SOLEIL
Fast Orbit Feedback System

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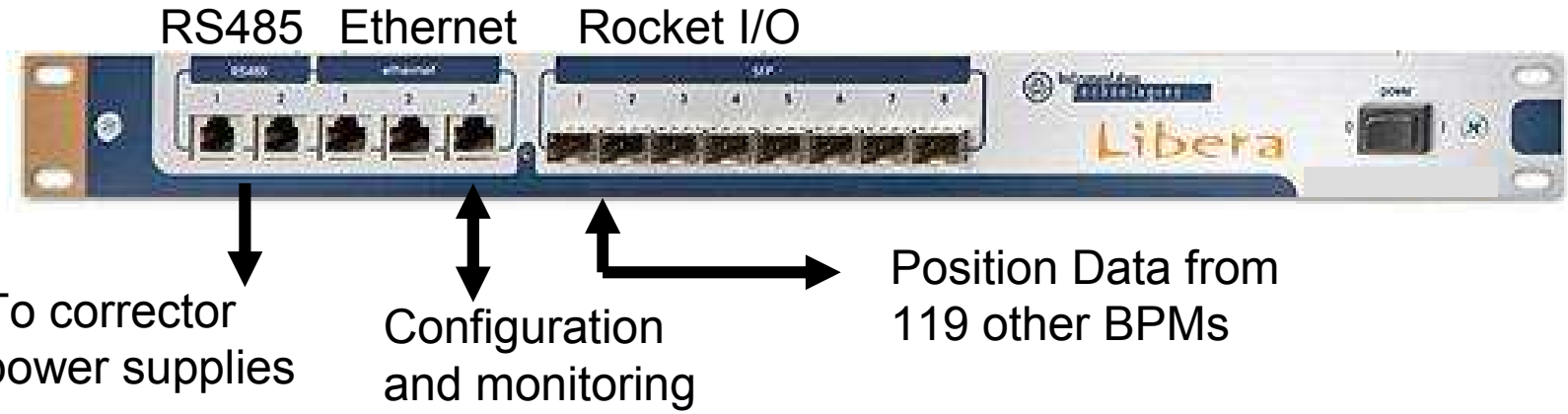
On behalf of the Diagnostics group

Summary

- Fast Orbit Feedback Architecture
  - Elements of the systems
  - Data distribution
- Data Processing
  - Communication controller
  - Matrix multiplication
  - Controller
  - RS 485 Communication
- FOFB status
  - Status
  - Download process
  - FOFB efficiency
  - Future improvements
- Conclusion

FOFB Architecture

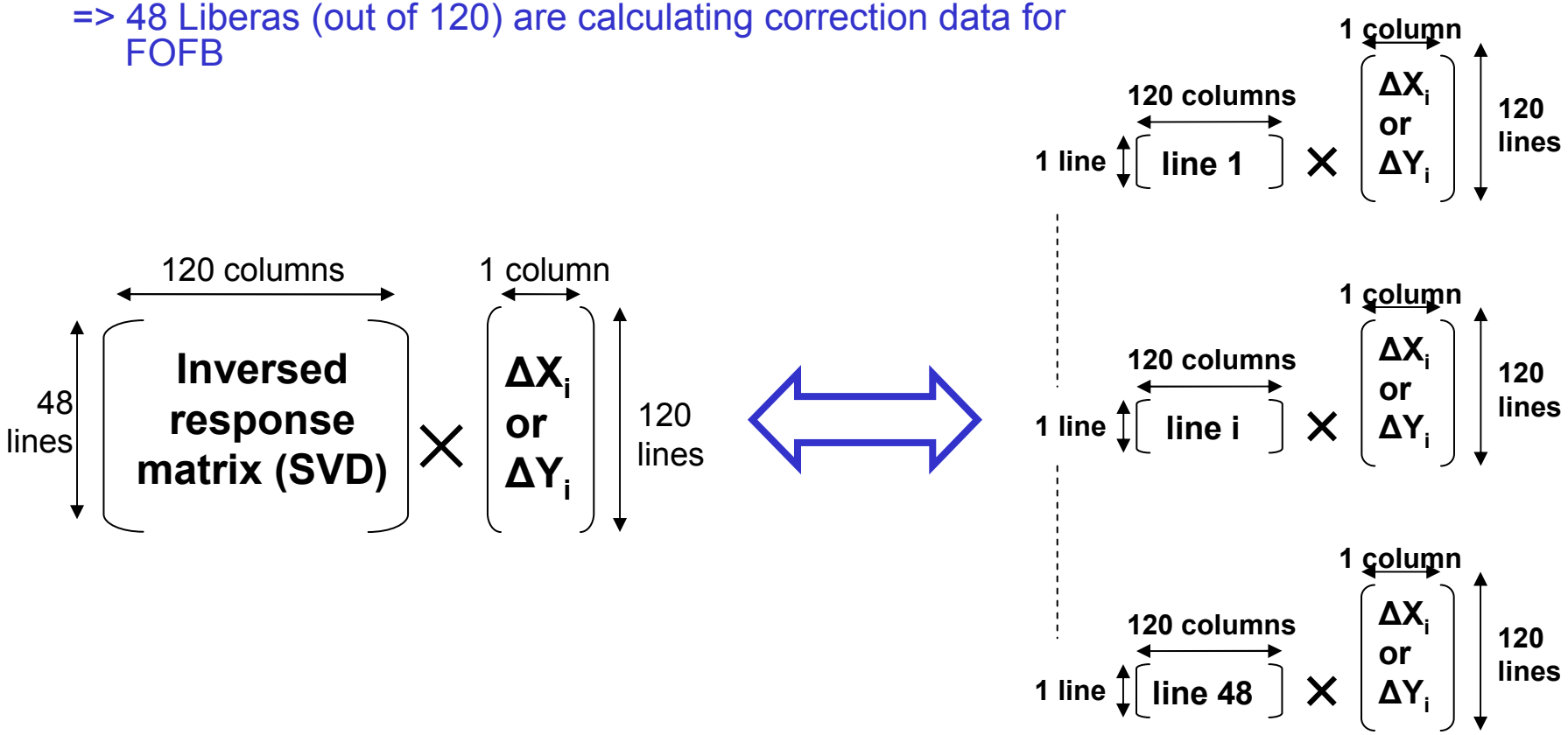
- Dedicated air coil correctors
  - over stainless steel bellows at each side of straight sections
- An ‘all embedded’ solution
  - All the processing of the FOFB is done in the LIBERA FPGA, on top of the position calculation provided by Instrumentation Technologies
  - Need all interfaces built in the LIBERA for data exchange.



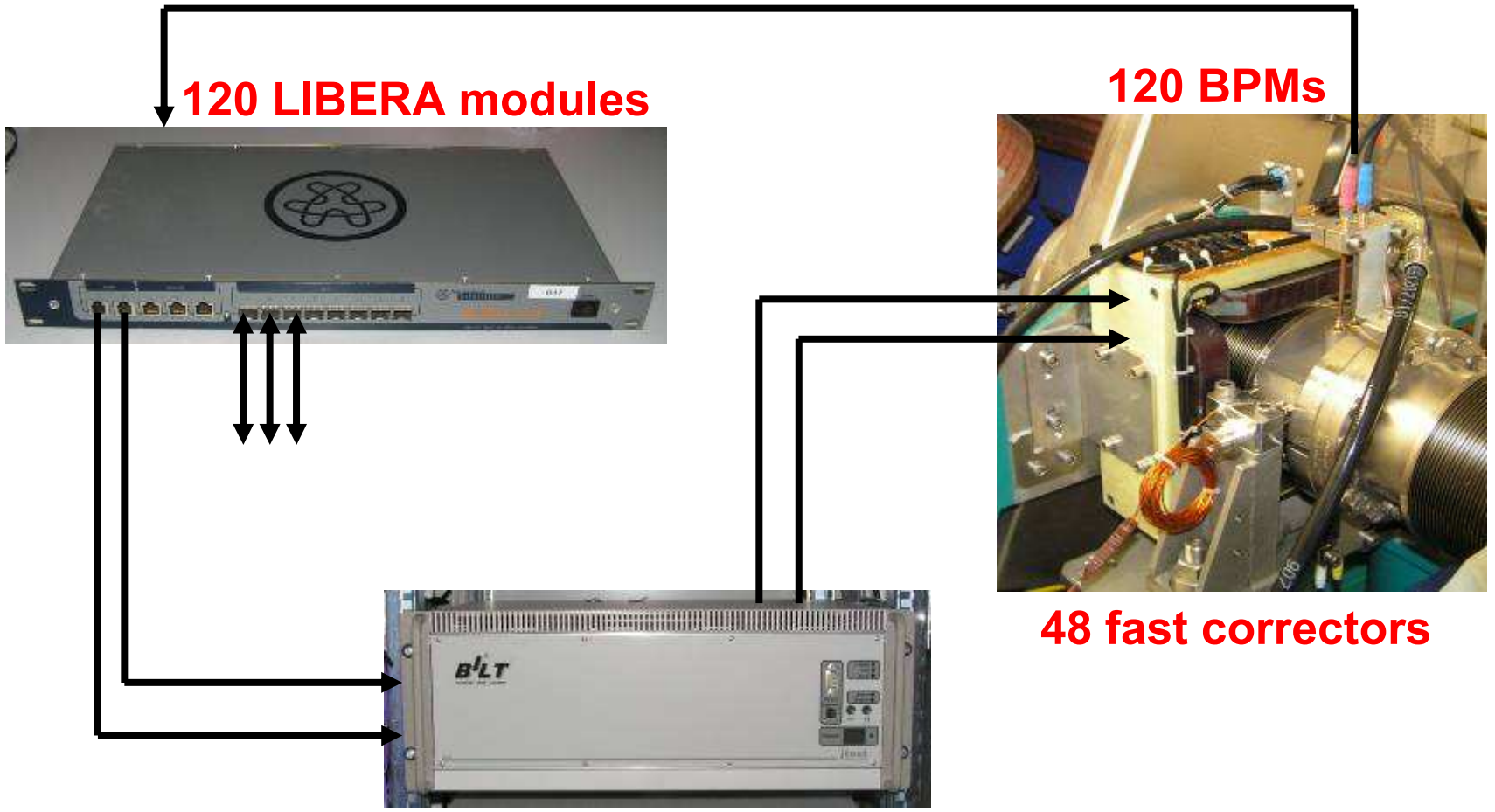
FOFB Architecture

- Matrix multiplication is split and distributed
  - Inverse response matrix (SVD computation is done off-line)
  - Processing of one line of the matrix is done in one Libera FPGA

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

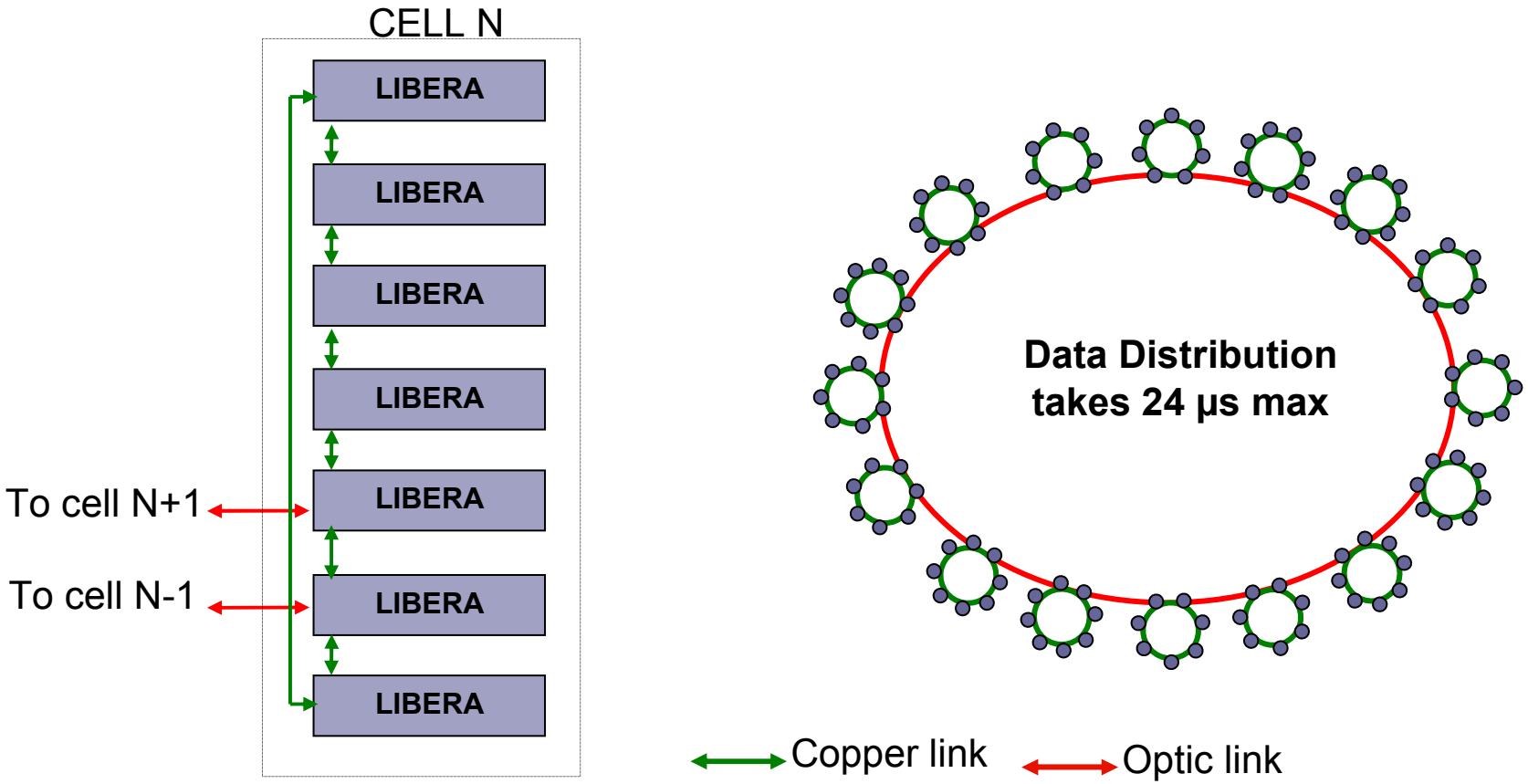


FOFB Architecture:



FOFB Architecture:
Fast Dedicated Network

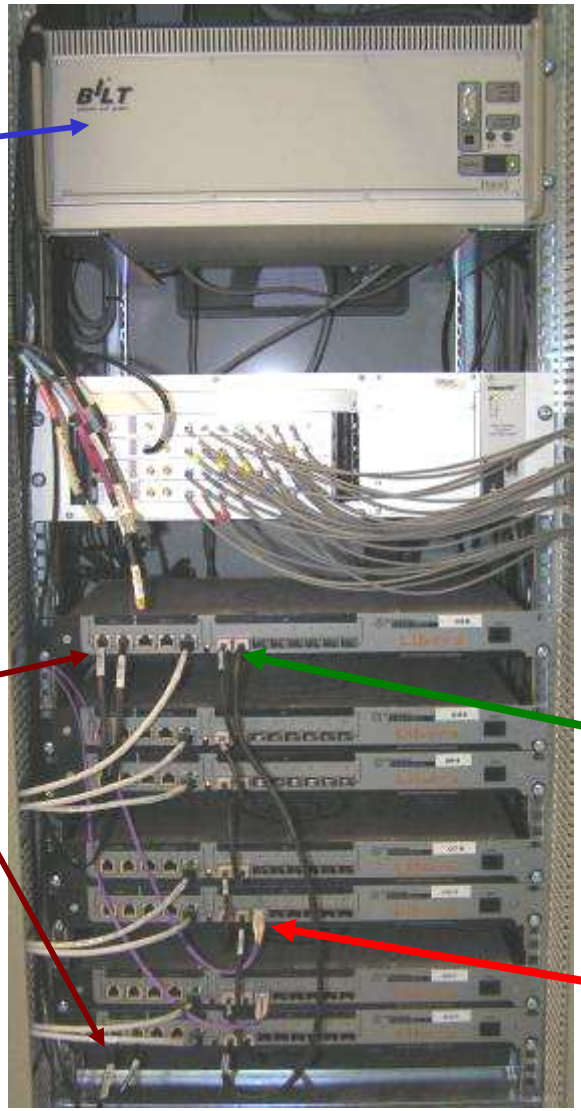
- Global Feedback:
  - Fast Acquisition data (~10 kHz) have to be delivered to all BPM modules



FOFB Architecture:

4 power supplies
=> 2 correctors

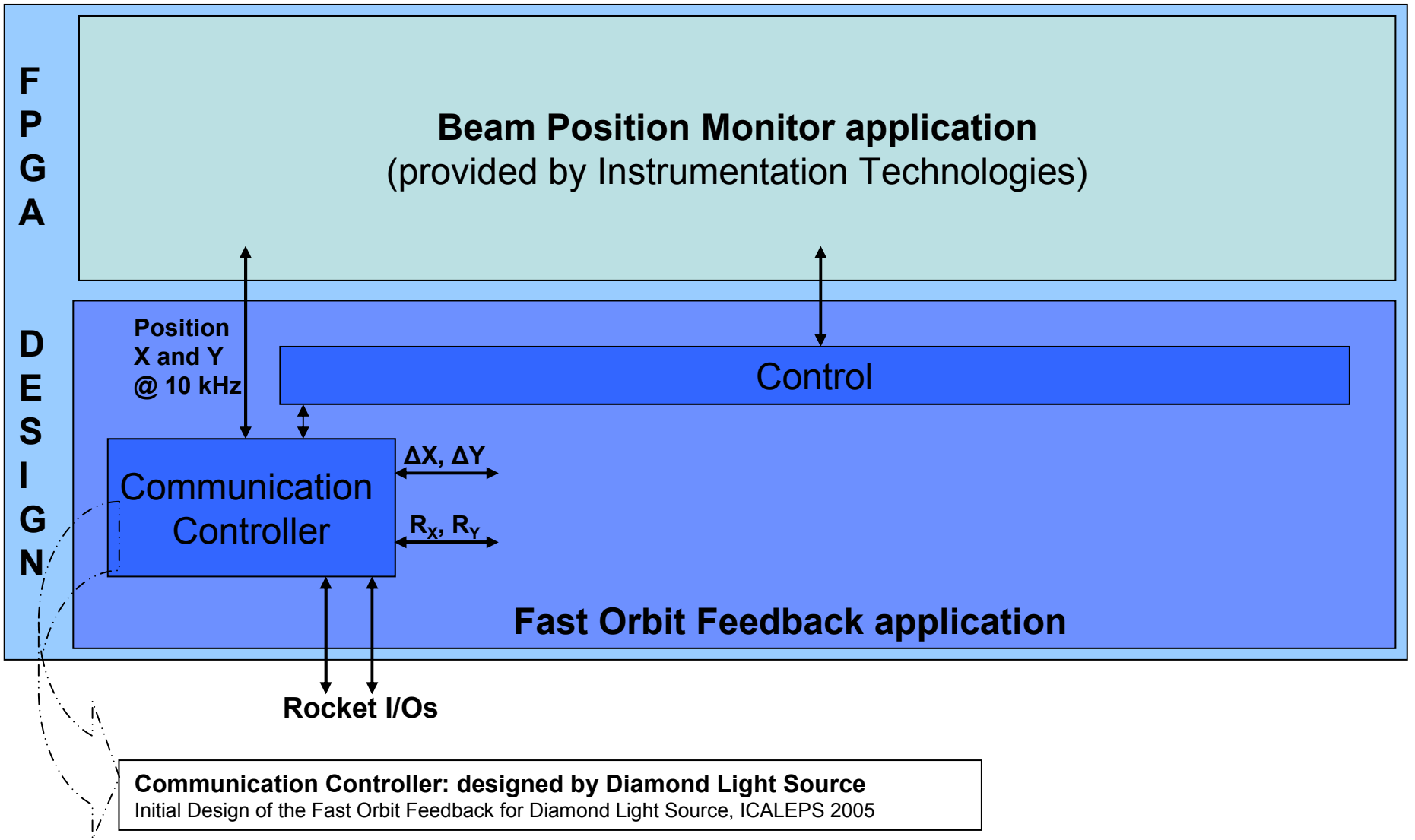
RS 485
links



Copper
links

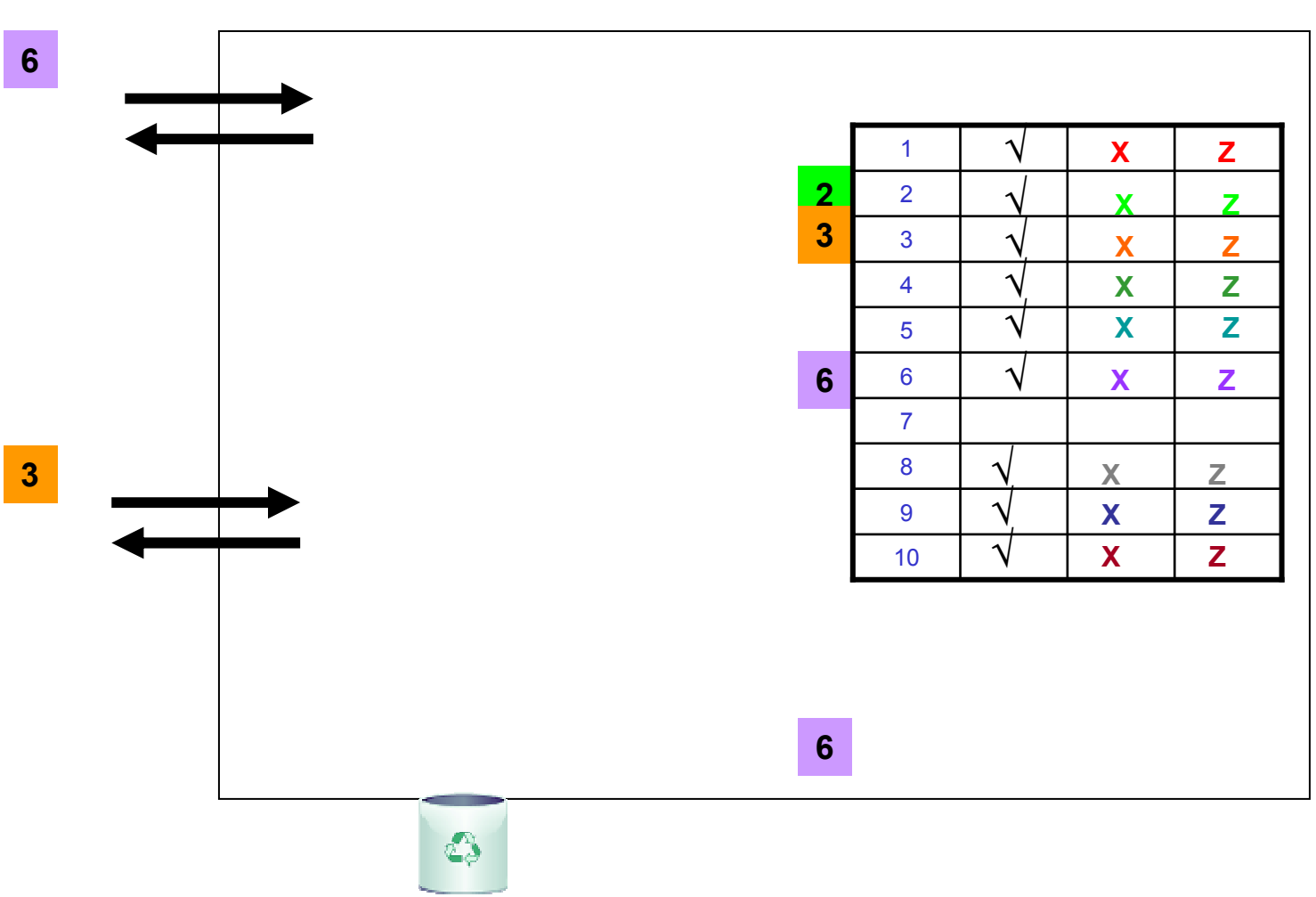
Optic
fibers

Data Processing:
inside the Libera FPGA



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

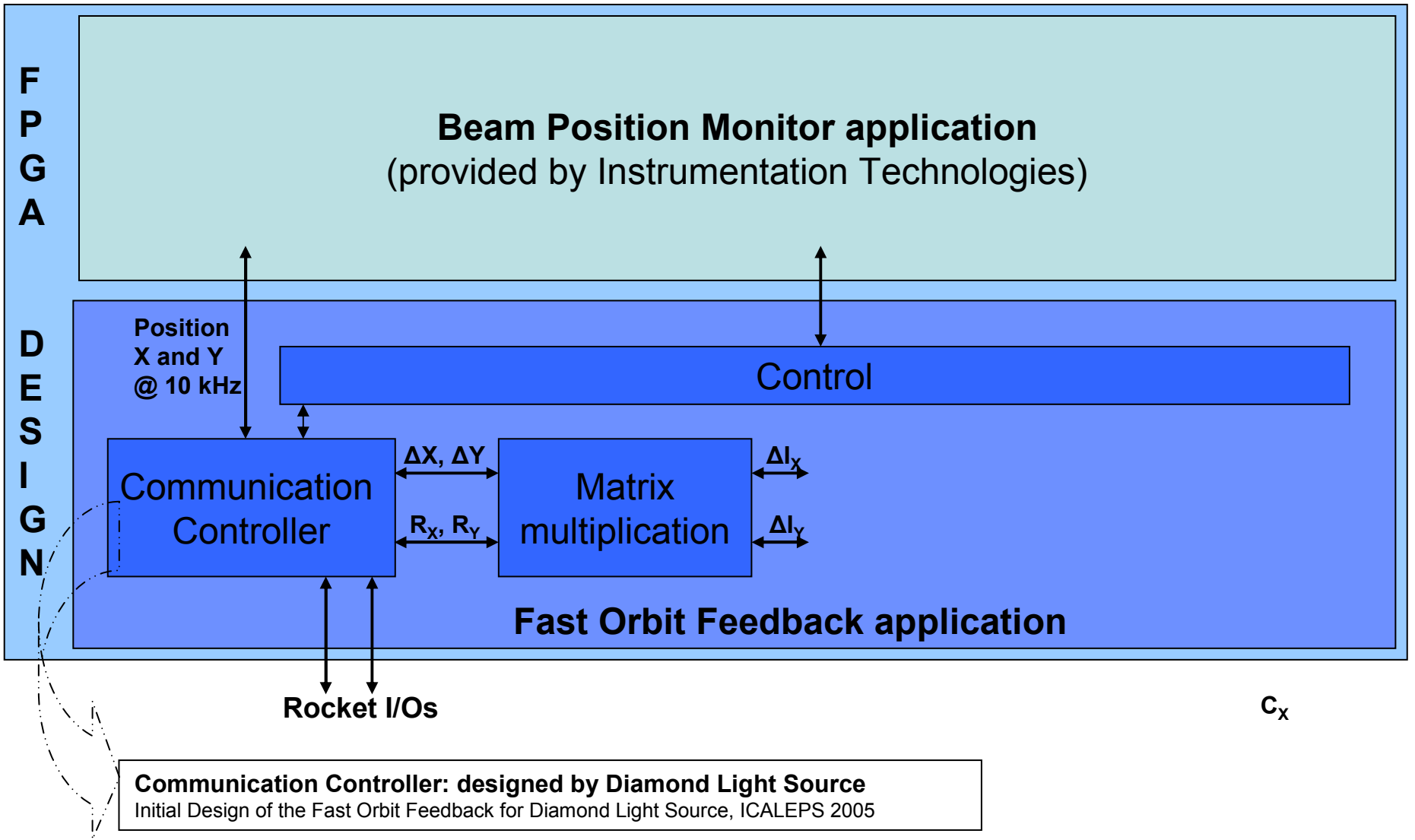
Data processing:
Communication Controller



Number of BPMs on the network = 9

Time needed for data distribution = 5 µs

Data Processing:
inside the Libera FPGA



Communication Controller: designed by Diamond Light Source
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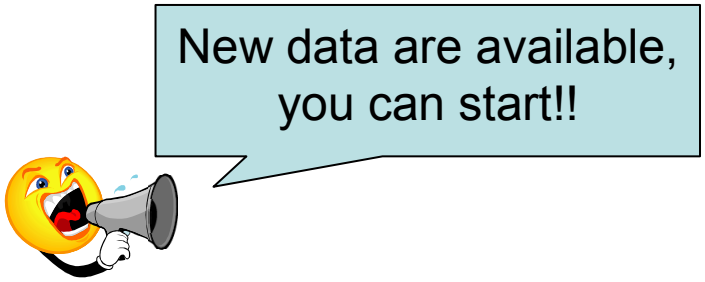
Data processing:
Matrix multiplication

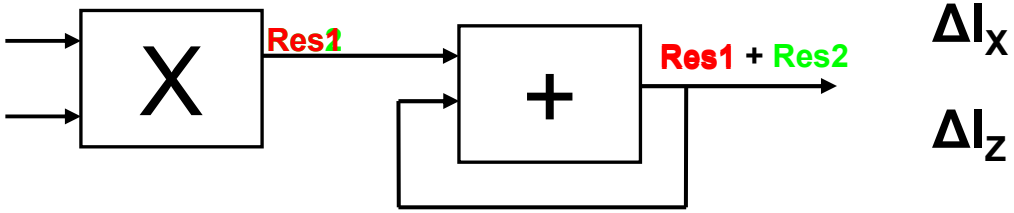


One line of the inverse response matrix

1	2	3	4	5	...	...	118	119	120
R^{-1}	R^{-1}	R^{-1}	R^{-1}	R^{-1}	...	...	R^{-1}	R^{-1}	R^{-1}

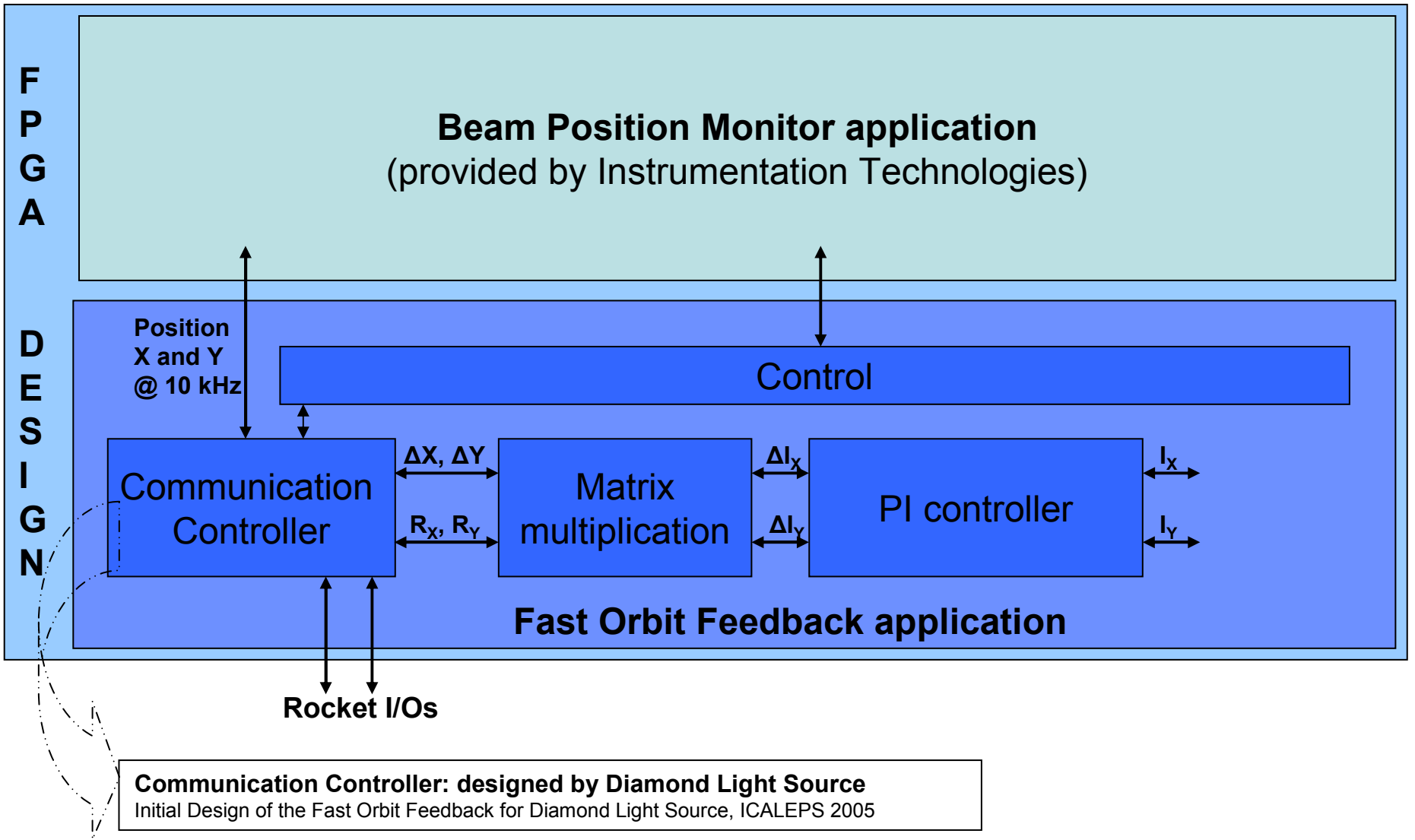
Orbit

1	√	X
2	√	X
3	√	X
4	√	X
5	√	X
...	...	...
...	...	...
118	√	X
119	√	X
120	√	X



Multiplier Accumulator

Data Processing:
inside the Libera FPGA



Data processing:
Controller

- PI controller is used
  - Proportional coefficient is not implemented in the FPGA
    - the inverse response matrix is multiplied by the right coefficient before being sent to the FPGA
  - Integrator part is an accumulator with a configurable coefficient

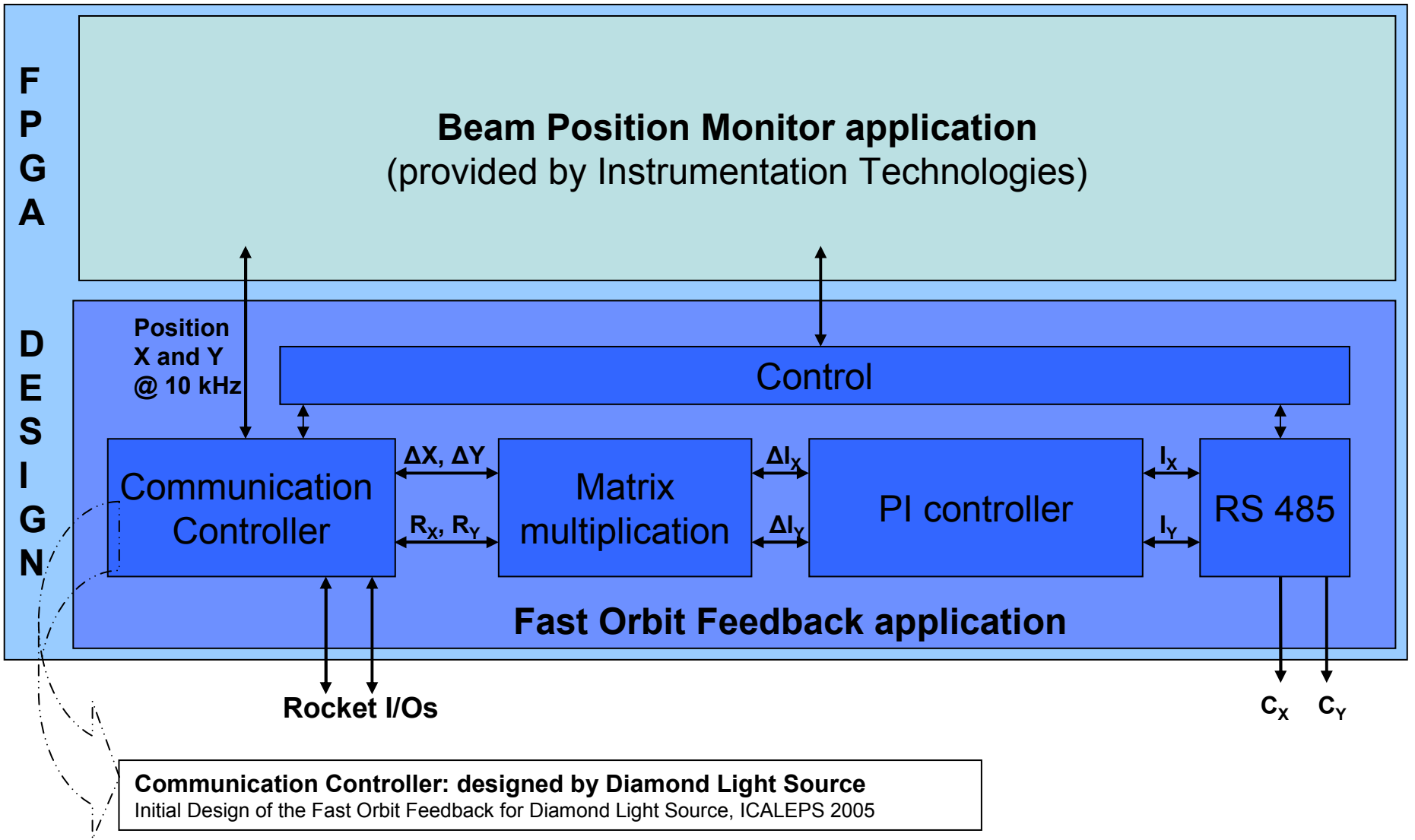
$$I_N = \Delta I_N + coeff * I_{N-1}$$

Next current setting

Matrix multiplication result

previous current setting

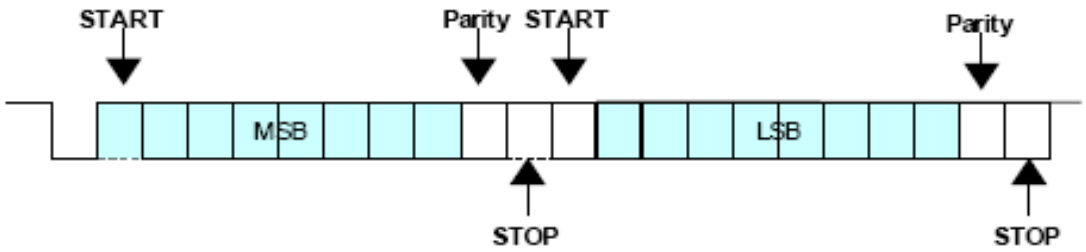
Data Processing:
inside the Libera FPGA



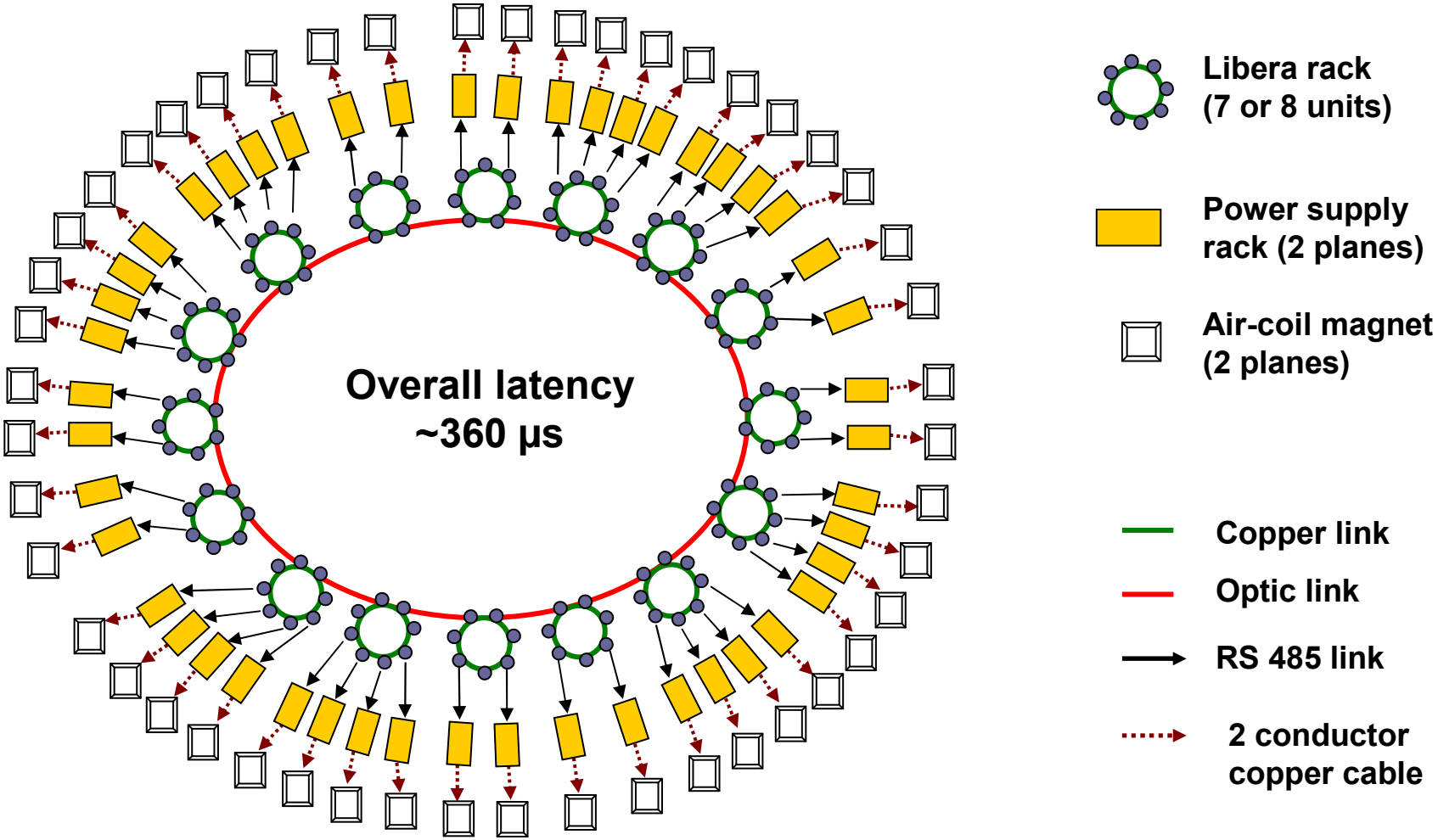
Communication Controller: designed by Diamond Light Source
Initial Design of the Fast Orbit Feedback for Diamond Light Source, ICALEPS 2005

Data processing: RS 485

- RS 485 serial link to power supplies:
  - One way communication: Libera => power-supply
  - Simple protocol:
    - 22 bits per frame: 16 bits for data (15 bits+1 for the sign)
      2 bits for parity
      4 bits for synchronization (start/stop)
  - Link rate is 1.25 Mbits/s
  - Transmission delay is around 20 µs



FOFB Architecture:
Power Supply Control



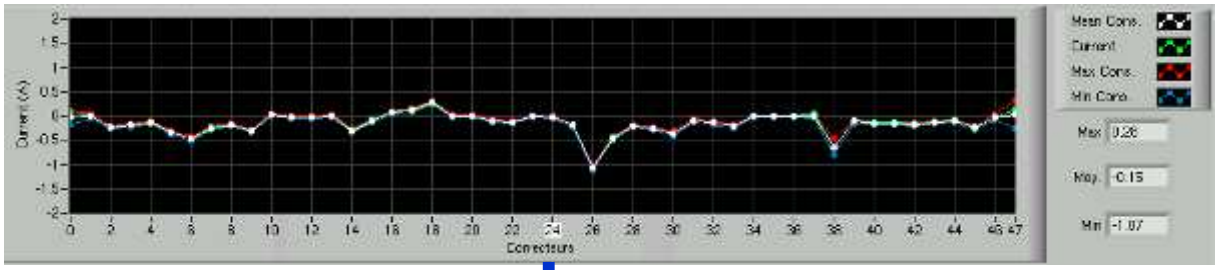
Processing latency

Position processing	190 µs
Data Distribution	60 µs
Matrix Multiplication	5 µs
PI controller	1 µs
Serialization and transmission to PS	20 µs
FPGA delay	**~280 µs**
Power supply latency	20 µs
Eddy currents in vacuum chamber	~60 µs

FOFB Status

- FOFB is in operation since mid-September :
  - Efficient from DC. No other orbit feedback running
  - RF part is not corrected by the FOFB but by a matlab routine (every 10 s).
  - At every injection (every 8 hours) a routine download the DC part of the current in the fast correctors into the slow ones.
  - For top-up operation: the download routine will run continuously (a 10s repetition rate has been tested successfully)

Download process



Fast correctors response matrix

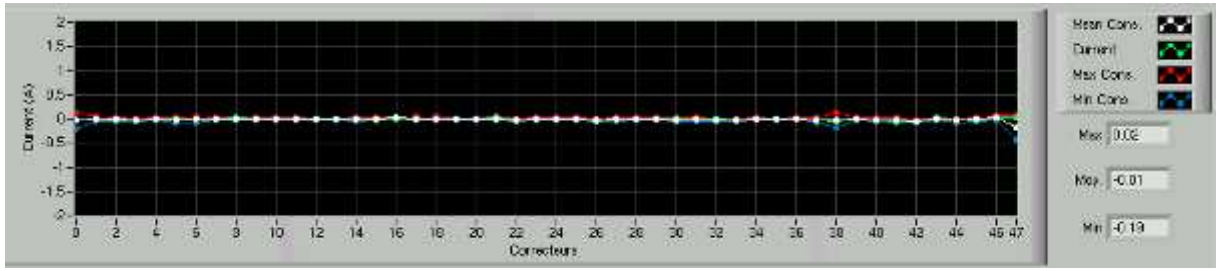
Orbit created by the DC current in the Fast correctors

Slow correctors

inverse response matrix

New Set points for Slow correctors

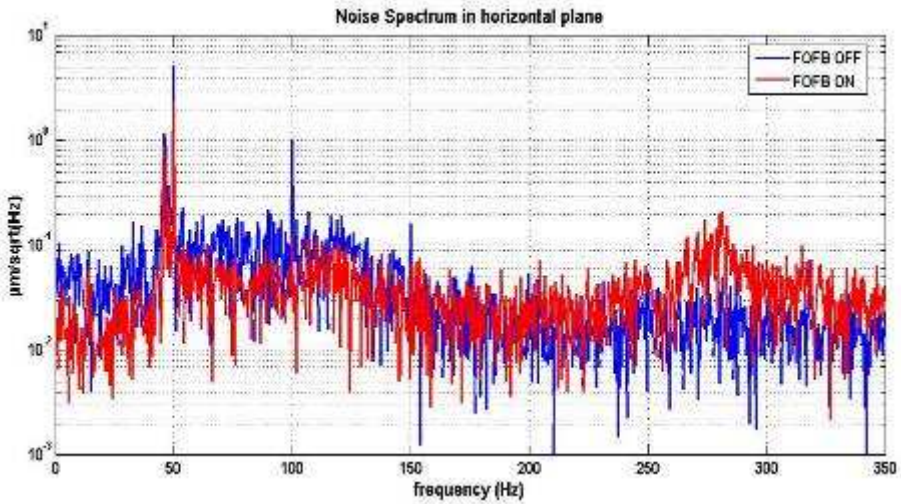
Orbit movement corrected by is automatically the FOFB

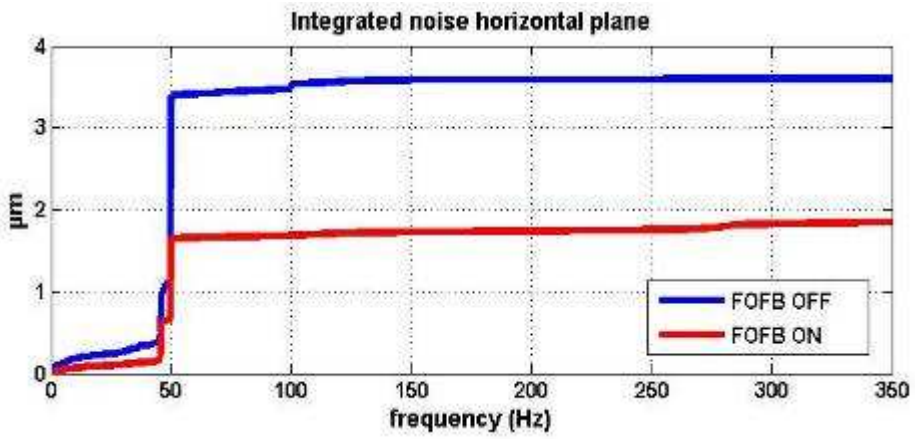


FOFB Efficiency (1-350 Hz)

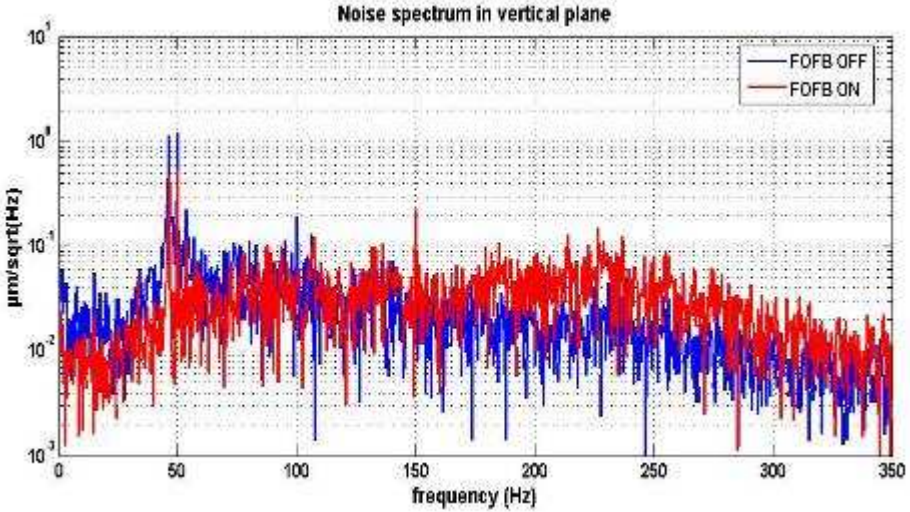
Measurement on a BPM outside the feedback loop

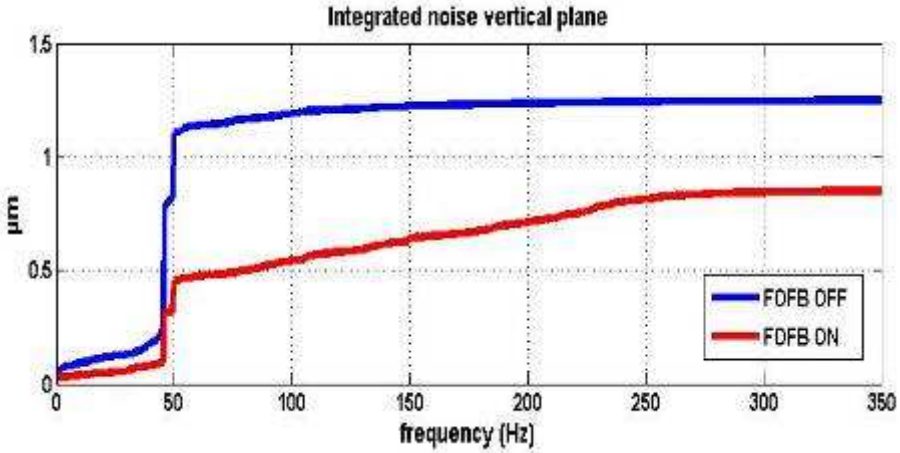
HORIZONTAL





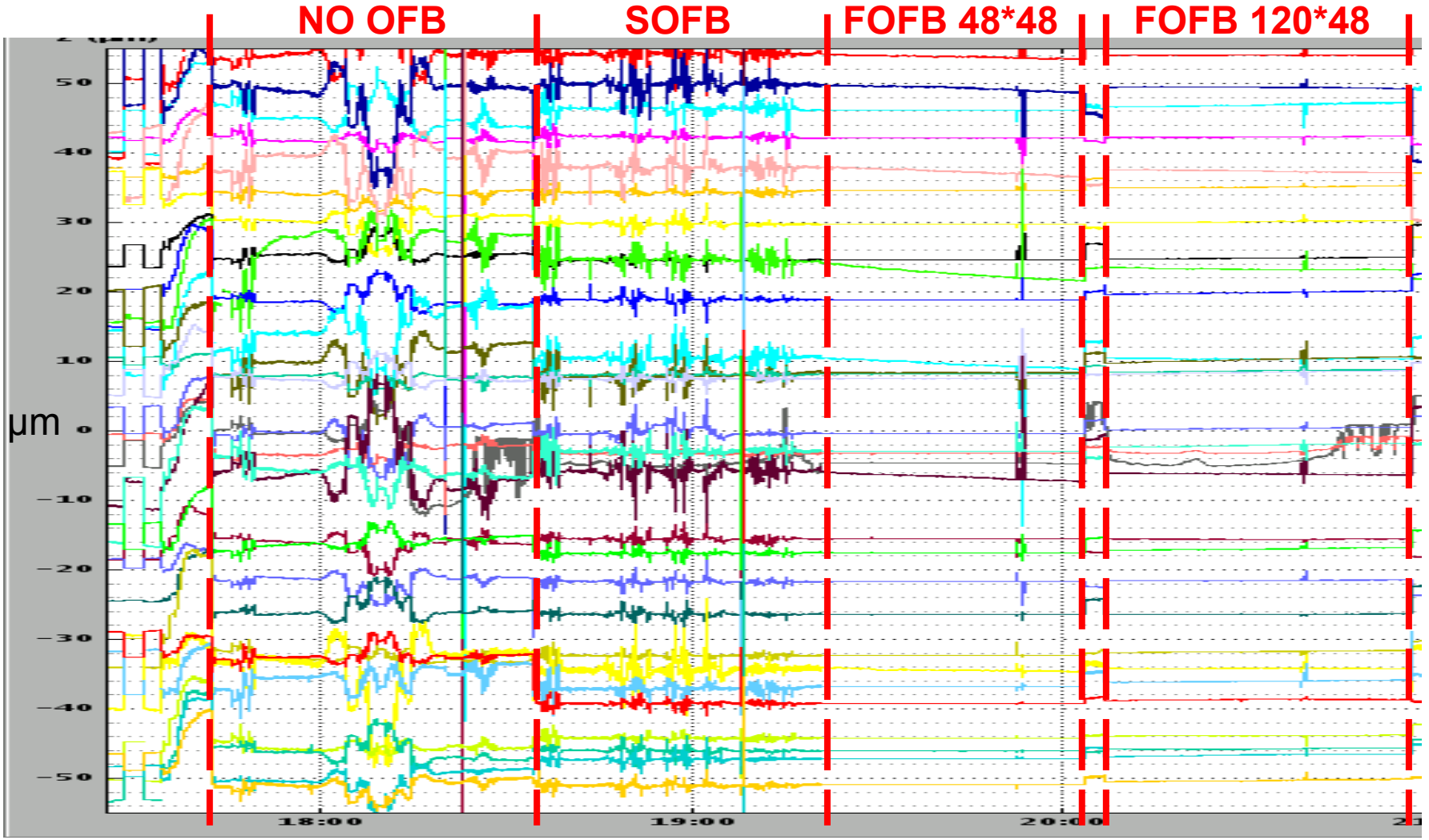
VERTICAL





FOFB Efficiency (0.01 Hz – 1 Hz)

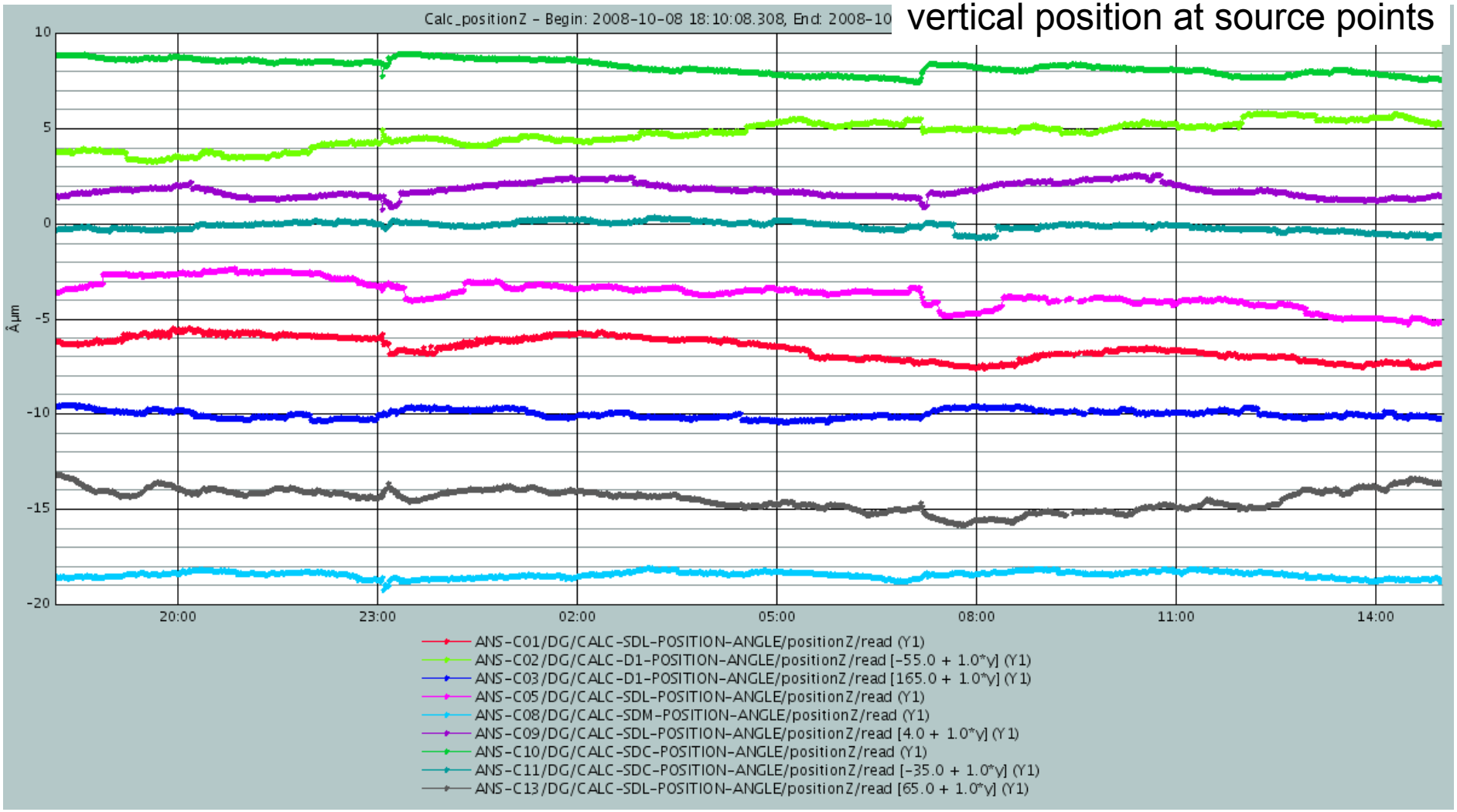
Effect on the perturbations caused by the insertion devices



vertical position at source points

FOFB Efficiency (DC-0.01 Hz)

Long term drifts



Results and further improvements

- Results:
  - No need for very good efficiency at high frequency
    - A damping factor of 2 is enough on 50 Hz -> done
  - We need a very good efficiency at low frequencies (0.01 Hz – 1 Hz)
    - beam stabilized:
      - with insertion devices moving -> done
      - with overhead cranes moving -> done
  - Stabilization of the long term drifts is about 1 µm rms
    - -> Needs to be improved
- Further improvements:
  - Optimisation on the eigen values
    - Different weight could be applied to different modes
  - Install the current dependence correction tables provided by release 1.82
  - Stability at the bending magnets source points:
    - Add more correctors
    - Include the X-BPMs in the loop

Conclusion

- SOLEIL FOFB system is very specific:
  - Advantages:
    - Dedicated air-coil correctors :
      - Cut-off frequency can be bring to 300 Hz if needed
    - Embedded system
      - Lower-cost using computing resources of FPGA BPM system
    - Flexibility
      - Easy change of correction algorithm
  - Disadvantages:
    - Set-up and optimization of the system take more time:
      - 2 sets of correctors: Different location and efficiency ->Download process
      - Any upgrade of the Libera firmware implies new integration and new test of the FOFB algorithm.
- First results have proven that this solution works and is very reliable.

Presentation is over !!