Facility Report of the Pohang Light Source

S. H. Nam

2nd Workshop on Beam Orbit Stabilization

SPring-8, Japan

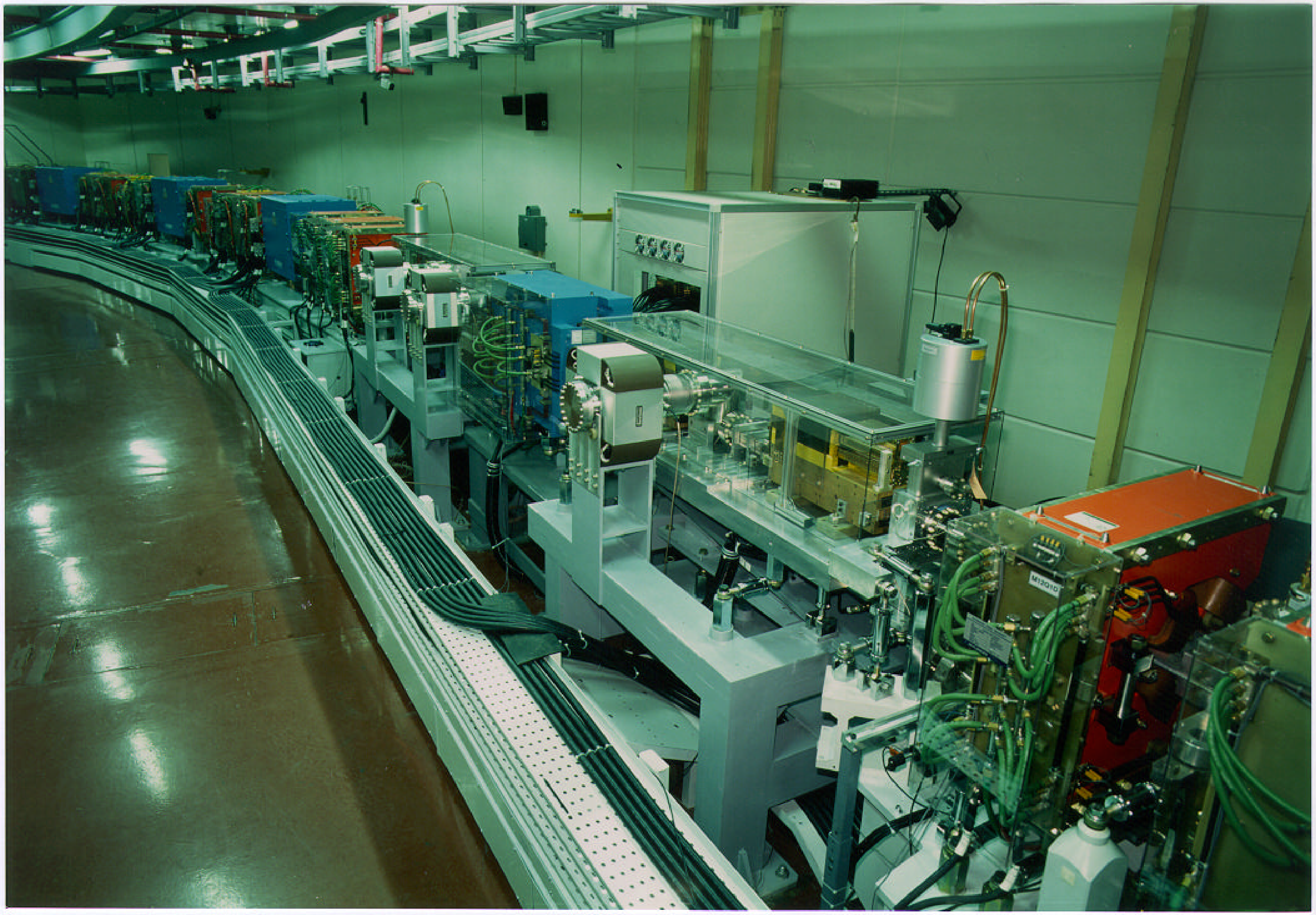
December 4-6, 2002

Aerial View of PAL

LINAC GALLERY

LINAC TUNNEL

Storage Ring



PLS Linac Parameter

Beam energy (GeV)	2
Beam pulse length (ns)	1, 2, 40
Pulse beam current (A)	> 2
Bunch Length (ps)	17~ 20
Number of accelerating columns	44
Operating mode	2p/3
Operating frequency (MHz)	2,856
MW Pulse length (?)	4.0
Number of klystrons	12
Klystron output power (MW)	80
Number of Energy Doublers	11
Energy Doubler gain factor	1.5~ 1.6
Total length of the linac (m)	~160
Accelerating column wall temperature (?)	45±0.2
Number of quadrupole triplets	6
Number of steering magnet sets	6
Number of bending magnets	3

PLS SR Parameter

	Designed Value	Achieved Value	Operation Value
Energy (GeV)	2 (2.5)	2 (2.5)	2.5
Stored current (mA)	300 (150)	450 (200)	170
Emittance (nm rad)	12.1 (18.9)	11 (-)	-
Lifetime @ 100 mA (hr)		28 [1)] (30)	30
Bunch length (mm), 1s	5	6	5-6
RF Voltage (MV)		1.6	1.6
Betatron Tunes			
- Horizontal (n_x)	14.28	14.23 (14.28)	14.28
- Vertical (n_y)	8.18	8.21 (8.18)	8.18
Synchrotron Tune	0.0109	0.0109	0.01
Chromaticities (x/y)	0/ 0	0.7/ 1.1	0.7/1.1
Linear coupling (%)	<10	0.8	0.8
COD (mm)			
- Horizontal (rms)		~0.5	0.9
- Vertical (rms)		~0.5	0.7
Dispersion (x/y) (m)	Max. 0.46	-	-
Injection Time (sec)		-	< 600
Damping Time (x/z) (ms)	16/8	-	-

PLS Operation History

Item \ Year	1996	1997	1998 [1)]	1999 [2)]	2000 [3)]	2001	2002 (Goal)
Energy [GeV]	2.0	2.0	2.0	2.0-2.5	2.5	2.5	2.5
Ave. Current [mA]	121.8	155.6	160.7	157	166.9	164.8	170
Lifetime @ 100mA[hr]	22.3	18.4	23.6	30.6	37.7	34.4	35
Linac Operation [hr]	4,810	5,481	5,116	5,224	5,280	5,646.6	5,640
SR Planned [hr]	3,236	3,960	4,272	4,224	4,272	4,056	4,464
SR Serviced [hr]	3,034	3,618	3,784	3,831	3,884	3,806	4,129
Availability [4)] [%]	93.8	91.4	88.6	90.7	90.9	93.8	92.5

1) Three main events: RF Window break, Interlock malfunction, Flooding
2) Operation energy increased from 2.0GeV to 2.5 GeV. Injection time was increased due to the energy ramping.
3) 2.5 GeV operation.
4) Regular injection time is excluded.

Year 2002 Accelerator Operation

• Total Operation Runs:	18
• Days of Operation per Run:	~10 Days
• User Operation:	185 Days (~4,440 Hours)
• Machine Study:	63 Days
• Shut-Down:	117 Days
(Maintenance and B/L Construction)	
• Operation Mode:	2.5 GeV (170 mA)
• Injection Period:	12 Hours
	(2 injections per a day)

Major Achievements of the PLS

† The main objective has been to achieve design parameters. (Especially the stored beam current level)

- **Achieved most of design parameters.**

Design	Max. Achieved	Provided
2.0 GeV 300 mA	2.0 GeV 450 mA	2.0 GeV 190 mA
2.5 GeV 150 mA	2.5 GeV 200 mA (RF Power Limited)	2.5 GeV 170 mA

- **SR Operation Energy Increase to 2.5 GeV by Ramping:** The PLS SR operation energy has been increased from 2.0 to 2.5 GeV since 1999 (Energy is ramped at the PLS SR).

- **2.5 GeV Full Injection:** Succeeded 2.5 GeV full injection by orbit correction of increased rms COD (5-6 times) due to septum leakage field.

Major Issues of the PLS

- Beam Stability
- Diagnostic Upgrade
- EPICS
- RF Power Budget Upgrade
- Linac Energy Stability
- Next Generation Light Source

Status of the PLS Beam Diagnostic System

Beam Position Monitors

- **Total Number : 112 (108 arcBPM's + 4 IDBPM's: BERGOZ)**
- **Resolution: < 5 mm (limited by 12-bit ADC)**
  Demonstrated <1 mm resolution in lab test.
  Have plan to upgrade resolution of all BPMs to <1 mm.
- **Performance Improvement: Found solution for erratic output signals (483 MHz TE mode excitation) of ID as well as arc BPMs.**

PBPM:

- **Total Number : 1**
- **Resolution: < 1 mm**

Diagnostic Beam Line:

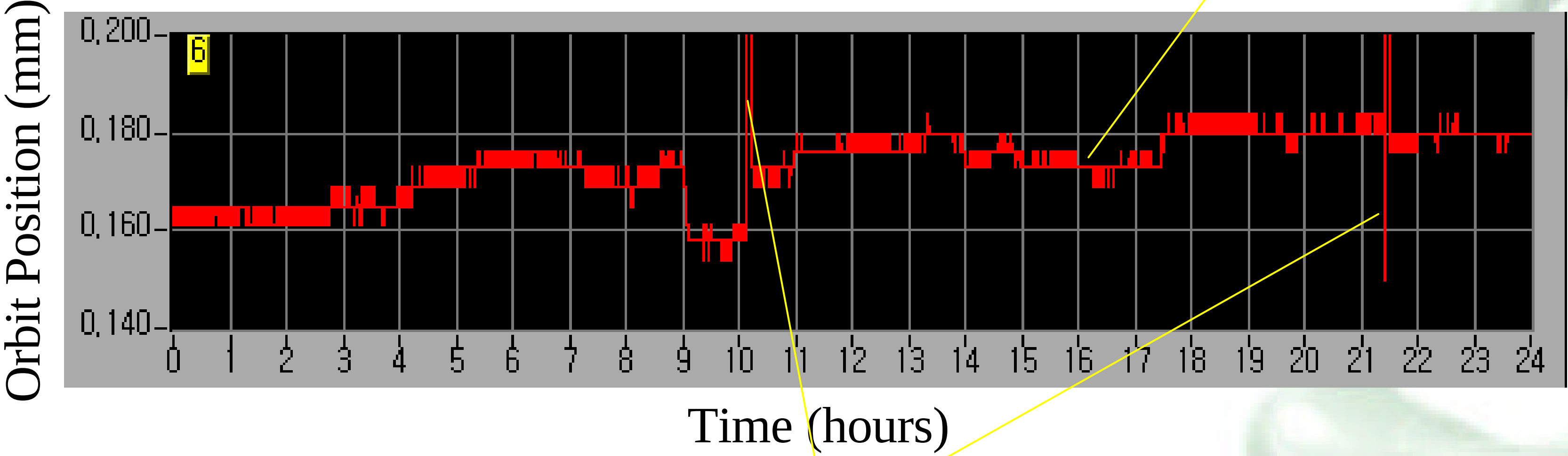
- **Have one visible (with a streak camera) and one x-ray (with Kirkpatric-Baez mirror) diagnostic beam line.**
- **X-ray pin hole diagnostic beam line is under construction (<10 mm resolution).**

Performance of the PLS BPM

Measurement of 24-hour Orbit Drift

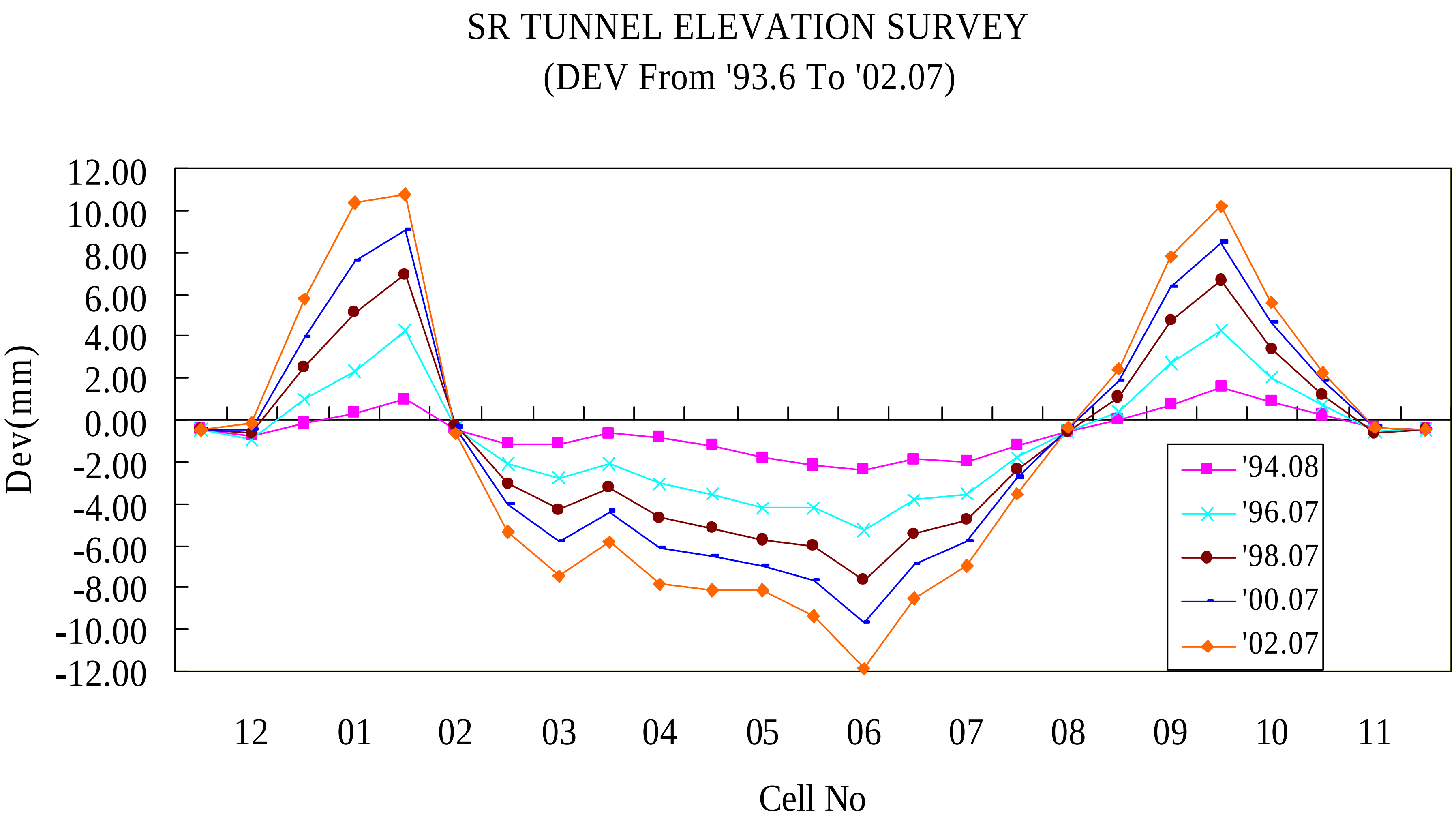
~ 4-μm Resolution

BPM66Y on 6/26/2001



Orbit Excursions during Beam Fill-Ups (2.0 to 2.5 GeV Ramping)

Tunnel Elevation Survey of the PLS SR



Summary of the SR Tunnel Elevation

- **Deformation (Hill to valley):**
  Total accumulated : 23 mm for 9 years
  Average: 2.5 mm/ yr.

- **Deformation reduction ratio: 10 %/yr.**

- **Max. adjustable range of the PLS SR girder: 50 mm**
  Still within the adjustable range.

- **Current deformation of the PLS SR tunnel is about 2.0 mm/yr.**

- **This corresponds to 5.5 mm/day (peak-to-peak).**

- **Under investigation: What is the actual effect on SR orbit drift?**

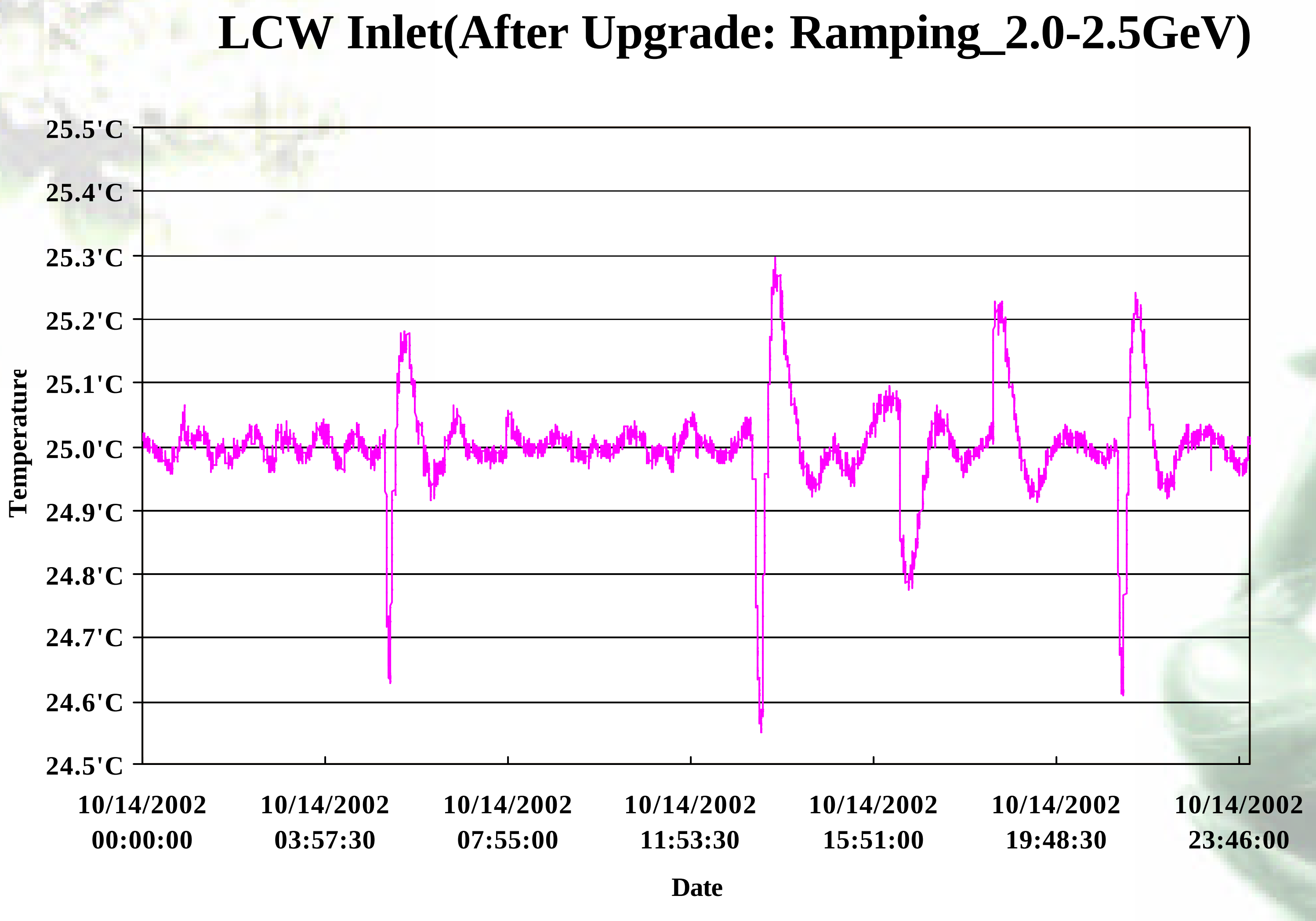
Improvement of LCW and Air Temp. Control

- **Air Temperature Control Improved**
  - **From < ± 1.0 °C**
  - **To < ± 0.1 °C**
  - DT **: ~ 2.6 °C**

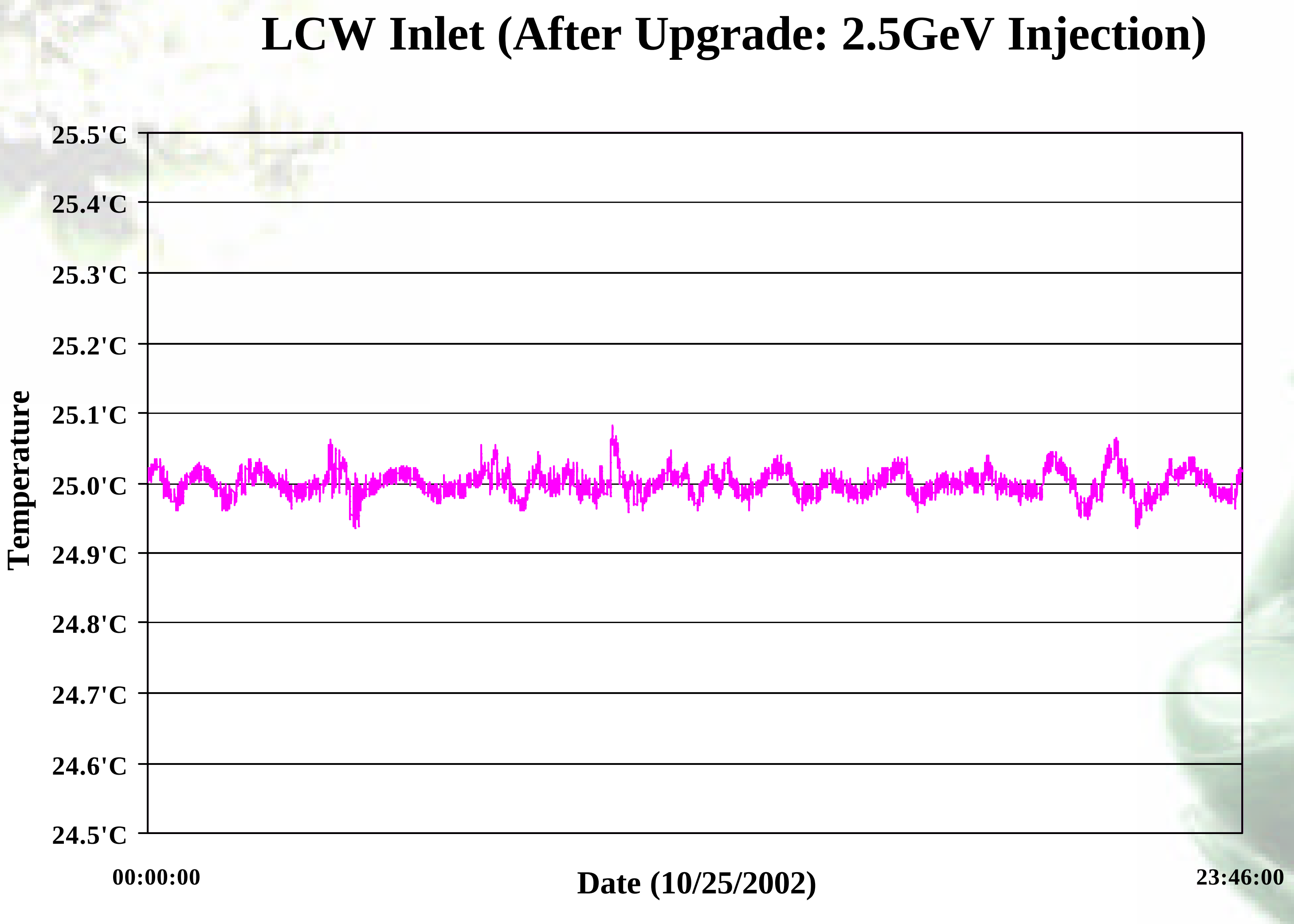
- **LCW Temperature Control Improved**
  - **From < ± 0.5 °C**
  - **To < ± 0.1 °C**
  - **Feedback Control Period: 5~6 min.**
  - **Upgrade to < ± 0.02 °C program is under way.**
  - DT **during ramping: ~ 0.7 °C (Utility Bldg. Point)**

- **Beam Orbit Sensitivity Factor**
  - **Air: ~ 8 mm / °C (Need further measurement)**
  - **LCW (Vacuum Chamber Point): ~ 50 mm/ °C**

LCW Inlet Temp. Variation (Ramping)

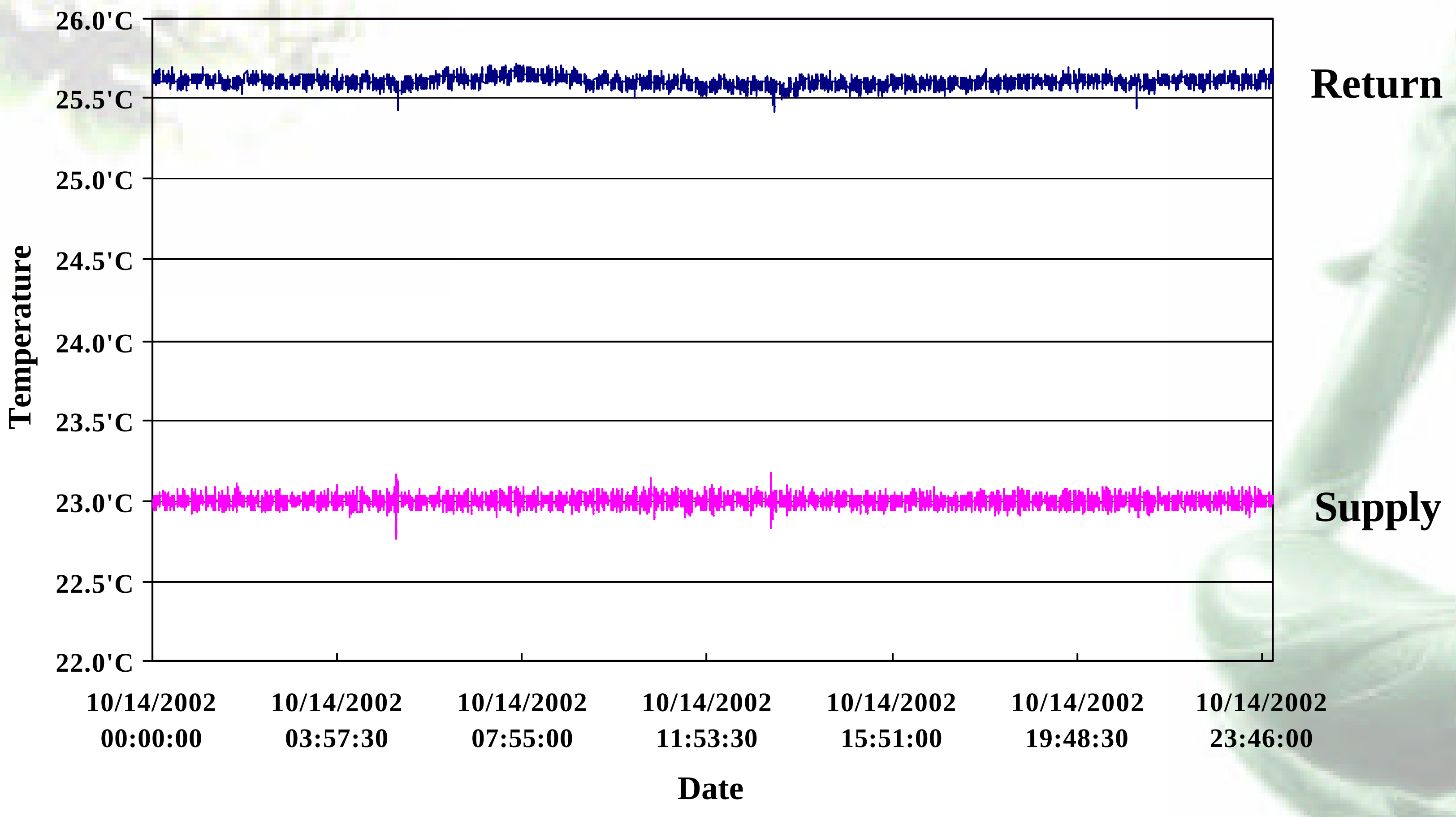


LCW Inlet Temp. Variation (2.5GeV)

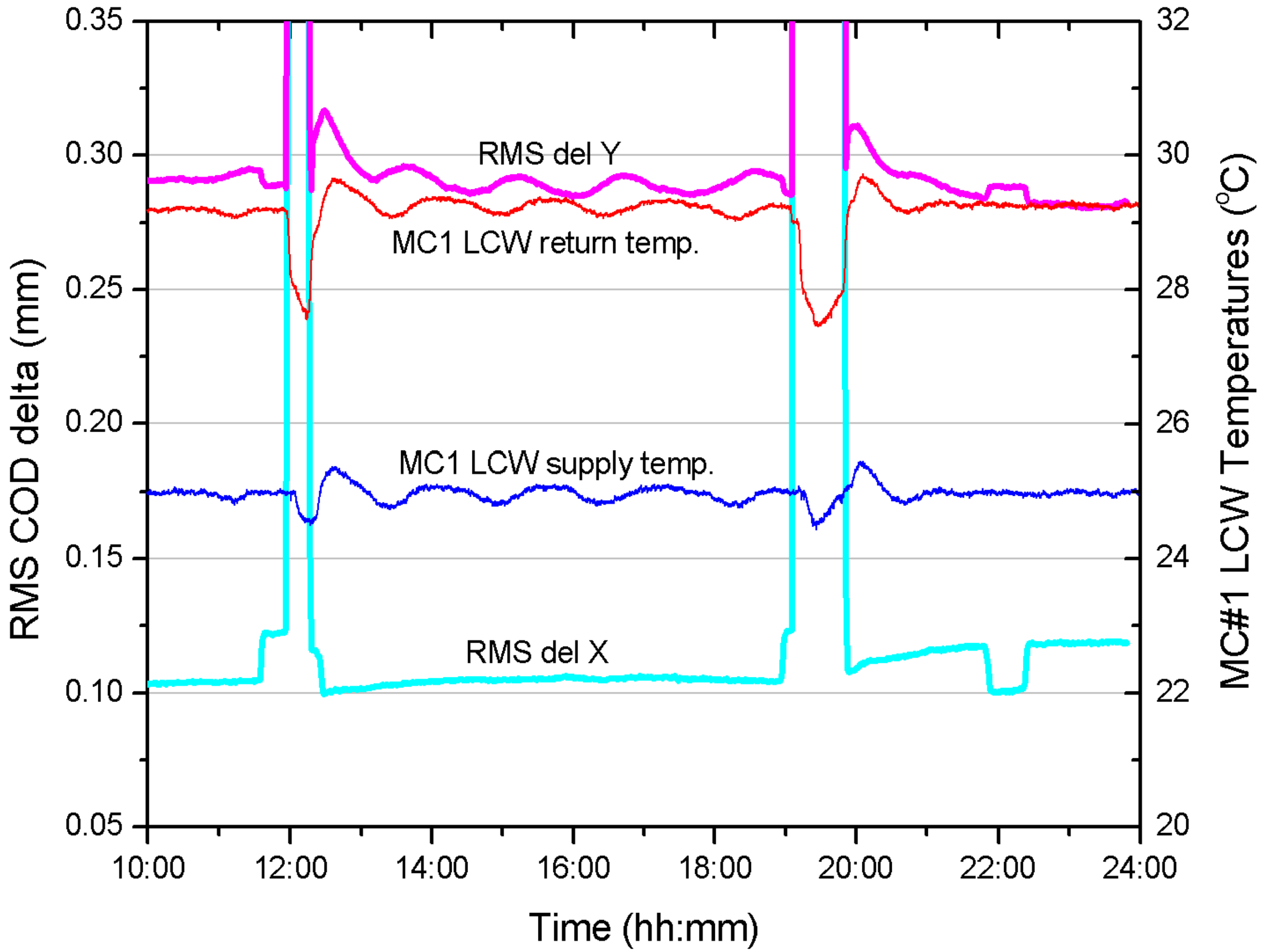


Air Temp. Variation

Air Temp. of Cell No. 10 &11 (After Upgrade)



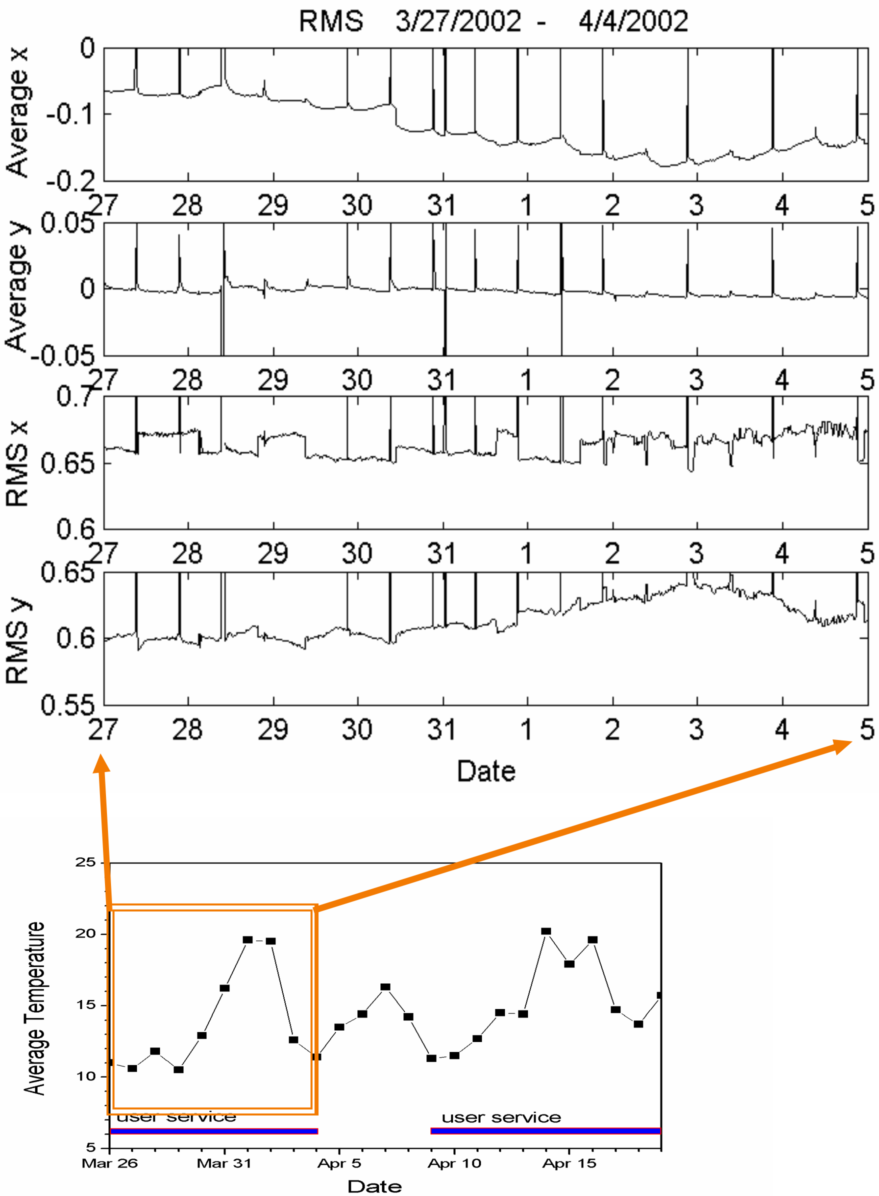
Effect of LCW Temp. on Orbit



10/10/2002

Sensitivity:
~ 50 mm/ °C

Effect of Outside Temp. on Orbit



- **Average horizontal orbit drift:**

  ~ 100 mm / 10°C

  Sensitivity: ~10 mm/°C

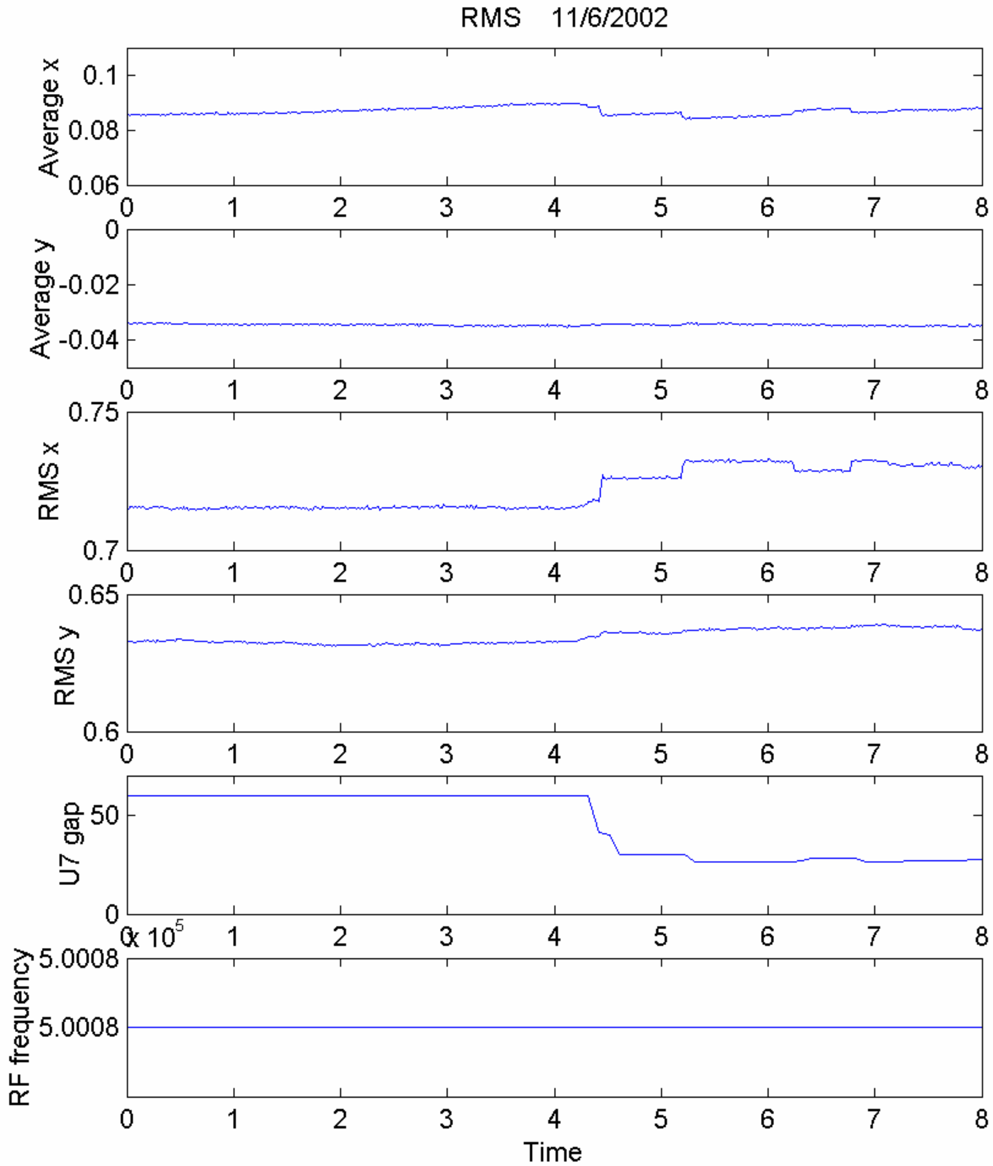
- **Vertical orbit drift (r.m.s.):**

  ~ 40 mm / 10°C

  Sensitivity: ~4 mm/°C

- **Horizontal orbit drift (r.m.s.): Shows no clear dependence on temperature. The orbit change in the figure is due mostly to the U7 ID gap change.**

Effect of ID Gap on Orbit



- **U7 ID Gap Control:**

  20 mm to 60 mm

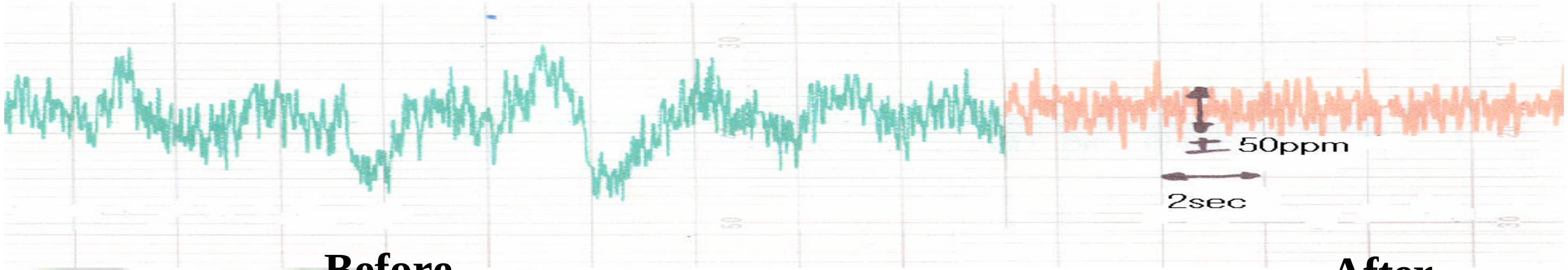
- **Vertical orbit change:**

  ~ 6 mm

- **Horizontal orbit change:**

  ~ 17 mm

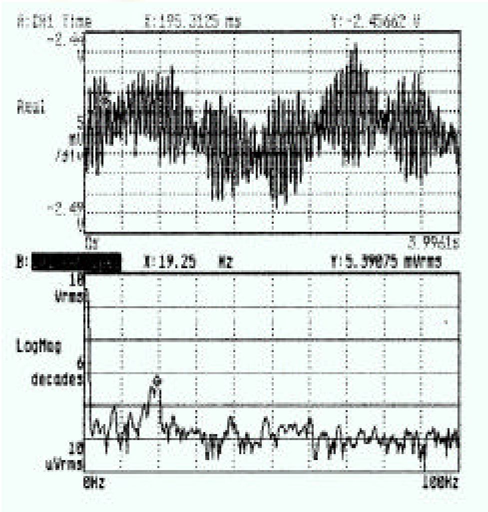
Effect of MPS Performance on Orbit

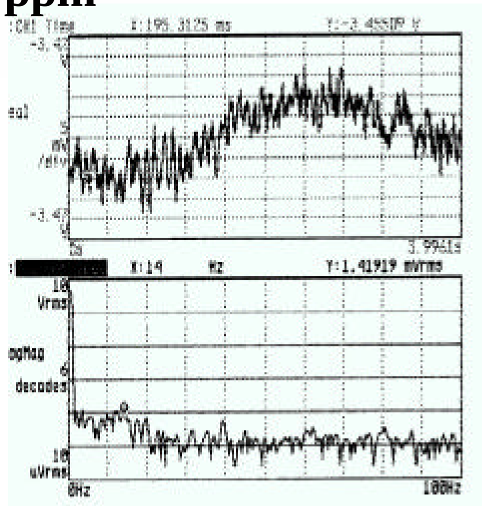


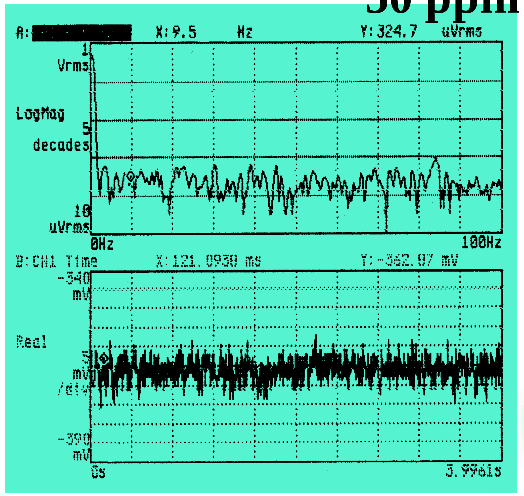
MPS Stability

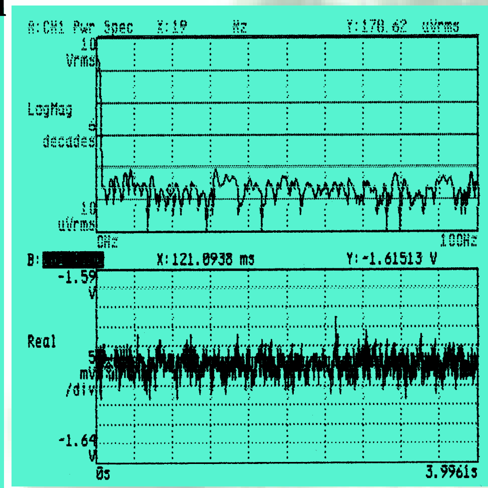
Before Upgrade: < ± 100 ppm

After Upgrade: < ± 50 ppm









Horizontal BPM
- BPM8-1 X 100Hz, 4Sec
- ~ 32 mm pk-pk
- MPS Ripple: ~ 18 Hz

Vertical BPM
- BPM8-1 Y 100Hz, 4 Sec
- ~ 28 mm pk-pk
- MPS Ripple: ~ 18 Hz

Horizontal BPM
- BPM8-1 X 100Hz, 4Sec
- ~ 12 mm pk-pk
- MPS Ripple: No peaks

Vertical BPM
- BPM8-1 Y 100Hz, 4 Sec
- ~ 16 mm pk-pk
- MPS Ripple: No peaks

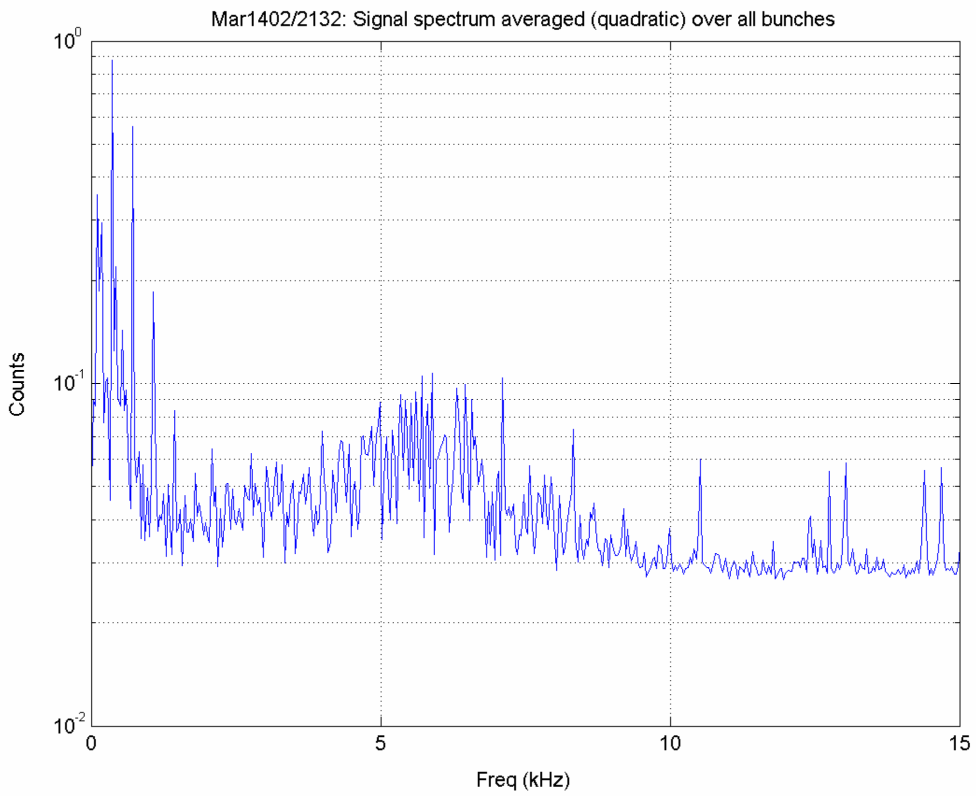
PLS MPS Performance Table

ITEM		Bending	Q4	Q5	Q6	Q1,2,3	SF	SD
Stability (⊕ ppm)		50	30	40	30	30	40	40
Ripple (%)	8.125Hz			0.00097				
	8.75Hz				0.00207			
	11.25Hz					0.0038		
	12.87Hz							0.0257
	13.25Hz						0.0043	
	14.75Hz		0.0017					
	30Hz	0.00081						
	60Hz	0.0022	0.0067	0.0085	0.0018		0.00143	0.00117
	180Hz	0.0044	0.0278	0.0053				
	540Hz	0.0035	0.0278	0.0052				
	900Hz	0.0035	0.0255	0.0058				
	1.08kHz	0.0035	0.0097	0.0058				
	1.262kHz	0.0036	0.021	0.005				
	1.62kHz	0.004	0.025	0.0053				
	1.972kHz	0.0038	0.0247	0.0035				
	2.344kHz	0.004	0.025	0.0045				
	2.692kHz	0.004	0.0217	0.00037				

Effect of RF Noise on Beam Stability

- Phase noise amplitude in the range of 30 Hz - 35 kHz are below 60 dB from the main RF signal.

- Detail study of RF noise effect on beam stability is in progress. Preliminary result shows that ID photon intensity fluctuation is not strongly depend on RF noise amplitude.



- BPM Signal Spectrum measured when there exists klystron phase noise in the frequency range to 1 kHz.

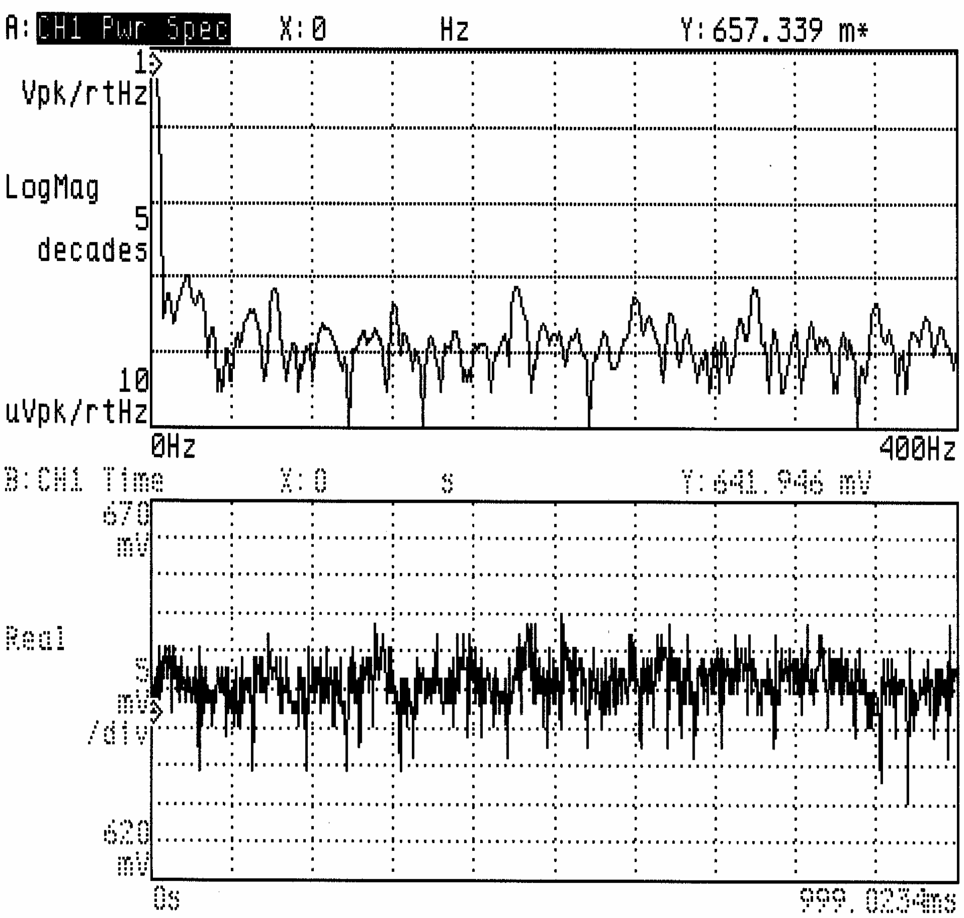
Others Considered in Beam Stability Study of the PLS

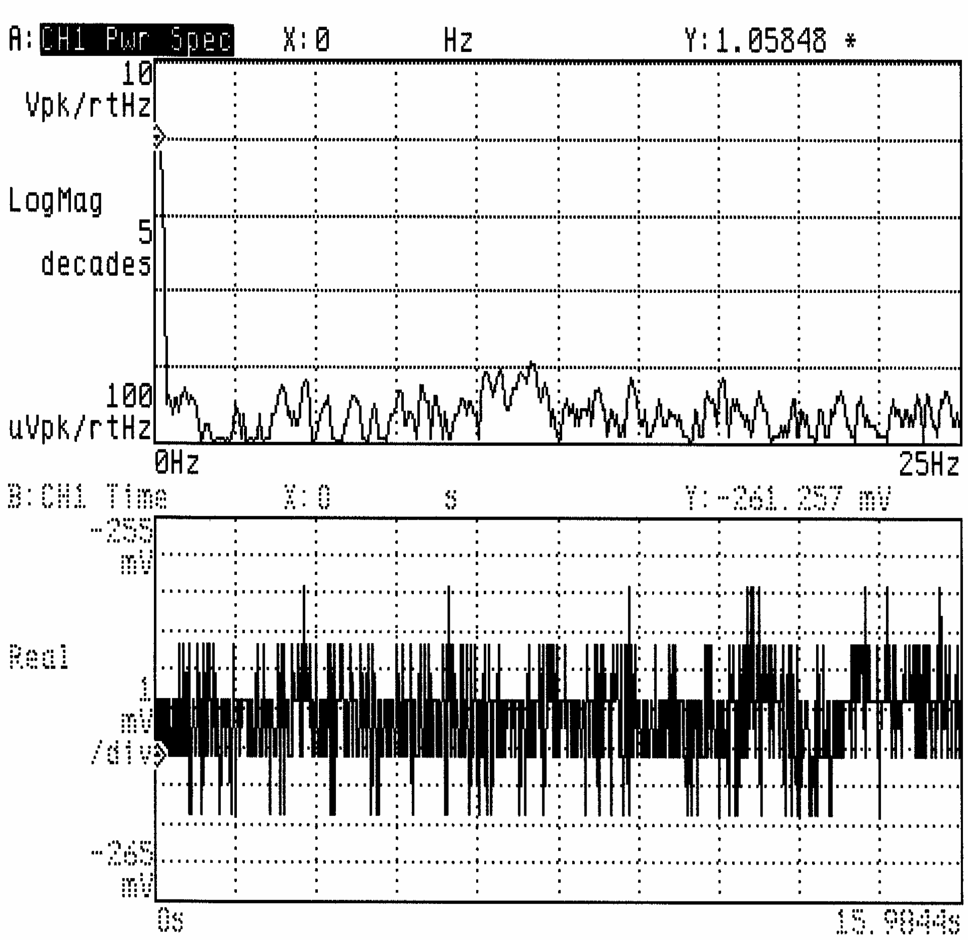
- **Effect of Stored Current Amplitude on Beam Stability**
  - ➢ **Sorting out the current dependence is difficult.**
  - ➢ **Beam stability is affected more by others than the stored current.**

- **Effect of Mechanical Vibration on Beam Stability**
  - ➢ **< 40 Hz : No clear evidence found**
  - ➢ **> 40 Hz : Need to be measured.**

- **Effect of Motions of Mechanical Components on Beam Stability**
  - ➢ **Mechanical components: Girder, Magnet, Vacuum Chamber, BPM**
  - ➢ **Some deformation of magnets are measured with the energy ramping operation mode (2.0 to 2.5 GeV).**
  - ➢ **However, no significant mechanical component motions are measured during the 2.5 GeV direct injection mode.**

Horizontal Beam Position Stability of the PLS SR: BPM Signal

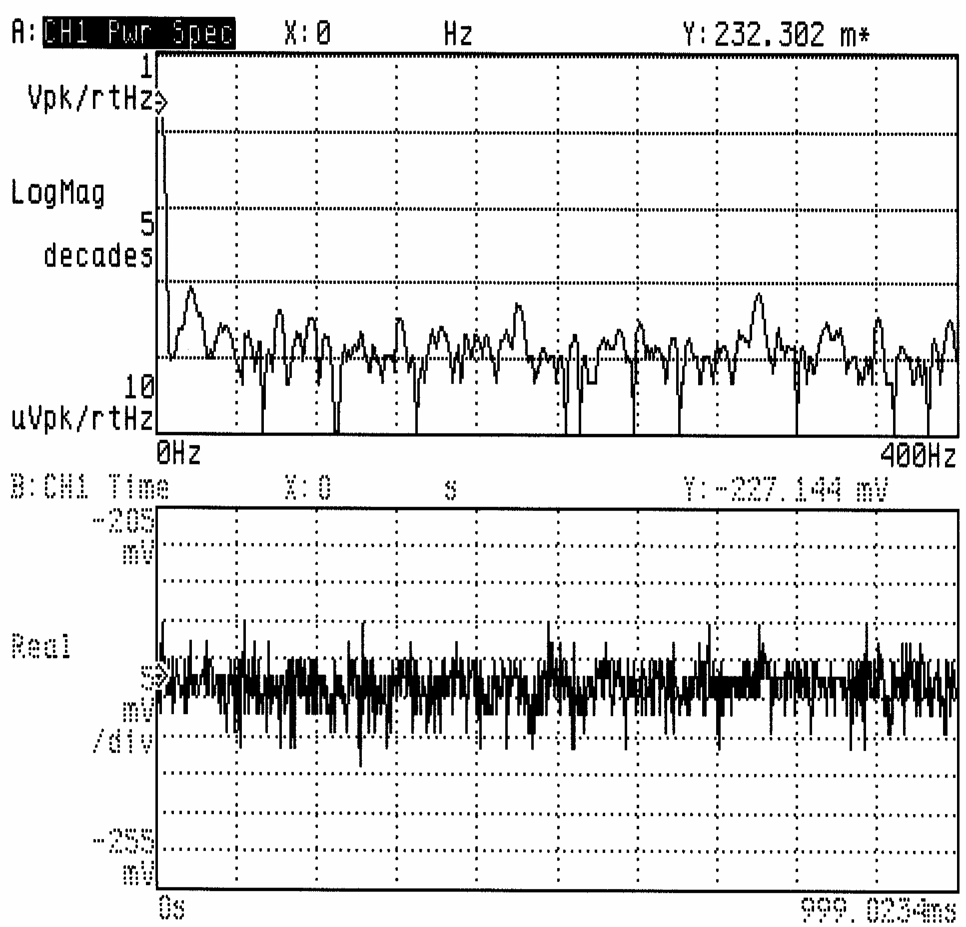


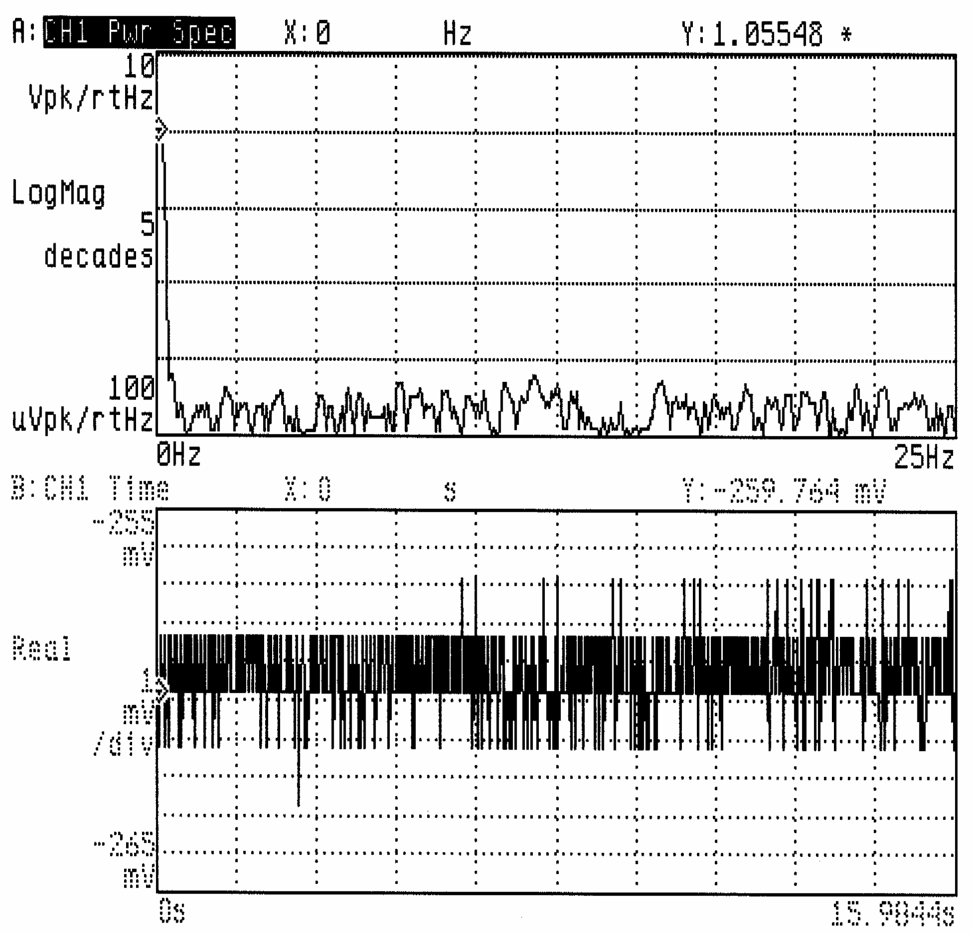


- **400Hz**
- **~ 16 mm pk-pk**

- **25Hz**
- **~ 5 mm pk-pk**

Vertical Beam Position Stability of the PLS SR: BPM Signal

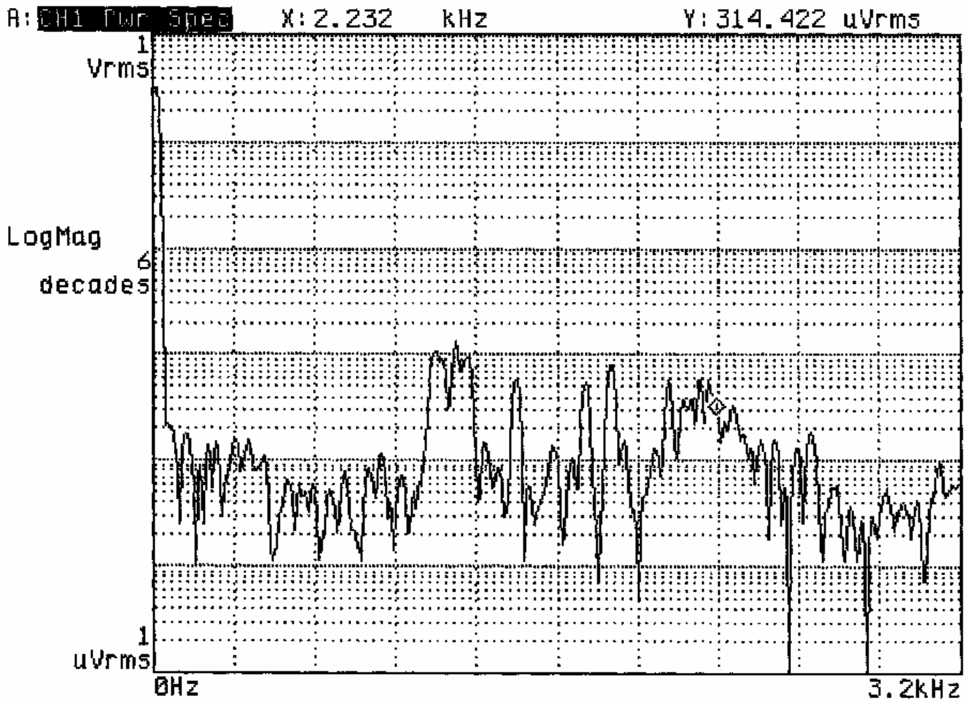




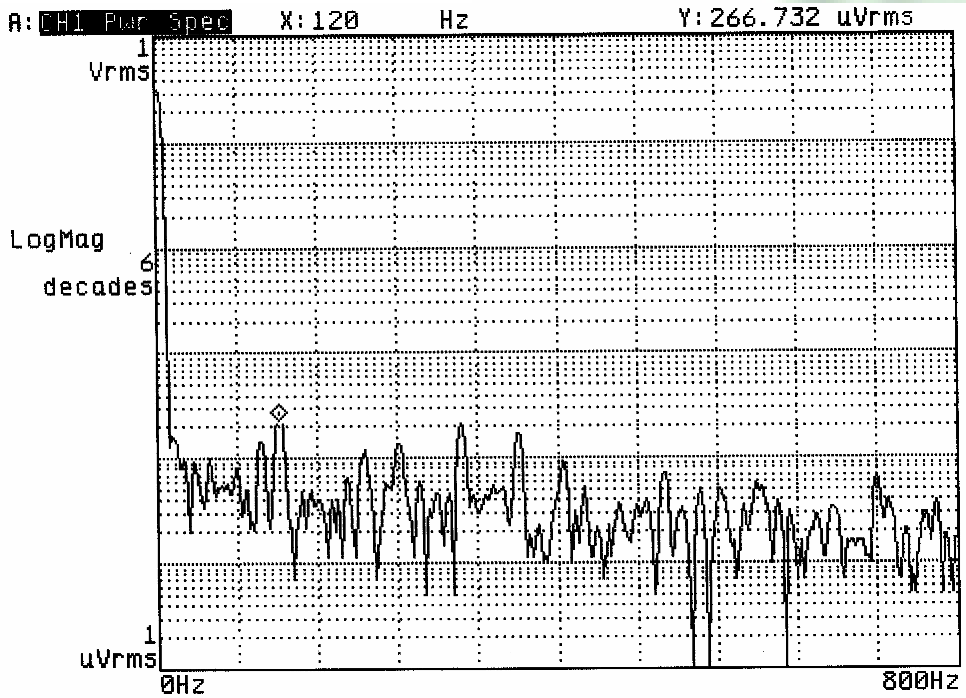
- **400Hz**
- **~ 12 mm pk-pk**

- **25Hz**
- **~ 3.3 mm pk-pk**

Vertical Beam Position Stability of the PLS SR: PBPM Signal



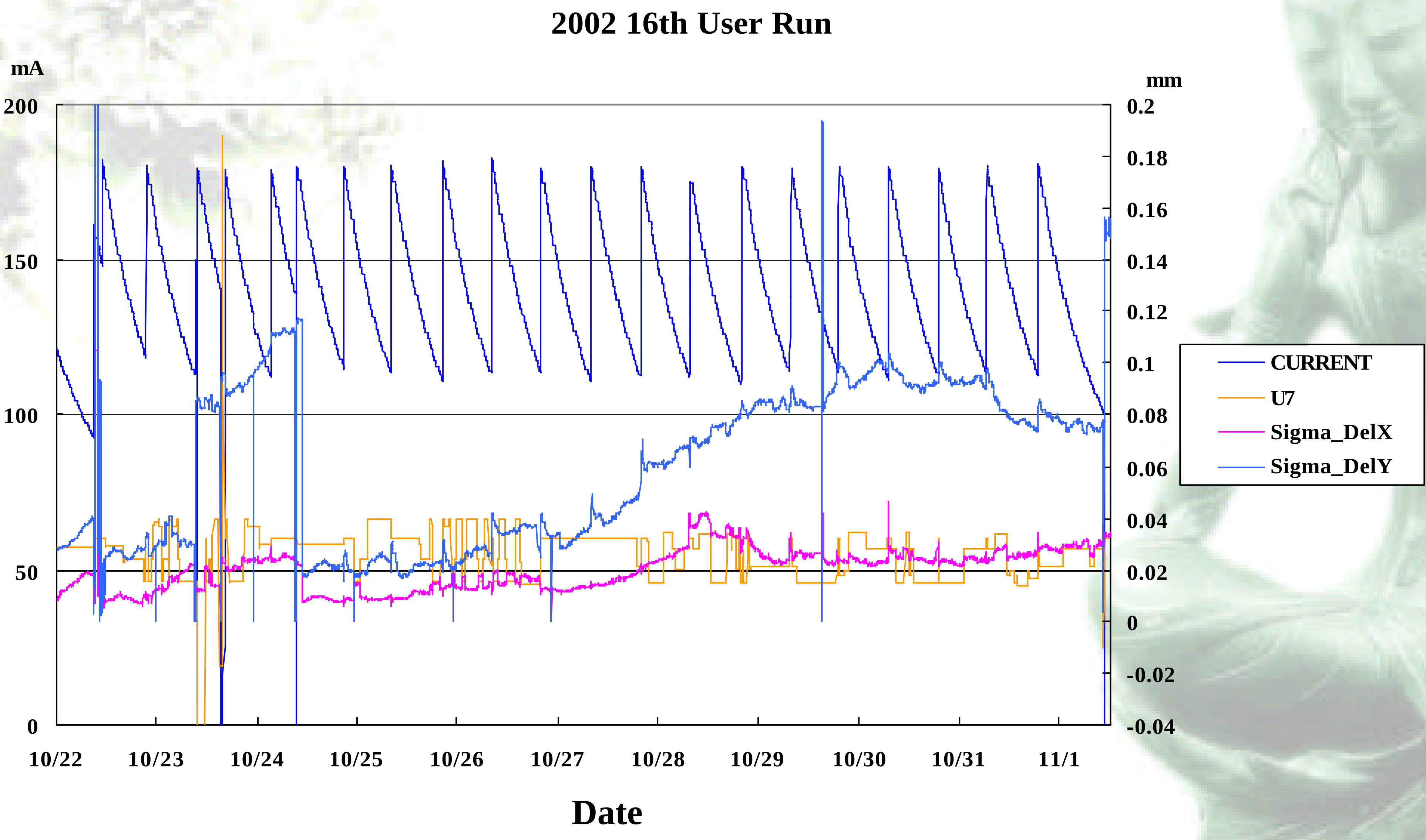
3.2kHz



800Hz

- **PBPM Bandwidth: several kHz**
- **Orbit Fluctuation at frequencies > 1 kHz has been observed.**
- **Sources of the fluctuation are not yet fully explored.**
- **RF noise may be one kind of the sources.**

Example of 10-day Run Operation Data of the PLS SR



Summary of the PLS Beam Orbit Stability

- **Vertical orbit:**
  - **~ 80 mm/run Drift : Mainly due to outside temperature change.**
  - **< 20 mm/12-hr Drift (User service hour after injection is normally 12-hr.) : Mainly due to MPS stability, LCW temperature.**
  - **~ 15 mm orbit change observed just after injection, even in 2.5 GeV direct injection mode. : Cause is not clear yet. Need further investigation.**
  - **50 to 100 mm sudden step change of orbit: Cause is unknown. Need further investigation.**
- **Horizontal orbit:**
  - **~ 30 mm/run Drift : Mainly due to U7 ID gap and outside temperature change.**
  - **< 10 mm/12-hr Drift : Mainly due to MPS stability, LCW temperature.**

Sensitivity Factors of Beam in the PLS SR

Source		Sensitivity Factor or Amplitude			
Item	Range	Orbit drift	Girder	Magnet	BPM
Tunnel Air Temp.	< ± 0.1 °C	~8mm/°C (Need study)	10~80mm/°C	~10 mm/°C	-
Magnet cooling water temp.	< ± 0.1 °C	50 mm/°C	-	~2 mm/°C	
RF cavity cooling water temp.	< ± 0.2 °C				
Vacuum chamber cooling water temp.	< ± 0.1 °C	50 mm/°C	Error range (<3mm)	Error range (<3mm)	~20 mm/°C
Beam current decay		~ 30 mm (180-100 mA)			
Outside temp.	20 °C Max. Change	~4 mm/°C (V RMS) ~10 mm/°C (H Av., w/o FB) ~0.7 mm/°C (H Av., w/ FB)			
ID Gap Change (U7)	20-60 mm	X: < 20 mm Y: < 10 mm			
MPS	<± 50 ppm	X: ~12 mm pk-pk Y: ~16 mm pk-pk			

Future Works to Improve the PLS Beam Stability

- First Step Improvement of the PLS Beam Stability: < 5 µm
- Future Works

(1) Global & Local Orbit Feedback System: Under preparation

(2) RF Frequency Feedback: Under operation (Av. Hor. Orbit < 7 µm)

(3) Beam Based Alignment: Under preparation

(4) LCW Temp. Control Upgrade to < ± 0.02 °C: Under preparation

(5) Upgrade of MPS

Unipolar 46 Units: Reduce low freq. Ripple (10-20 Hz)

Stability < ± 10 ppm

Bipolar 140 Units: Reduce ripple (1.5 kHz Switching)

12 bit to >16 bit controllabiltiy (Currently 1 bit ~ 6.3 µm)

(6) Automatic Girder Mover with Hydrostatic Level System

Automatic alignment: < 10 µm error

(7) Diagnostic Upgrade (Electron Beam and Photon Beam Diagnostics)

Additional Presentations by the PLS staff

(1) Dr. S. J. Park: "Activities of Source Suppression for Improving Orbit Stability in PLS" 17:05-17:25, Dec. 4

(2) Dr. H. S. Kang: "Sources of Slow Orbit Movement and Orbit Feedback Systems in PLS Storage Ring" 11:30-11:50, Dec. 5

(3) Dr. E. S. Kim: "Orbit Stability in PLS Storage Ring" 15:30-15:50, Dec. 5

Thank you for your attention!!