國家同步輻射研究中心
National Synchrotron Radiation Research Center

Fast Orbit Feedback Scheme and Implementation for TPS

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Outlines

1. FOFB infrastructure
2. BPM & FOFB computation module
3. Corrector power supply & CPSC interface
4. Simulation
5. Summary

FOFB Infrastructure

Orbit Stability Requirements of the TPS

Beam size $\sigma_{x,y}$ and beam divergence $\sigma_{x',y'}$ for 1 % coupling, 24P79H2 configuration. Natural horizontal emittance is 1.6 nm-rad.

Source point	σ_x (μm)	$\sigma_{x'}$ (μrad)	σ_y (μm)	$\sigma_{y'}$ (μrad)
12 m straight center	165.10	12.49	9.85	1.63
7 m straight center	120.81	17.26	5.11	3.14
Dipole (1 degree source point)	39.73	76.11	15.81	1.11

Rules of thumbs for vertical orbit stability:

σ_y/10 : ~ 0.5 μm stability is required.

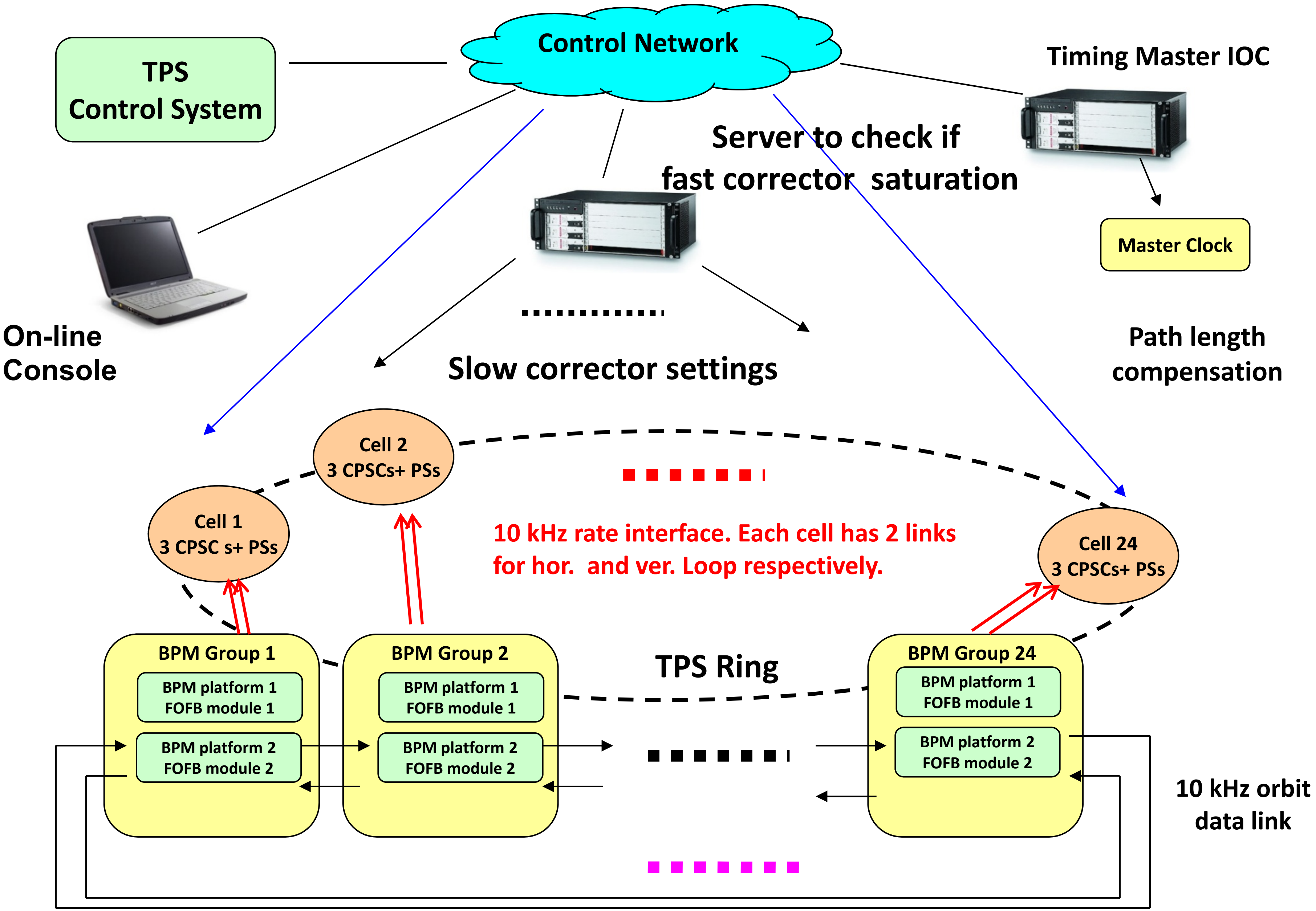
or further

σ_y/20 : ~ 0.25 μm stability is required.

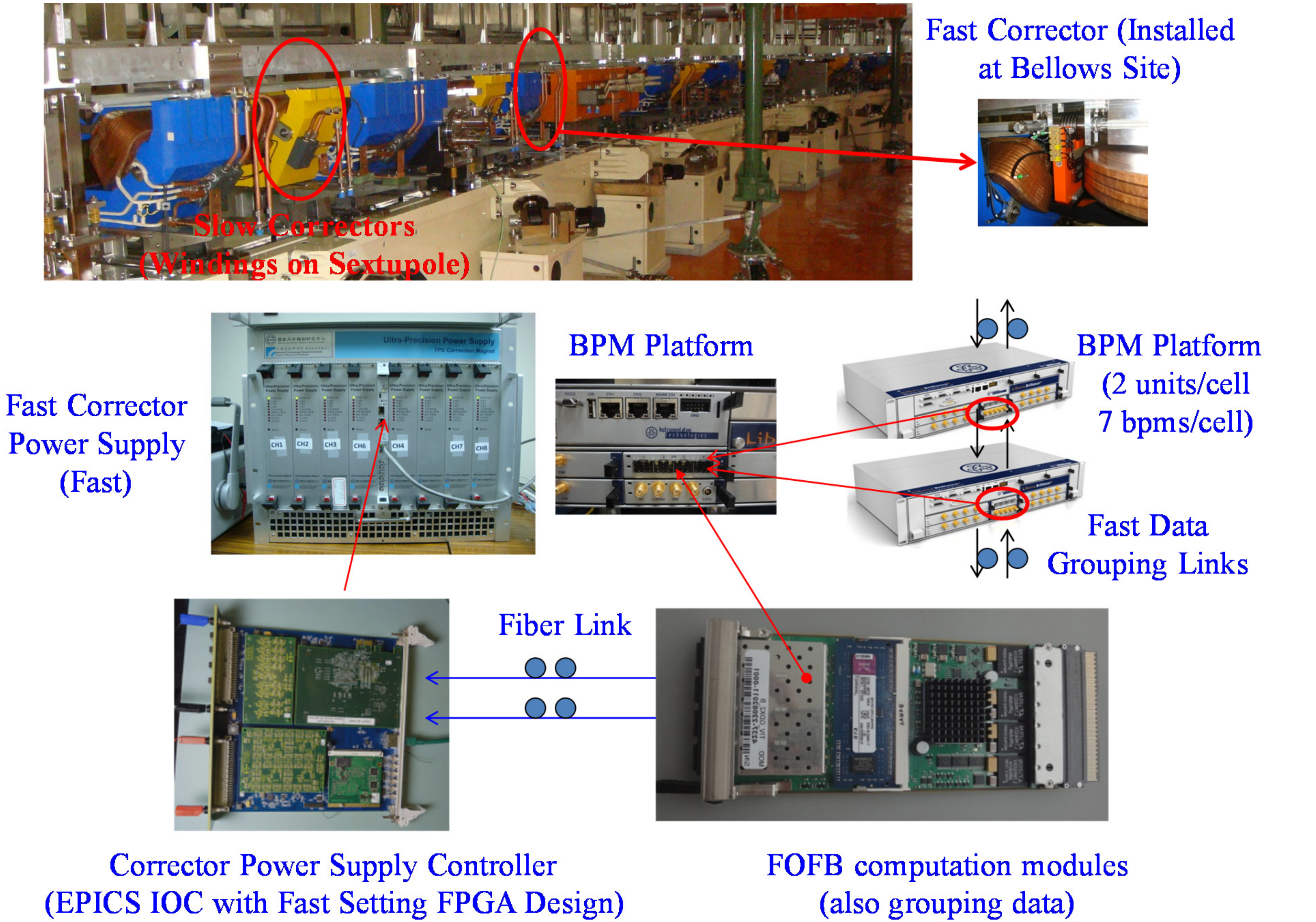
Reference:

1. Paragraph of "Accelerator" in the TPS Design Handbook

Infrastructure for FOFB

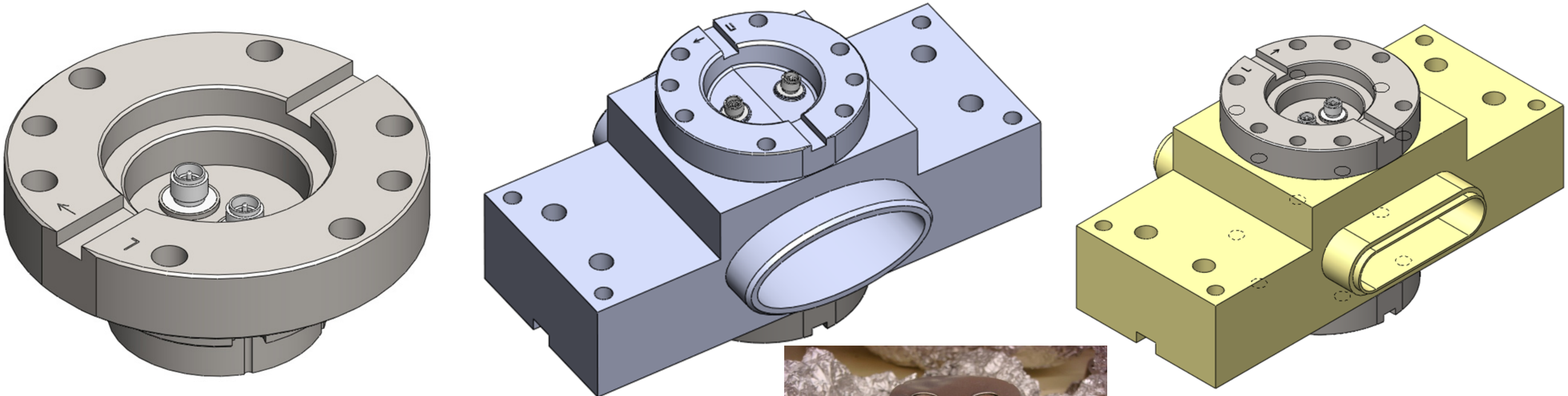


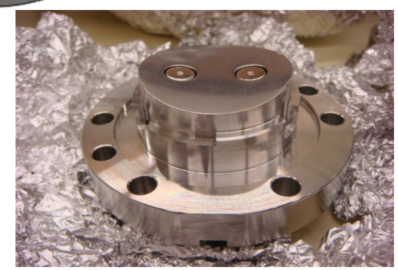
Major Components for FOFB in one cell



BPM & FOFB Computation Module

Beam Position Monitor

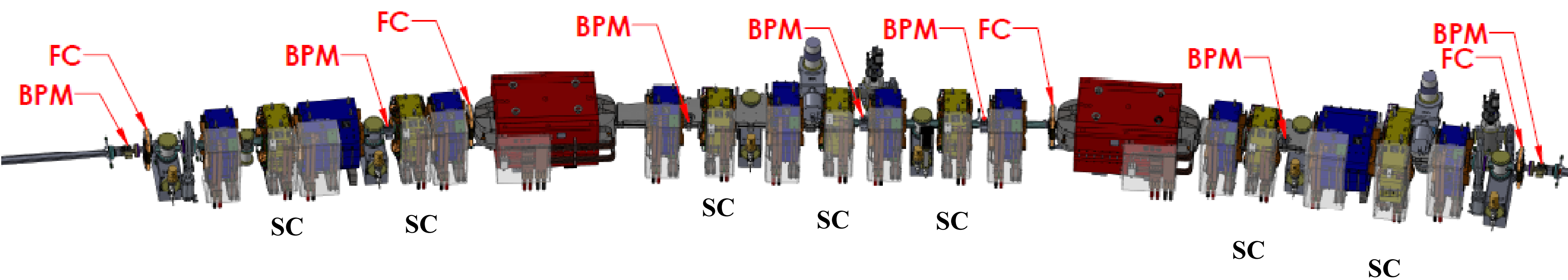




BPM*7

Fast corrector*4

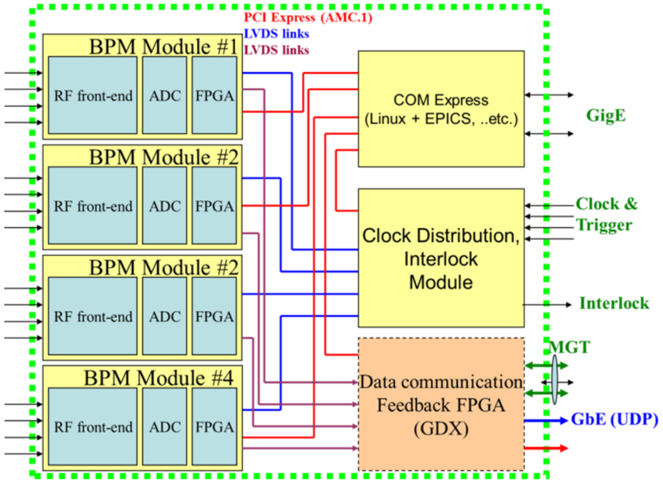
One cell



Slow corrector*7

BPM Electronics

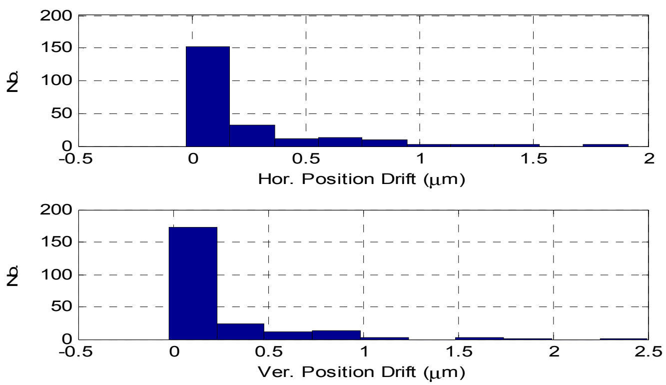
- Libera Brilliance Plus.
- 76 units (60 booster & 168 SR BPM)
- ICB + BPM + Timing + GDX modules
- GDX support BPM grouping & FOFB functionality



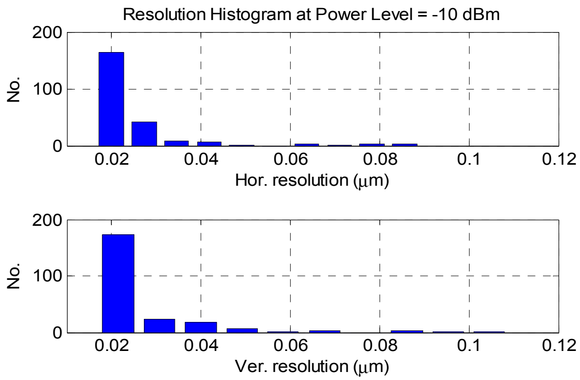
specification & measured performance

Parameters	Beam Charge/Current Range	Spec. (in rms)	Measured (in rms)
Single pass sensitivity and resolution	100 pC	< 1 mm	0.2 mm
Turn-by-turn resolution	0.5 mA	< 1 mm	0.15 mm
	10 mA	< 100 um	10 um
	500 mA	~ 1 um	1 um
Resolution (10 Hz update rate)	0.5~10 mA	< 1000 nm	80 nm
	100~500 mA	< 100 nm	20 nm
Resolution (10 KHz update rate)	100~500 mA	< 200 nm	100 nm
Beam current dependence	100~500 mA	< 1000 nm	200 nm
Filling pattern dependence	100~500 mA	< 1000 nm	200 nm
Temperature dependence		<1000 nm/°C	~ 100 nm/°C

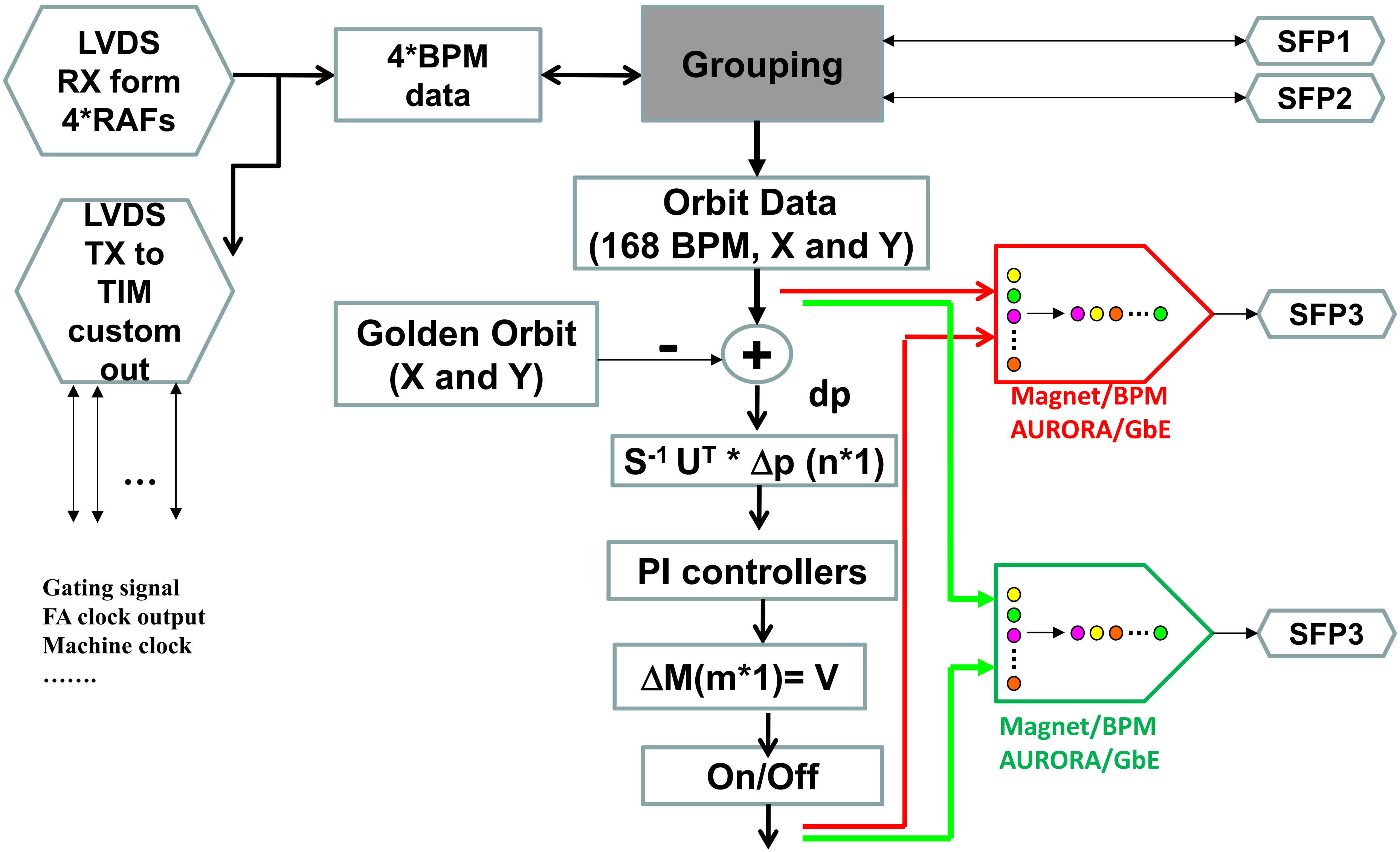
One hour stability test



10 hz resolution



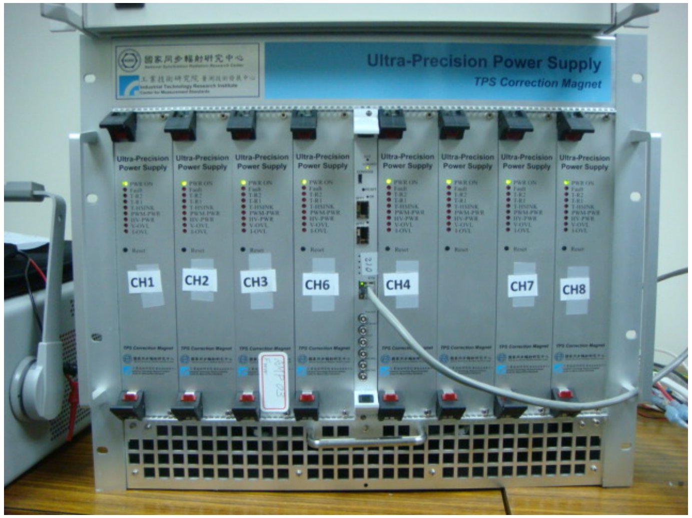
Block of FOFB computation modules



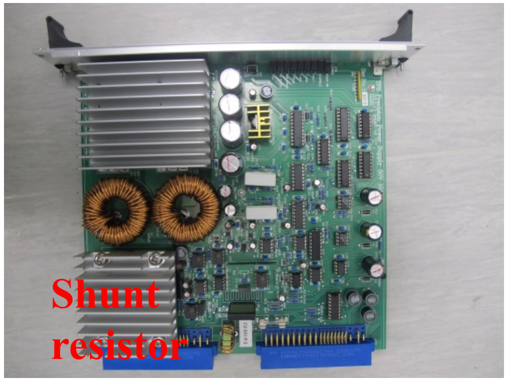
Corrector Power Supply & CPSC

Corrector Power Supply

- Switching power supply with analogue regulator. ±10A/± 48V
- Desiged in- house.
- Used for both slow and fast correctors.
  - Slow correctors: control resolution & low noize level
  - Fast correctors: fast respose.
- Two different controller and current sensors for slow (DCCT) and fast correctors (current sensing shunt resistor).
- Same control interface: CPSC(corrector power supply controller)



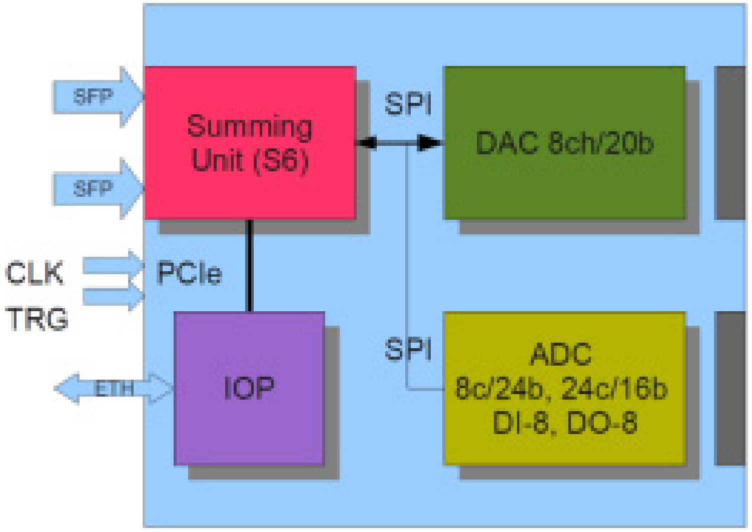
For slow corrector

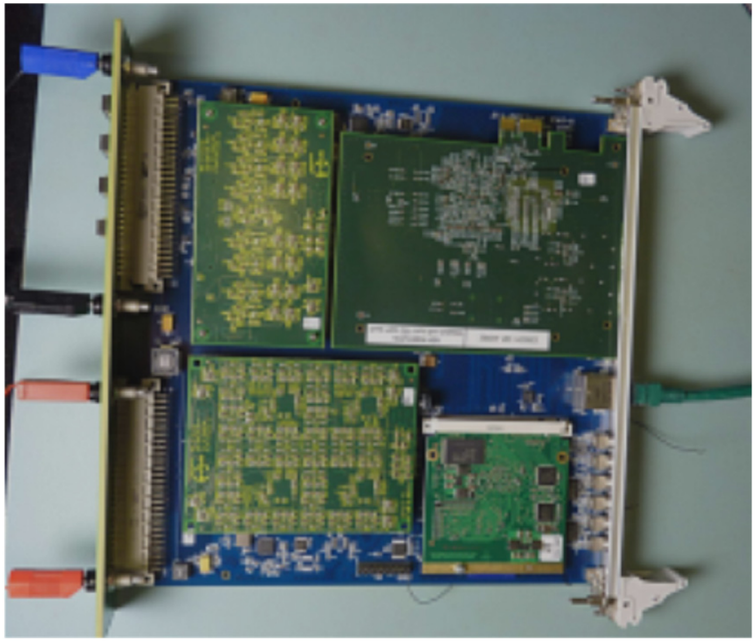


For fast corrector

Corrector Power Supply Controller (CPSC)

- The corrector power-supply controller (CPSC) :
  (1) Computer (2)Xilinx Spartan-6 FPGA (3) ADC (4) DAC
  - Slow access for the EPICS clients.
  - Fast settings from orbit feedback system or the feedfoward application such as skew compensation through SFP port.
- Waveform reading & writing
- DI/DO for timing, fault detect, and so on.
- Contracted to D-TACQ.

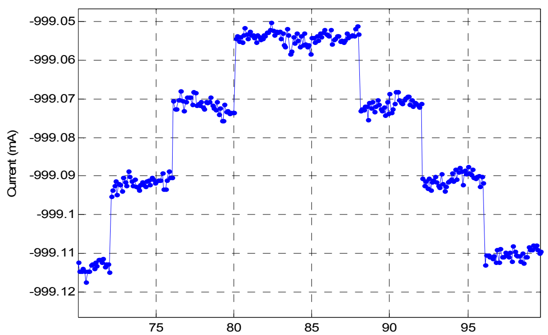




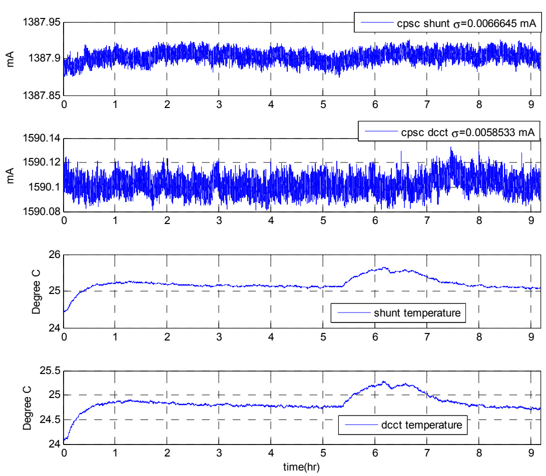
Power Supply Measurement

- 19 bit resolution achieve.
- Noise level is around -120 dB and would contribute <200 nm RMS orbit disturbances for total 168 slow correctors from DC~1kHz.
- Fast corrector ~ 1.3kHz bandwidth.
- 10 hour stability rms~ 5 uA.

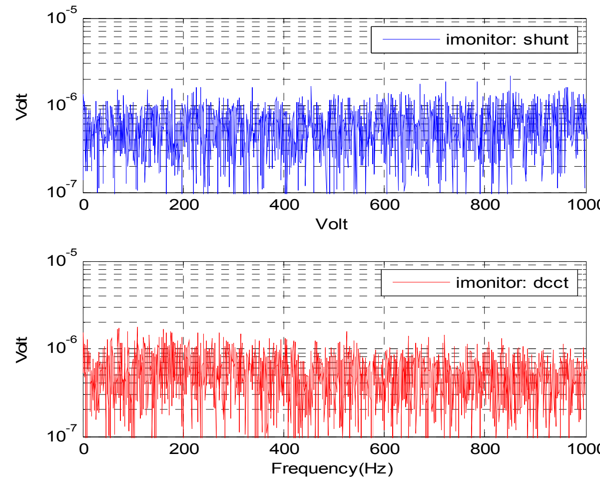
1bit step change



10 hour stability



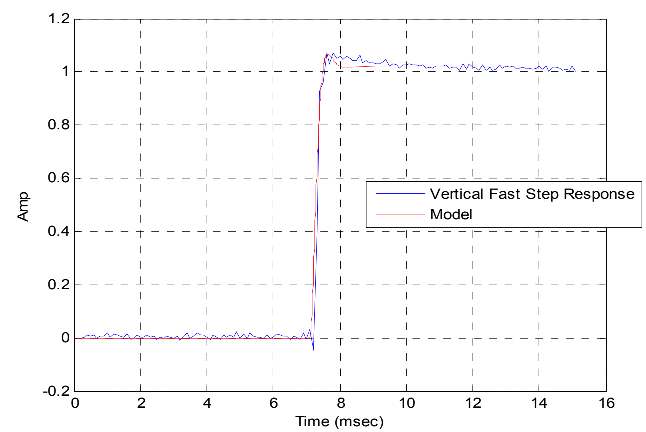
Noise level



Fast corrector

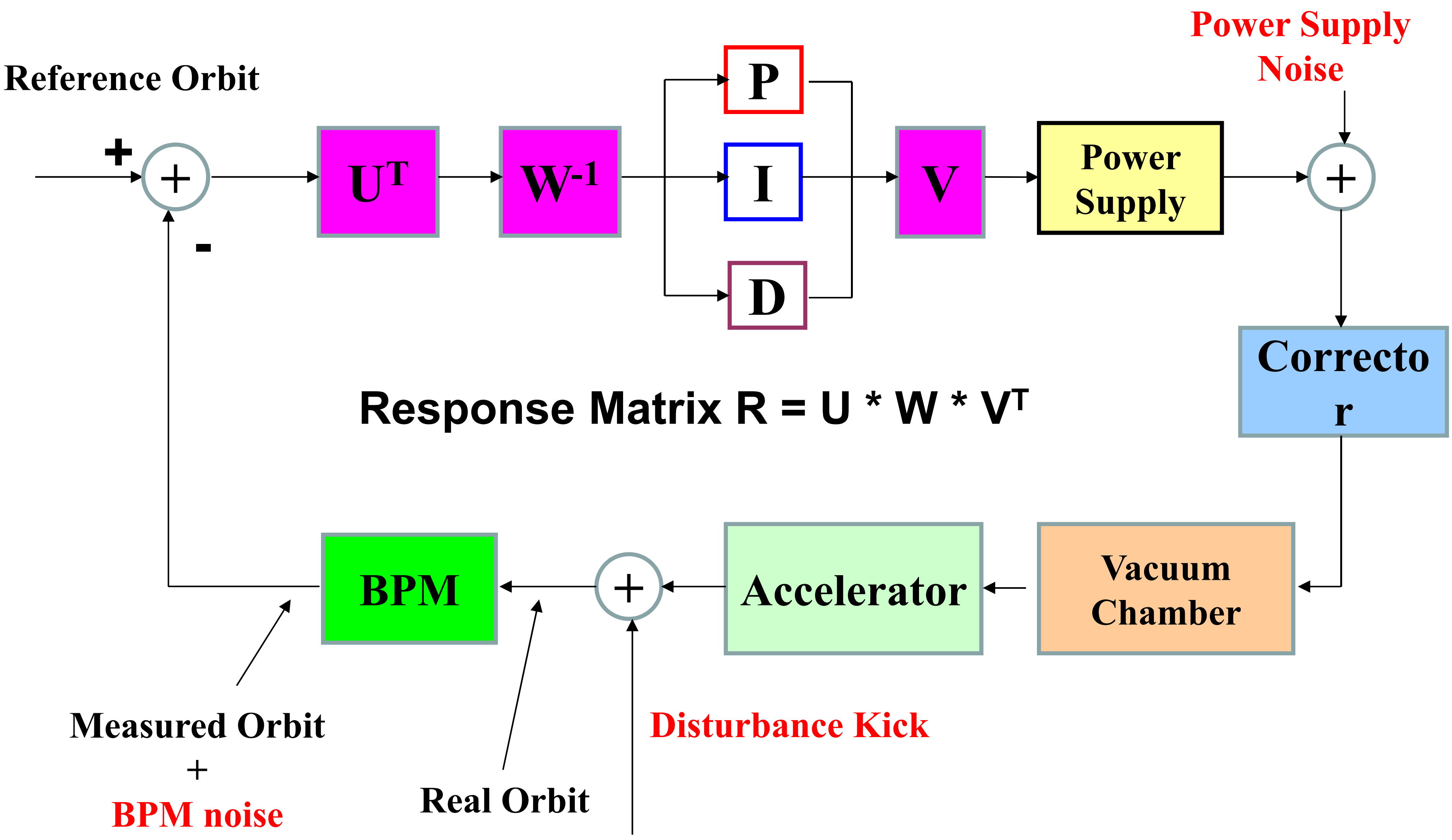
Slow corrector

Step response



Simulation

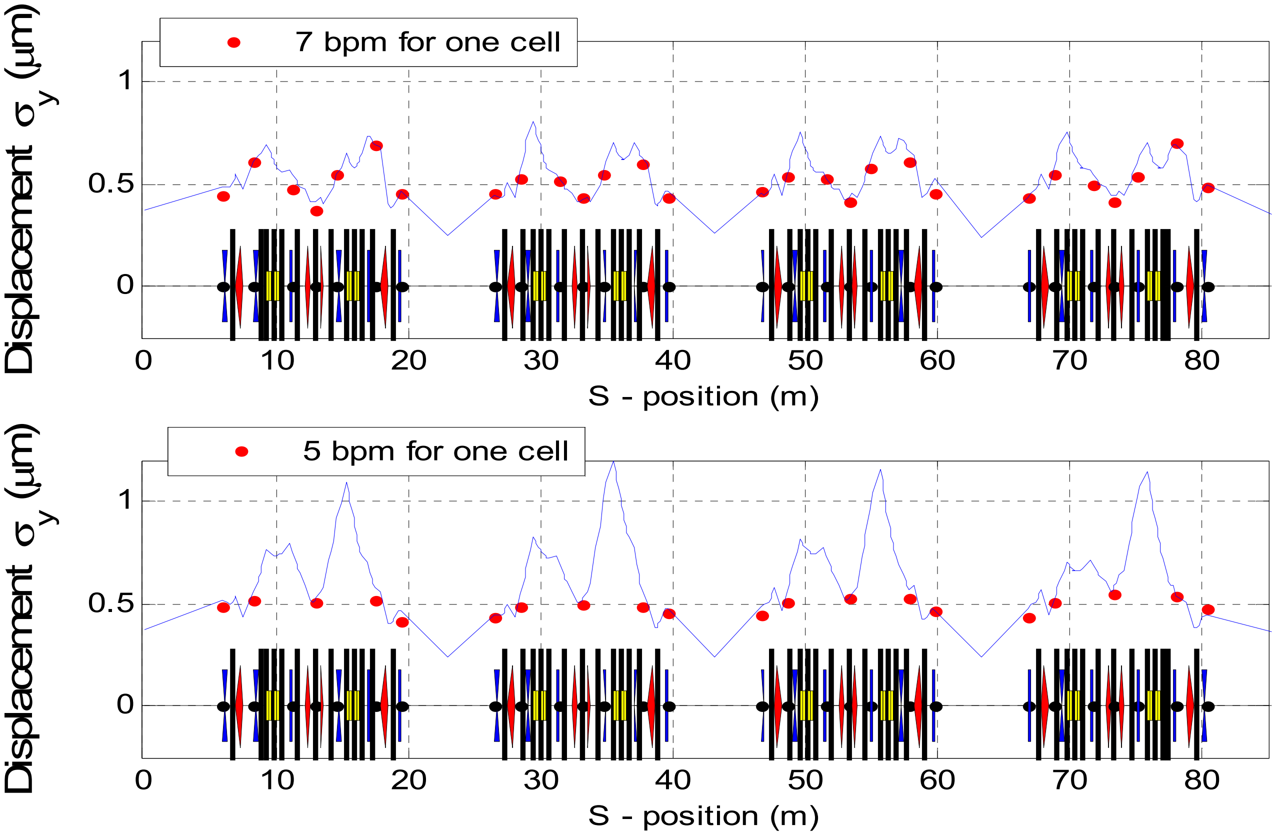
Orbit Feedback Loop Simulation



Static Simulation Results

Case 1: 7 bpms used for FOFB ~ 300 nm COD at straight line
~ 600 nm at bending section
Case 2: 5 bpms used for FOFB ~ 300 nm COD at straight line
~ 1000 nm at bending section

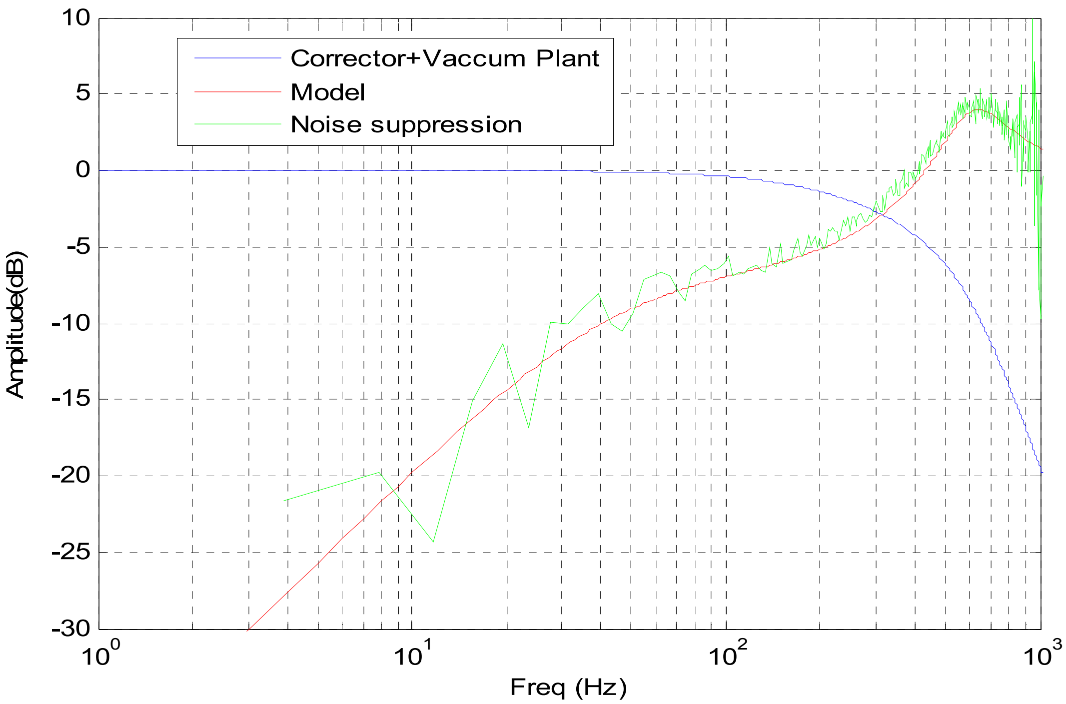
- **200 sets of random quadrupole displacements is taken.**



Noise Sensitivity Function

Sensitivity function = |1/(1+ $G_{\text{transfer function}}$)|

- Corrector bandwidth = 300 Hz
- PS bandwidth = 1.3 kHz
- Vacuum Chamber bandwidth = 500 Hz
- Noise suppression bandwidth is around 300 Hz.

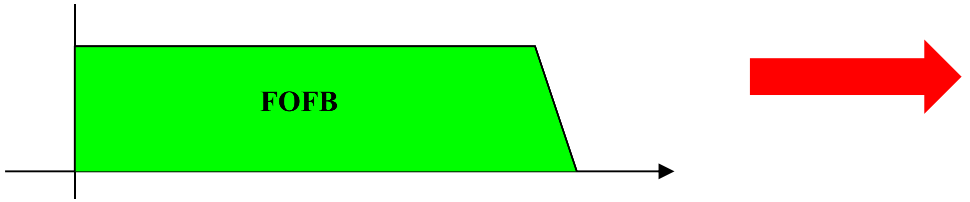


3dB B.W. ~ 300 Hz

Schemes to deal with slow & fast correctors

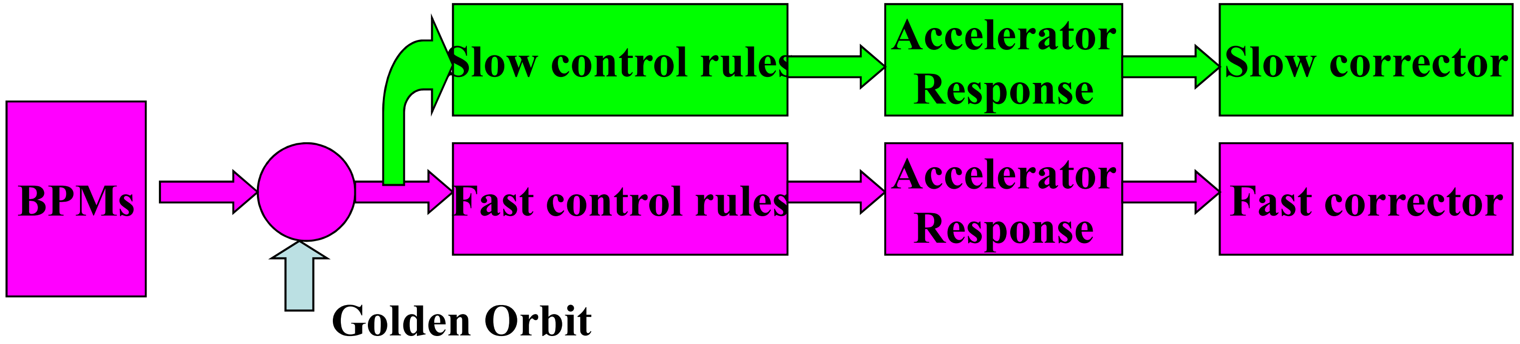
- **SOFB at beginning, then FOFB later, running FOFB only!**
- **SOFB and FOFB running as two independent system. Some with frequency dead-band**

- **FOFB run from DC, a slow system receives the fast correctors from their DC part to prevent saturation.**



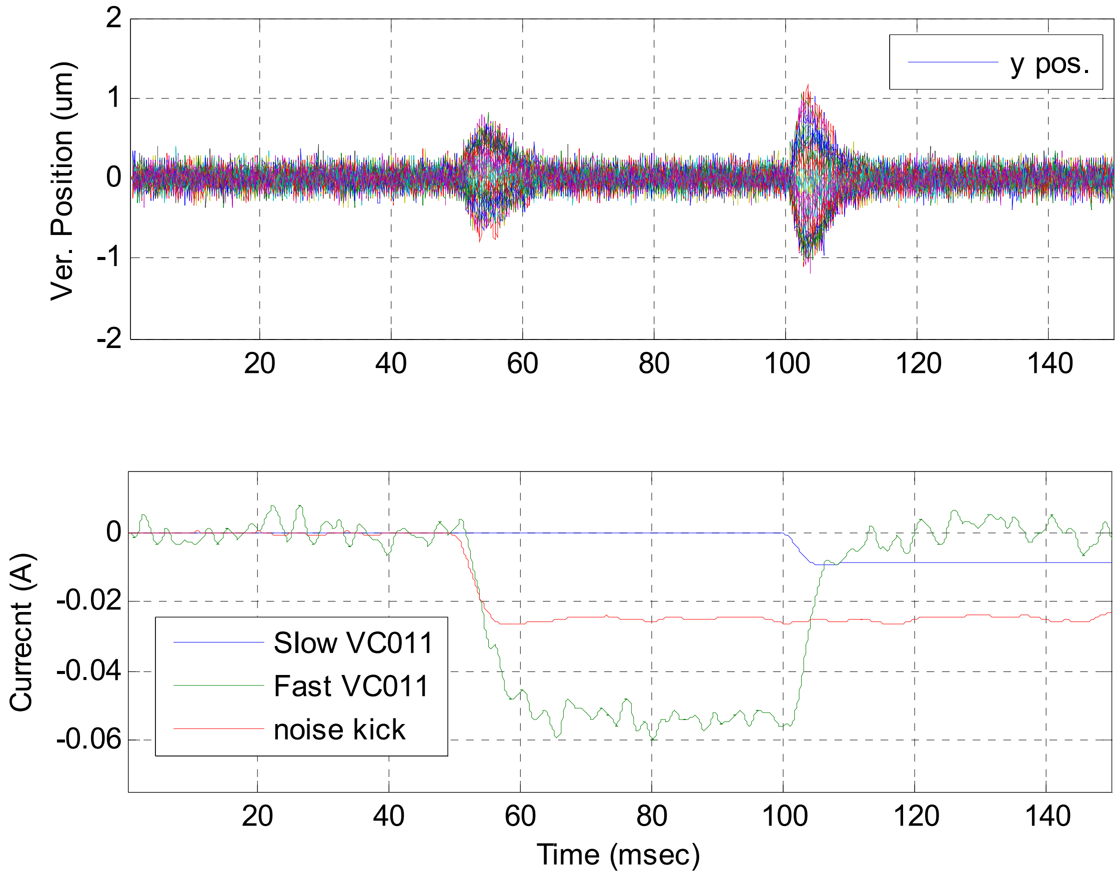
Current solution

- **Orbit feedback system with combined fast and slow correctors**



Orbit disturbance when correction transfer

- The transaction when DC part of fast corrector transfer to slow corrector.
- At 50 msec, a kick (~120 nrad) cause orbit excursion and soon FOFB suppress it in 10 msec and it results in one corrector (fast VC011) has 60 mA DC offset.
- At 100 msec, the nearby slow (slow VC011) take DC parts of the slow correctors and fast corrector decreasing to zeros.
- The transaction between slow and fast will only cause orbit disturbance less than 1 um and vanish in 10 msec.



Summary

Summary

BPM

New generation digital BPM electronics ready for install
20 nm resolution for 10 Hz; 100 nm resolution for 10 kHz

Corrector power supply

Analogue switching power supply

- **~ -120 dB noise level**
- **> 18 bit control resolution**
- **~ sync by external trigger**
  - **fast setting from FOFB**
  - **slow setting for EPICS clients**

FOFB scheme

Fast orbit feedback => 10 kHz update rate, 300 Hz bandwidth, run from DC
Latency: 10 usec (BPM) + 2 usec (computation) + 2 usec (fiber) ~15 usec
Slow corrector compensation

Thank You for Your Attention!