray	Bending magnets
Δ X (µm)	**σ_x/10**	**32**	**18**	**39**	**?**
	ΔX pp (fofb off) 3.5h	**12**	**10**	**15**	**4.5**
	ΔX pp (48x48) 2h	0	0	0	1.5
	ΔX pp (120x48) 3h	0	0.5	0.3	0.2
Δ X' (µrad)	**σ'_x/10**	**4.6**	**3.4**	**1.5**	**?**
	ΔX' pp (fb off) 3.5h	**0.5**	**2.5**	**1.5**	**11**
	ΔX' pp (48x48) 2h	0	0	0	0.9
	ΔX' pp (120x48) 3h	0	0.1	0	0
Δ Y (µm)	**σ_Y/10**	**6**	**0.65**	**0.55**	**1.5**
	ΔY pp (fb off) 3.5h	**4**	**5.8**	**3.2**	**17**
	ΔY pp (48x48) 2h	0	0	0	4.1
	ΔY pp (120x48) 3h	0.6	0.5	0.3	0.3
Δ Y' (µrad)	**σ'_Y/10**	**4.2**	**1.6**	**0.52**	**5.3**
	ΔY' pp (fb off) 3.5h	**0.3**	**1.6**	**1.6**	**1.6**
	ΔY' pp (48x48) 2h	0	0	0	0.6
	ΔY' pp (120x48) 3h	0	0.1	0.1	0.1

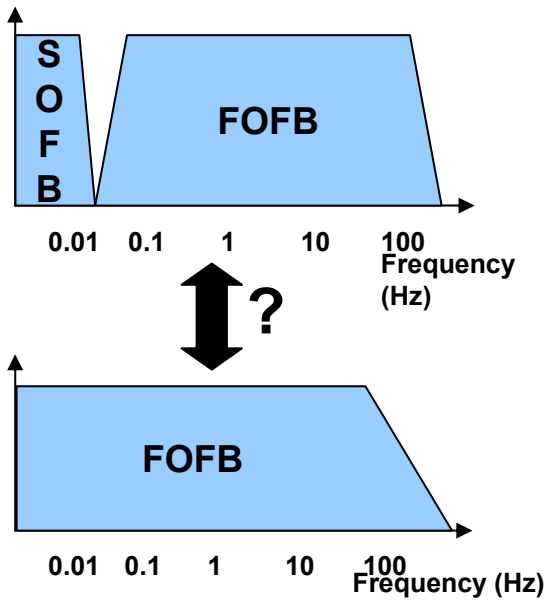
FOFB efficiency and future improvements

- High frequencies: 1-350 Hz
  - FOFB efficiency is already OK, but could be improved around 50 Hz (number of eigen values optimization)
  - Not much noise added (mainly around 200 Hz)



- Low frequencies: 0.01-1 Hz
  - Very good efficiency
  - Perturbations caused by insertion devices transitions or cranes movements are strongly suppressed

- Drifts: DC to 0.01 Hz
  - FOFB can correct the drifts for ~8 hours, before its correctors reach the saturation
  - Seems OK, even if it is not as efficient as the Slow Orbit Feedback System



Conclusion

- Low cost system
  - Using computing resources of FPGA BPM system
- Global orbit correction
  - Distribution of all BPM data around the ring with a dedicated network
- Air-coil correctors over stainless steel bellows with high cut off frequency
- Flexible
  - Easy change of correction algorithm
- First results are very promising
  - system should be available for user operation in the coming months

Acknowledgements

- SOLEIL Fast Orbit Feedback team:
  - Jean-Claude DENARD: Diagnostic Group
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  - Dominique PEDEAU: Diagnostic Group
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