Global Orbit Stabilization System for Photon Factory Electron Storage Ring

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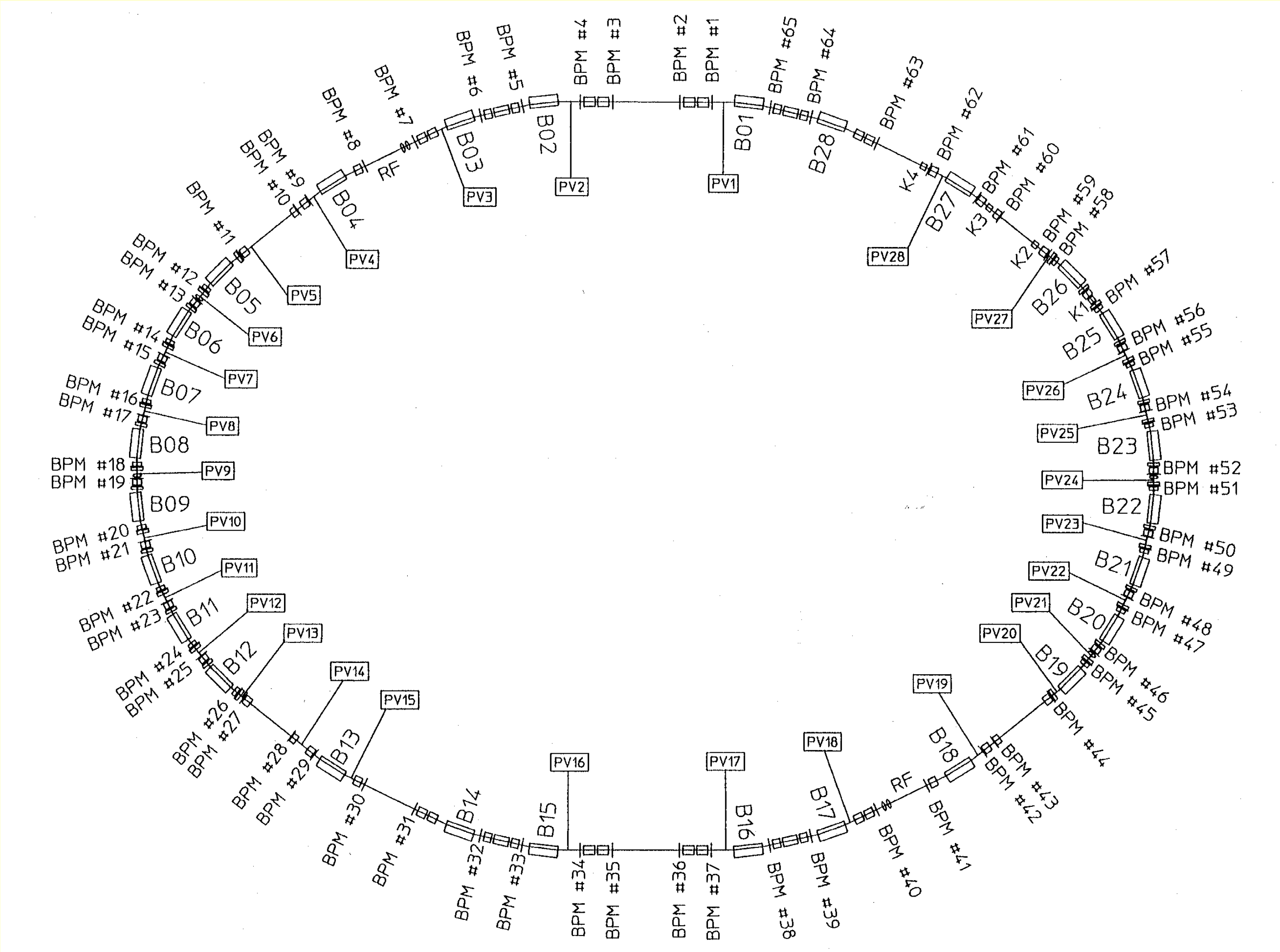
System Overview; Vertical COD Correction

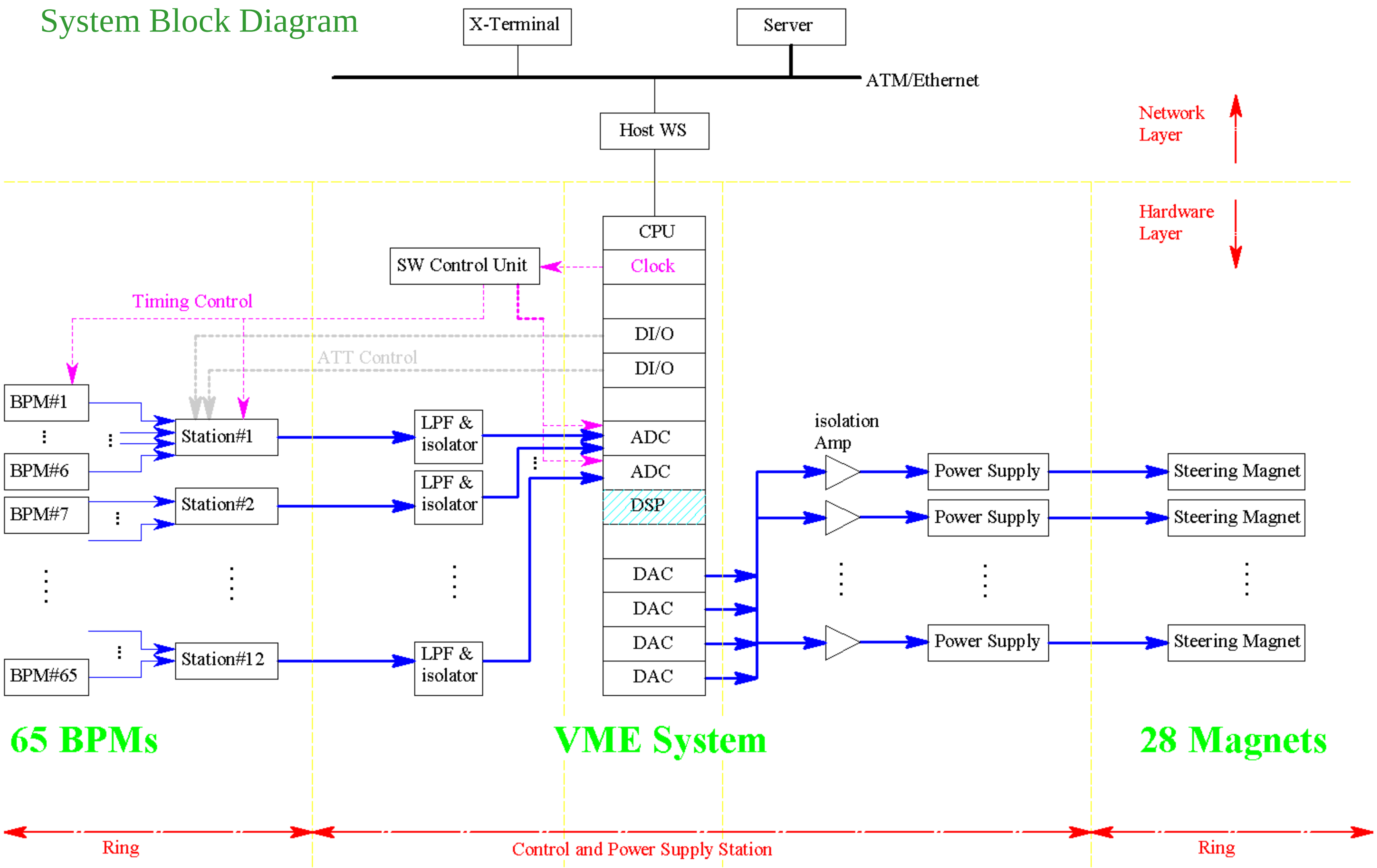
- Sources of orbit fluctuations:
  - Building vibration (1〜10mHz)
  - magnet cooling water temperature
  - AC power line
  - …. Etc.
- Frequency range of feedback system: ***up to 50Hz***

- Goal:
  - Fast data-taking (<1ms)
  - High Position resolution(<10?m)
  - High speed signal processing (<1ms)
  - Fast Steering Magnet & power supply (>100Hz)

Layout of BPM, Steering Magnets



System Block Diagram



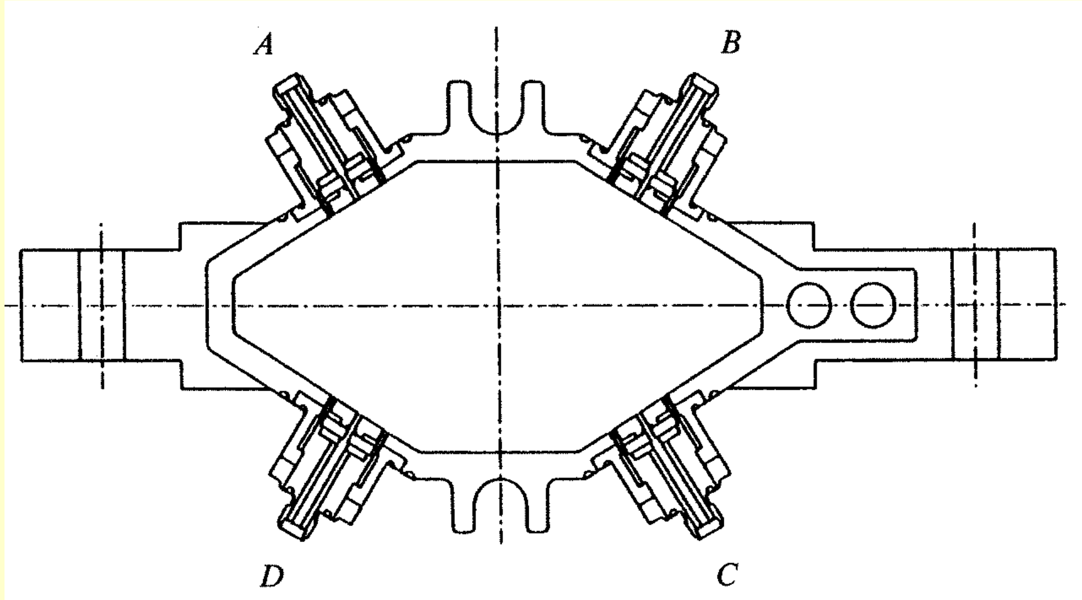
- Station #1..#12 contain multiplexers and superheterodyne detectors.
- LPF : Low Pass Filter, ATT: Attenuator, SW: PIN diode Switch

Beam Position Detection

- 65 Beam Position Monitors (BPMs)
  - 41: 4-Button, SMA feedthrough [new type]
  - 24: 6-Button, BNC feedthrough [old type]
- 5～6BPMs are scanned with PIN diode switch
- Superheterodyne detector
- Low Pass Filter (LPF) to avoid the effect of coherent synchrotron oscillation(fc=10kHz)
- Sampling time for whole BPMs: minimum 2ms
  - (For now, we took <u>12ms</u> for routine SR user operation)
- Measured relative accuracy: <3?m

Cross Section of BPM

- New type
  - 4 electrode



Signal Processing Hardware

- VME System
  - ADC (8-channel, 16bit) × 2
  - DSP(TMS320C40) ×1
  - CLOCK
  - CPU (CPU:68030, OS: VxWorks)
  - Digital I/O × 2
  - DAC (8-channel, 16bit) × 4
- Networking
  - ATM/Ethernet network
  - Host workstation

Signal Processing Scheme

1. Check the output voltage of each electrode (consistency check)
2. Calculate the beam position
3. Calculate the corrector current
   - We adopted the singular value decomposition(SVD) method
   - Number of eigenvalues : 5
   - inverse matrix is previously calculated and downloaded to DSP
4. PID control
5. Set the corrector current

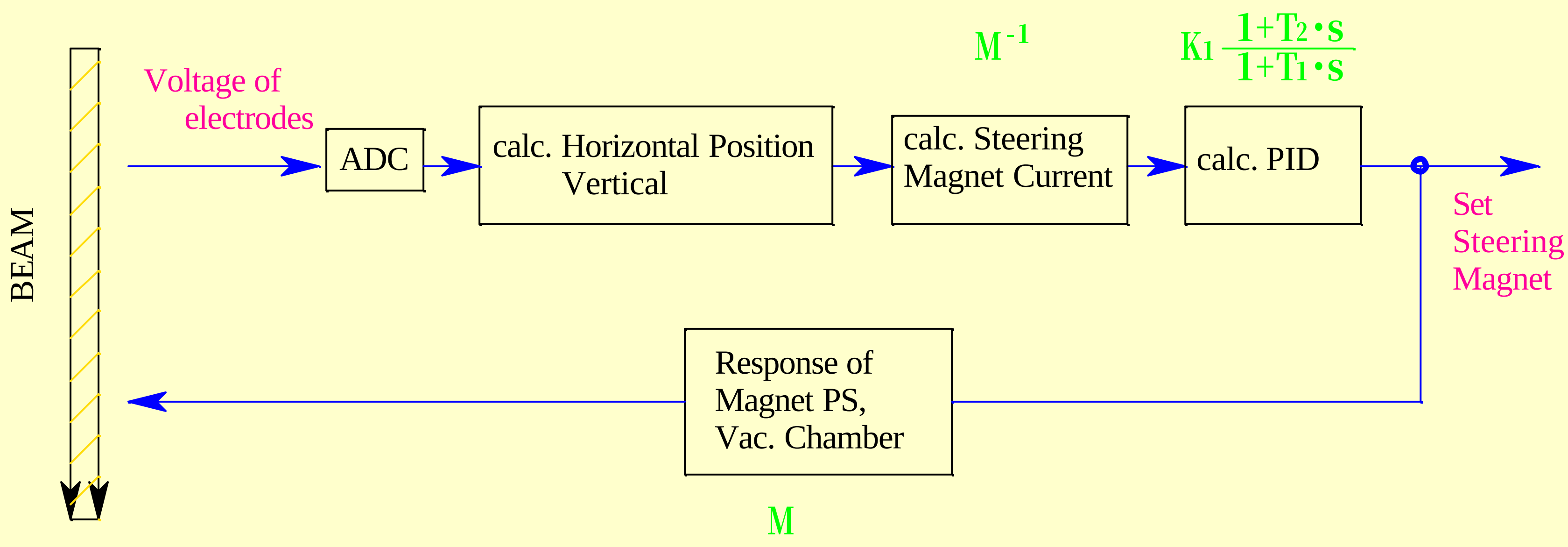
- Frequency response is mostly determined by the 0-th order hold effect.

Correctors

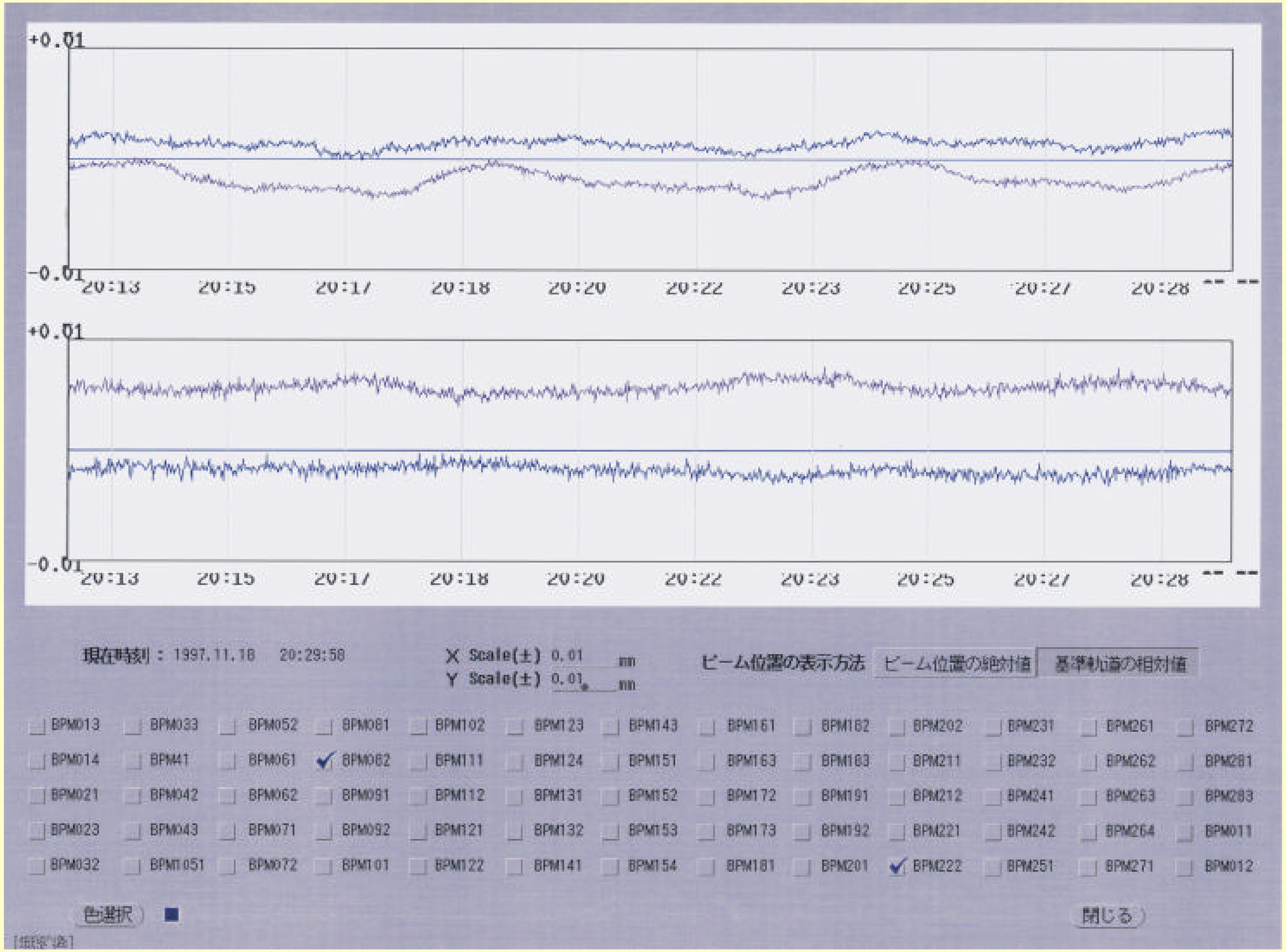
- 28 correctors for vertical feedback
- 0.35mm-thick silicon steel lamination magnet
- Frequency response of power supplies and magnets are high enough. (there is no reduction in gain/phase up to about 100Hz)
- Isolation amp is used to maintain isolation between VME and correctors.

For local feedback system, another 28 correctors for both vertical and horizontal plane will be installed.

Block Diagram of Global Feedback System

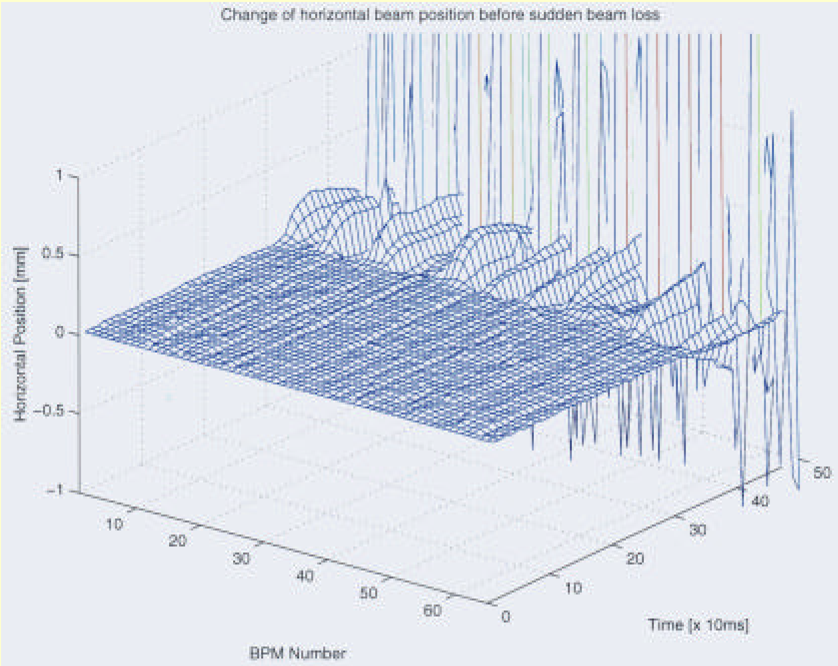


Measurement Example 1

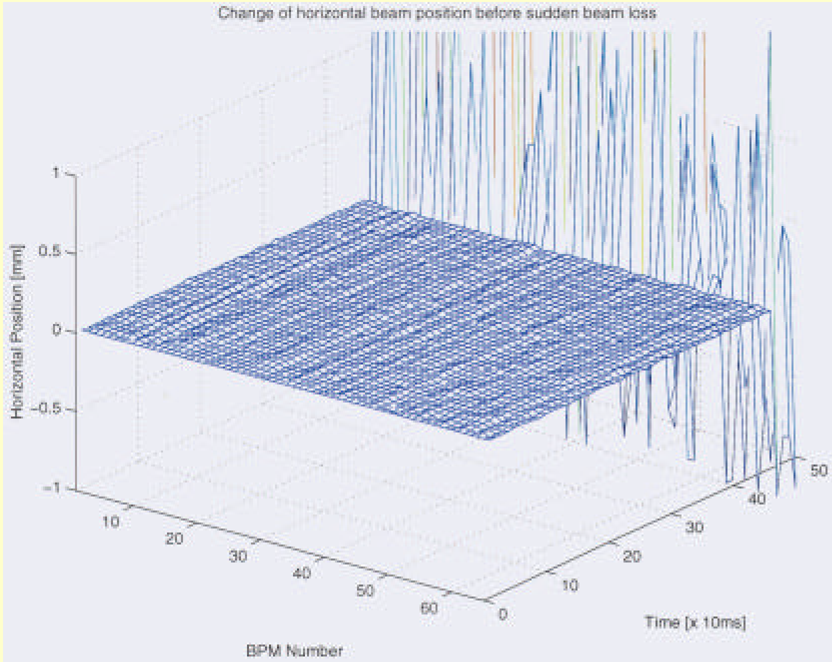


Measurement Example 2

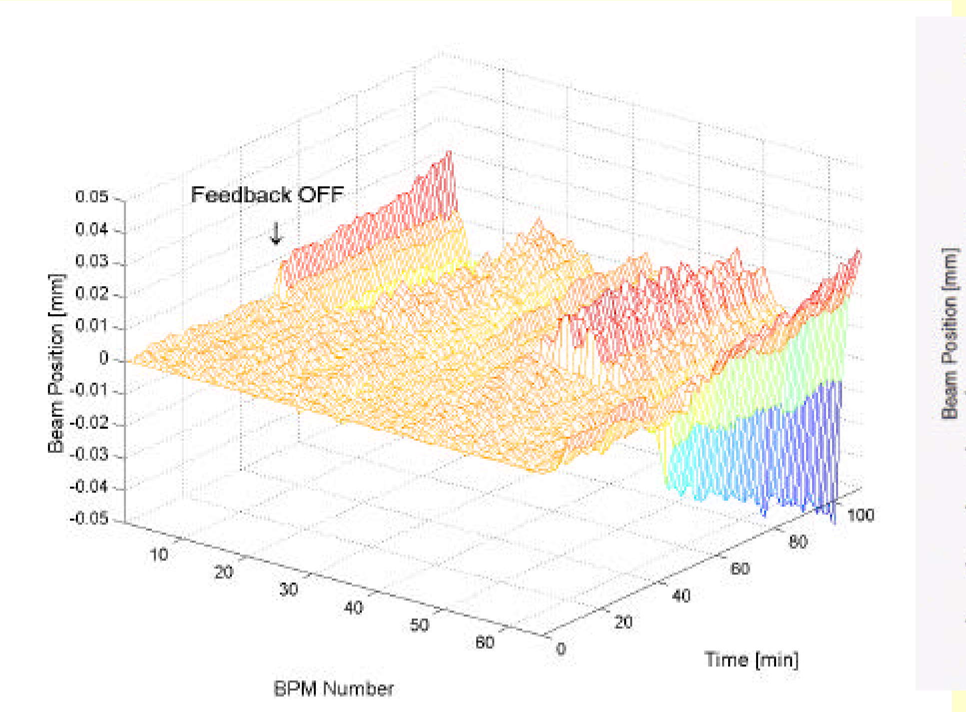
Beam loss due to magnet power supply failure



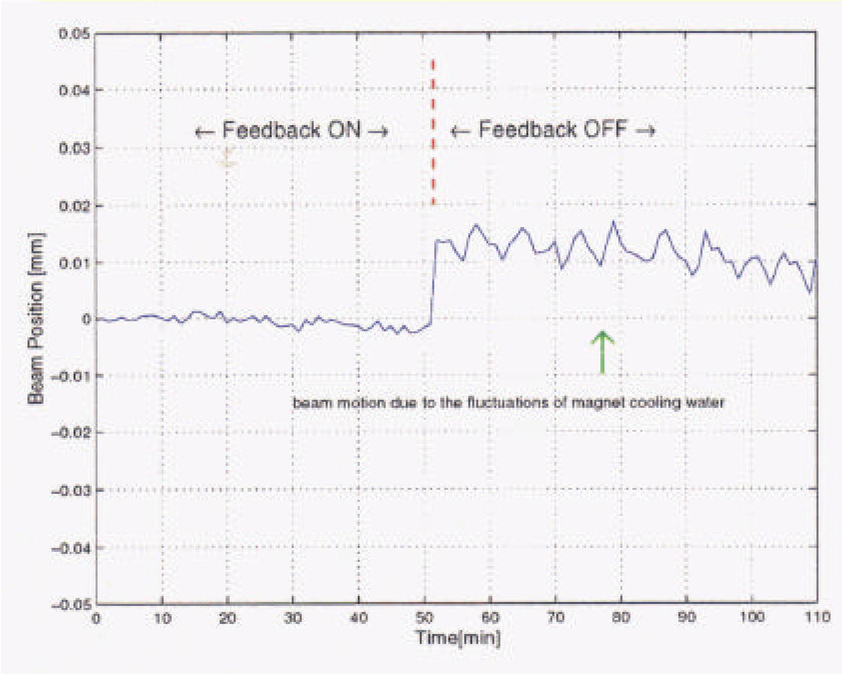
Beam loss due to RF trouble



Beam Motion with/without Feedback

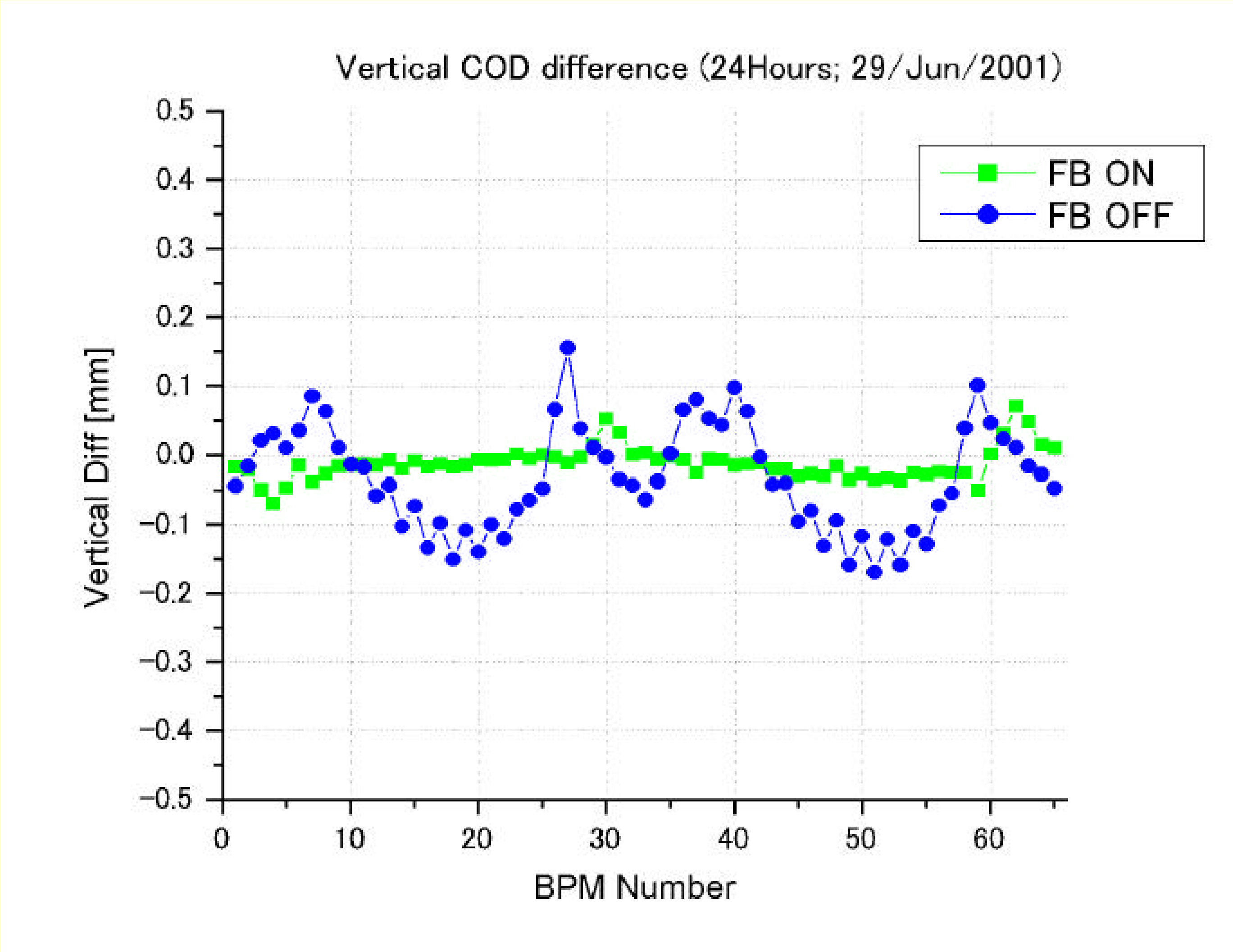


Beam Motion at BPM#50



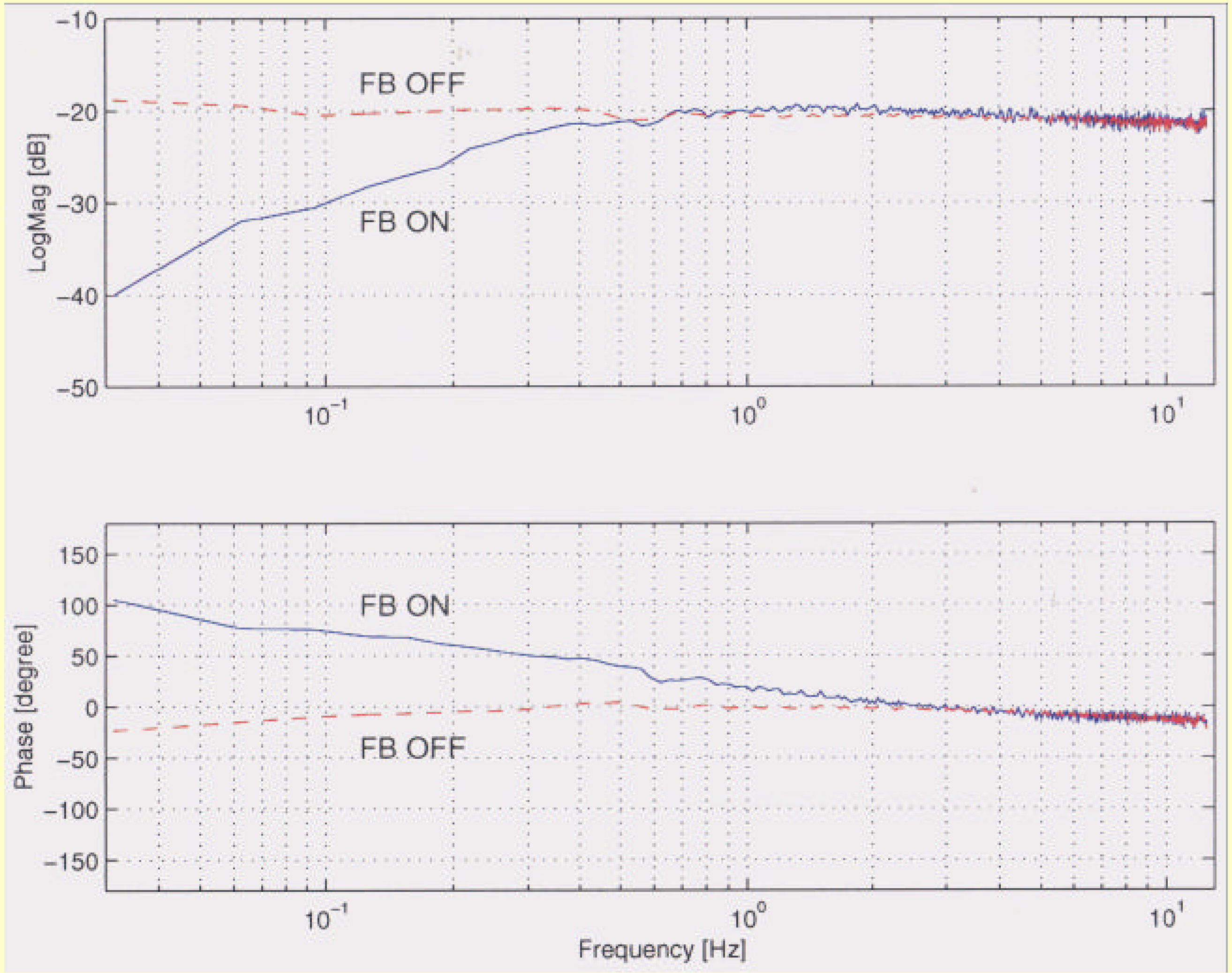
Vertical beam motion with and without global feedback. Feedback system was turned off at 50min and the kick angle of all correctors were set to be zero. After the feedback is turned off, drifts and vibrations of the beam positions are observed.

Vertical Orbit Drifts (for 24 hours)



Closed orbit distortion (COD) relative to the standard orbit of the PF-ring.

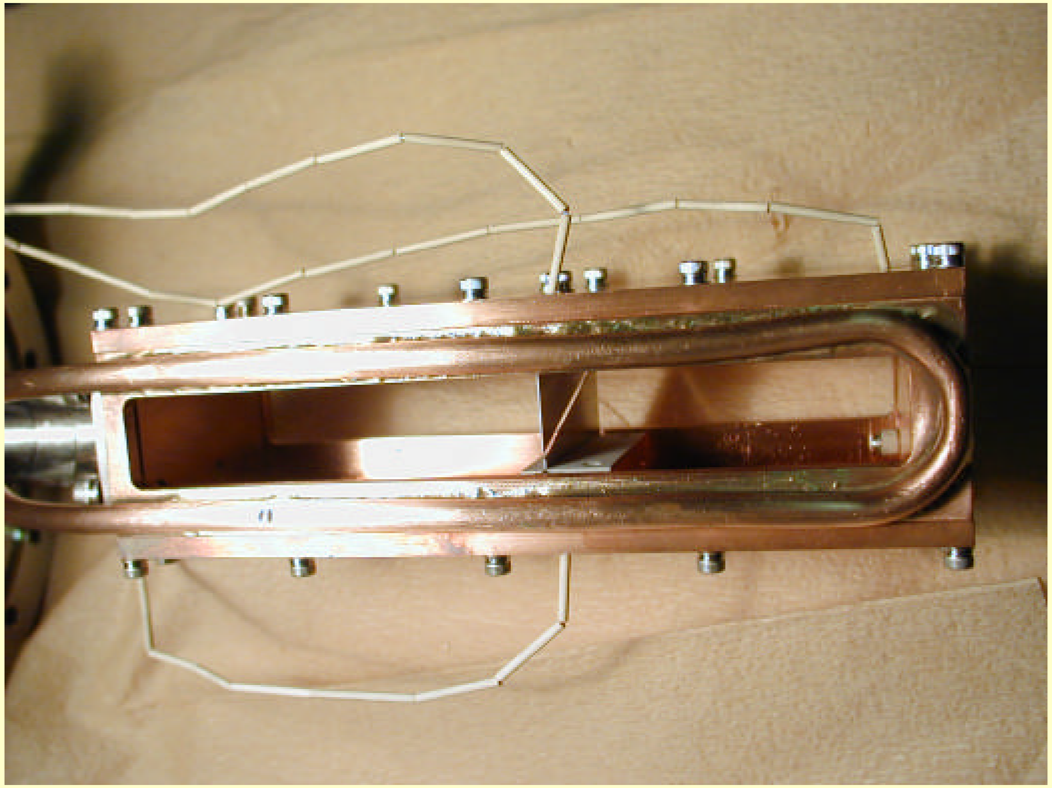
Frequency Response



Frequency response of the beam position to the excitation of a corrector. -3.0dB point is about 0.3Hz (At present, this parameters are used in the routine operation for SR users). We can easily increase the frequency response up to 1Hz by refining the PID parameters.

Photon Beam Position Monitor

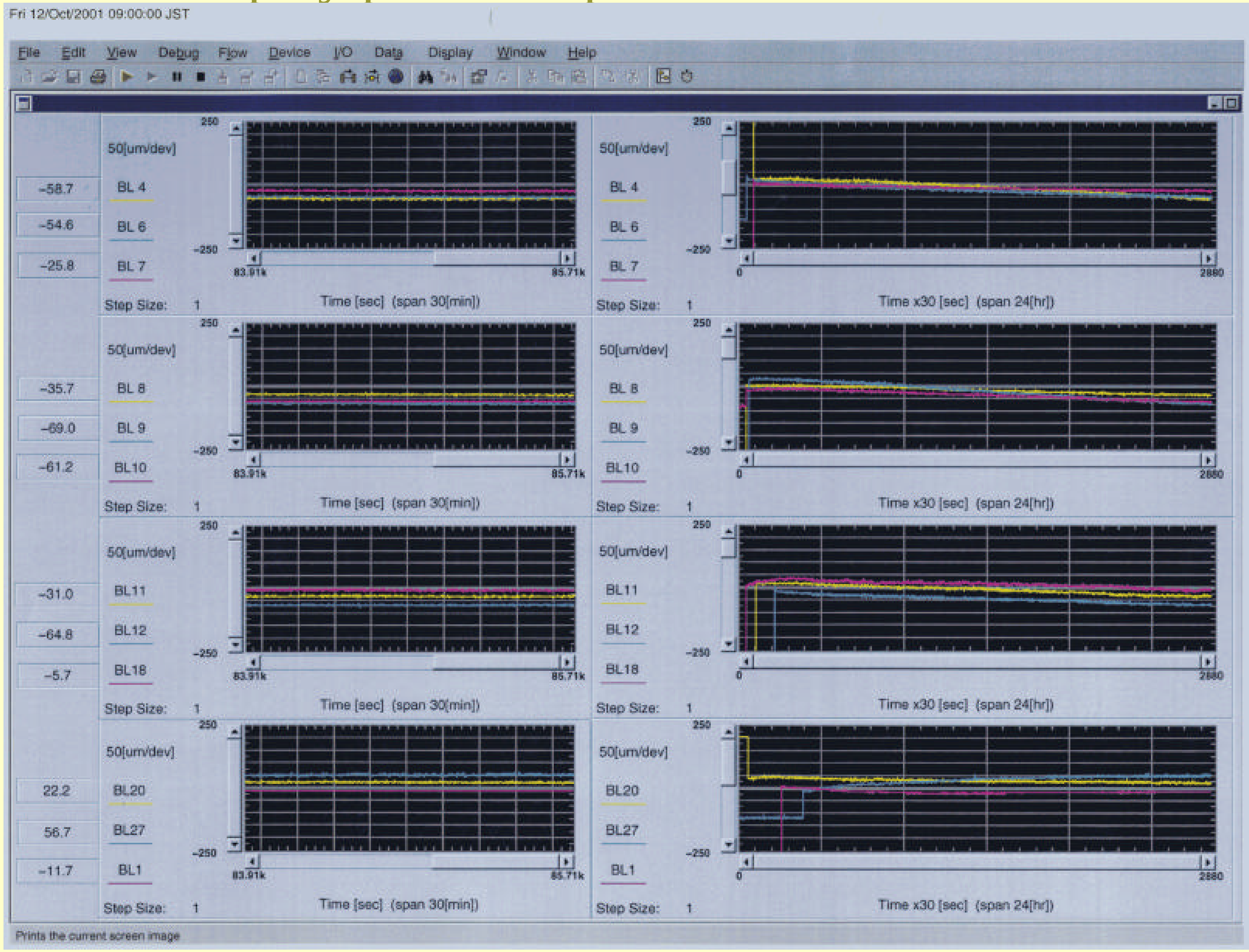
- Photograph of the monitor head



station	beamline number	position[mm]
1	BL-4	4925
	BL-6	4275
	BL-7	4300
	BL-8	4300
2	BL-9	4300
	BL-10	4300
	BL-11	4275
	BL-12	4300
3	BL-18	5690
	BL-20	4185
4	BL-27	9190
	BL-1	4300

Location of the monitor

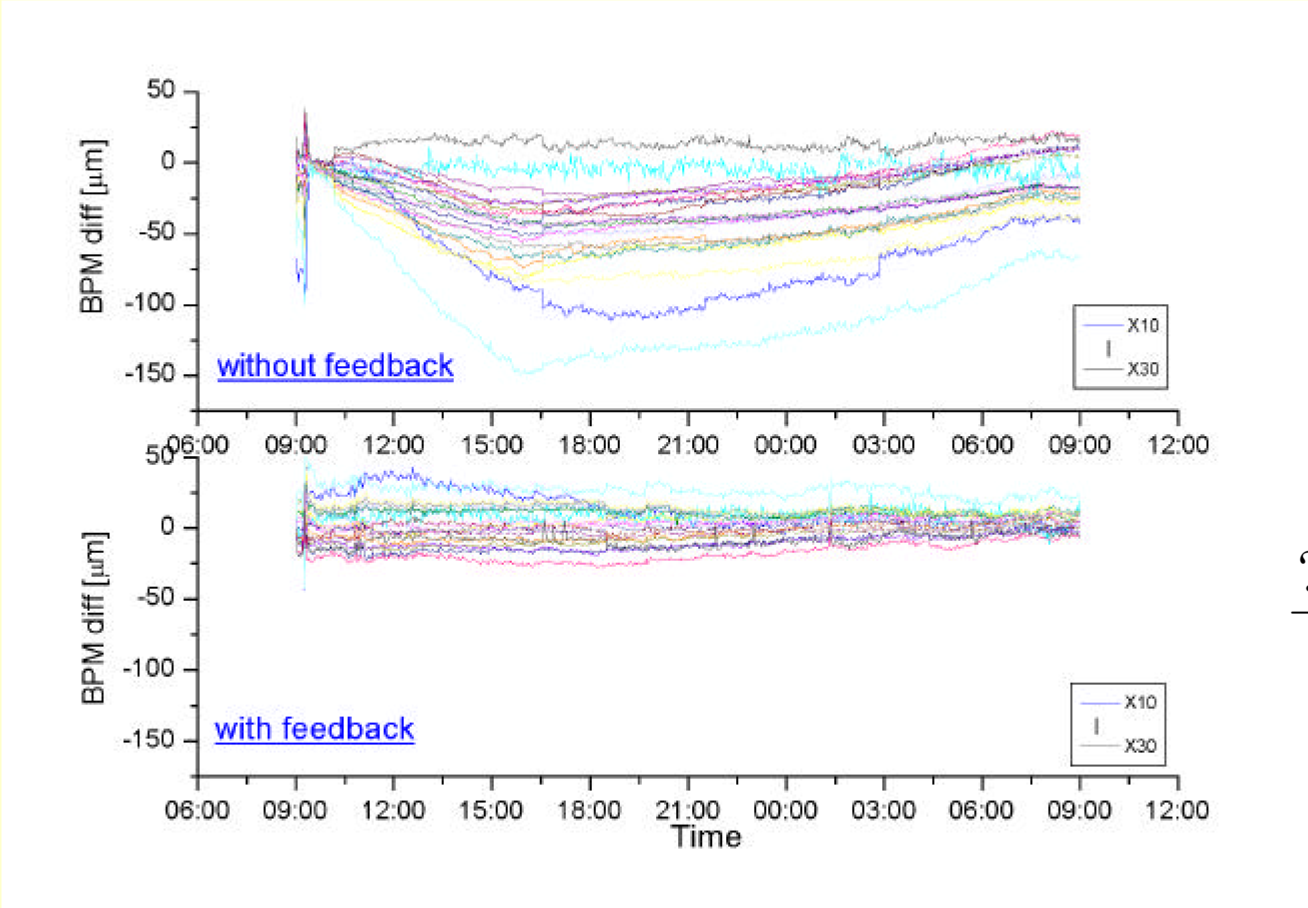
Display panel for photon beam monitor



Summary of Global Feedback System

- Global feedback system works very well to suppress the beam fluctuations up to 1Hz. (At present, For normal SR user operations, frequency range up to 0.3Hz are stabilized.)
- System bandwidth is limited due to the LPF to avoid the synchrotron oscillation. If we can remove the LPF (if the synchrotron oscillation is suppressed) and optimize the PID coefficient, the feedback bandwidth will be improved up to 50Hz
- Future Plan:
  - Local feedback system to stabilize the beam axis at the insertion devices using a reflective memory network.

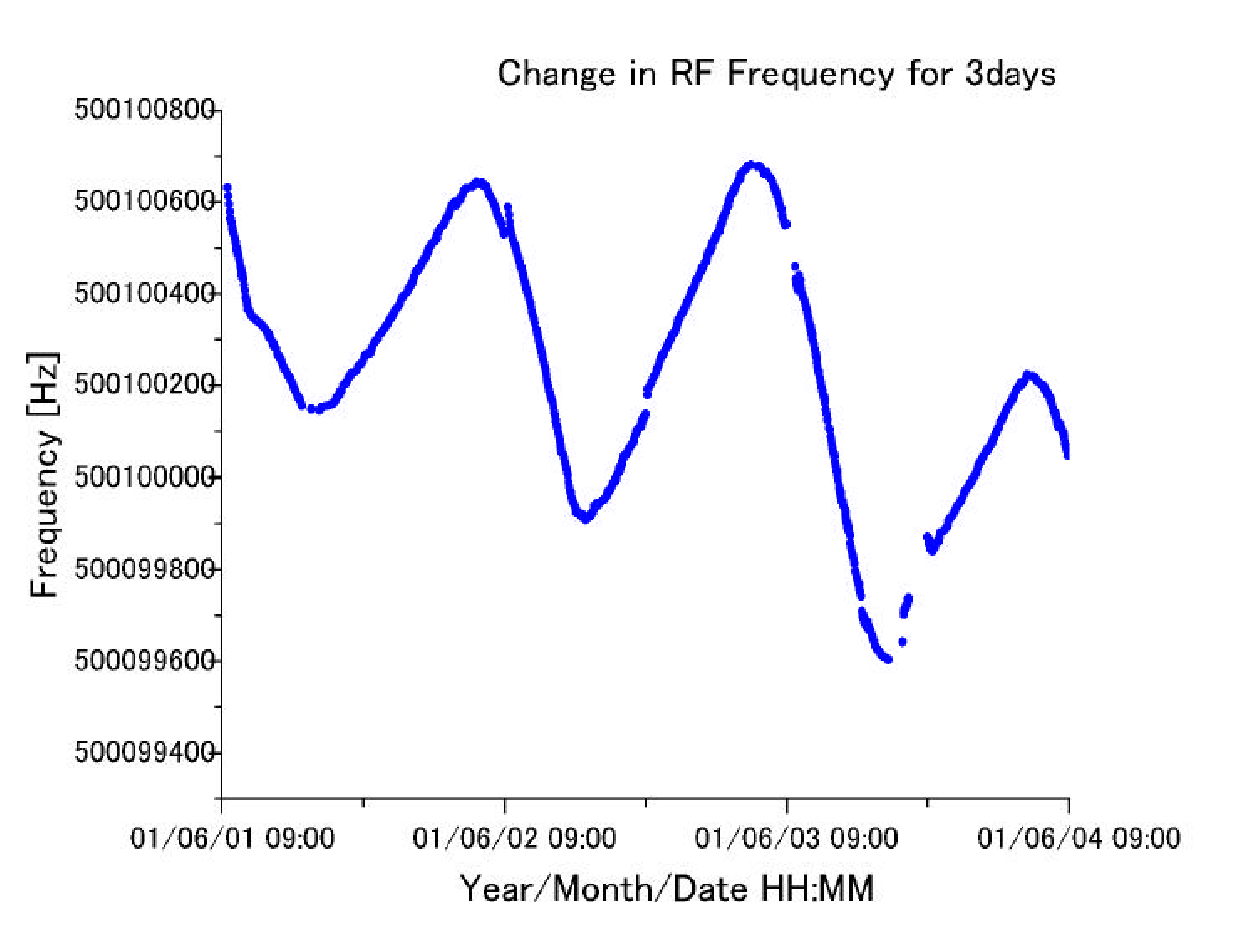
Horizontal Orbit Feedback (RF Frequency)



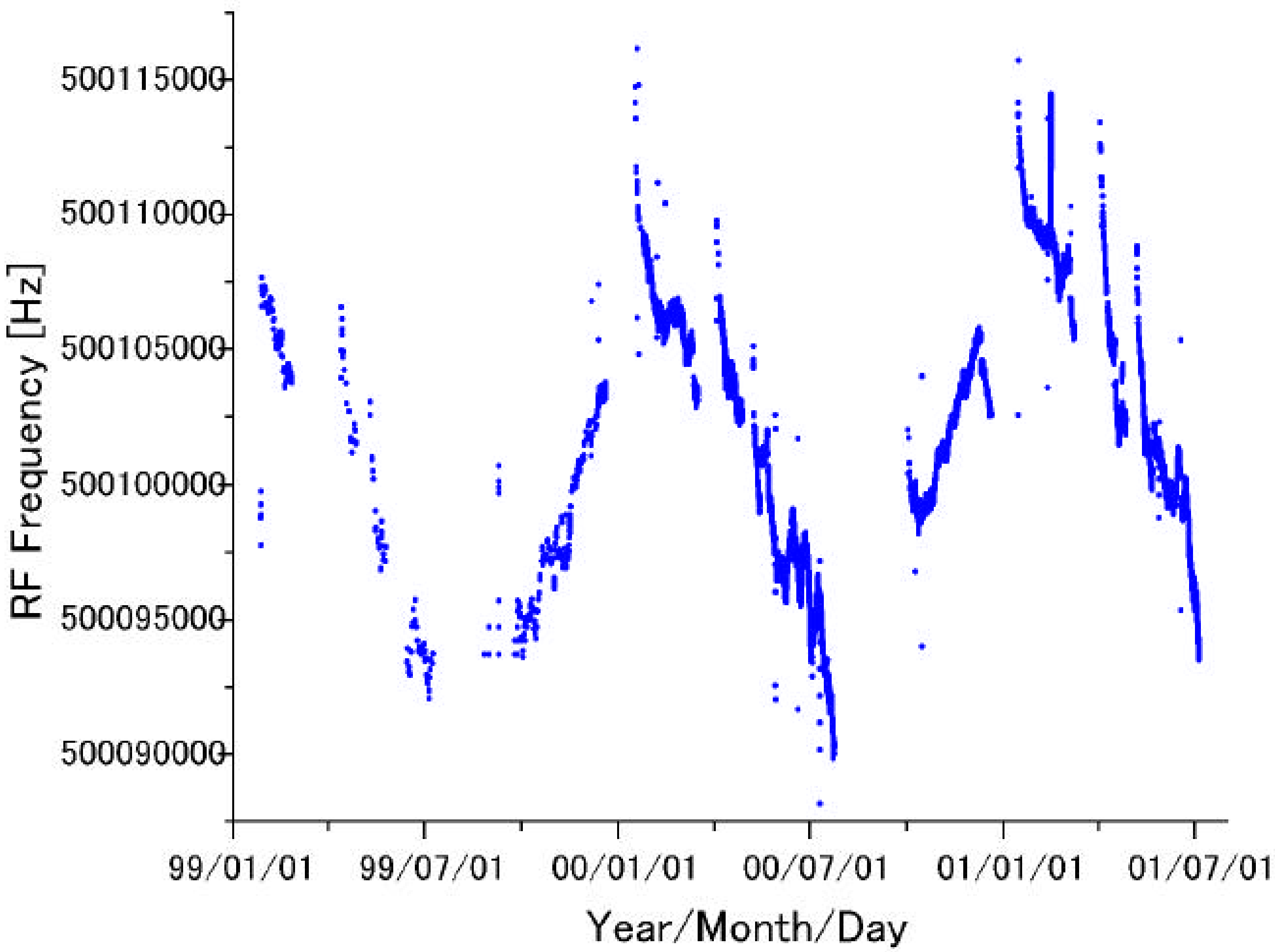
$$? x(s) \; ? \; ?(s) ? ? E/E ?$$

$$\frac{? f_{RF}}{f_{RF}} \; ? \; ? \; \frac{? \; ? x_i ?_i}{? \; ?_i^2}$$

Change in RF frequency; for 3days



Change in RF frequency; for 3 years



Change in RF frequency; for 3Month