National Synchrotron Radiation Research Center

3rd International Workshop on Beam Orbit Stabilization - IWBS2004

December 6-10, 2004

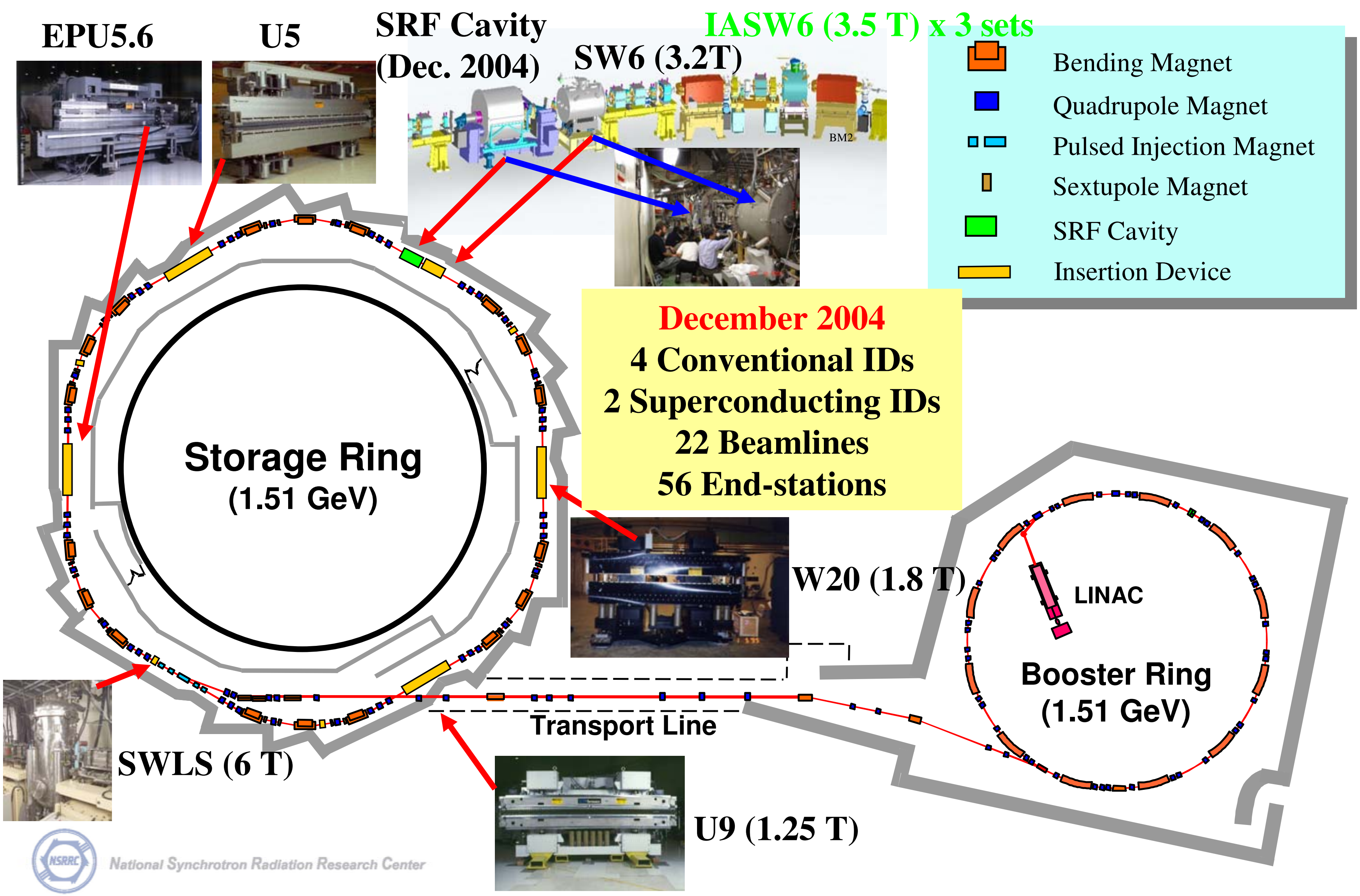
Hotel Kirchbühl, Grindelwald, SWITZERLAND

Orbit Stabilization at Taiwan Light Source

Kuo-Tung Hsu

December 6, 2004

NSRRC Accelerator



Major Parameters of the Storage Ring

Lattice type	**Combined function Triple Bend Achromat (TBA)**
Operational energy	**1.5 GeV**
Circumference	**120 m**
RF frequency	**499.654 MHz**
Harmonic number	**200**
Natural beam emittance	***25.6 nm-rad***
Natural energy spread	***0.075%***
Momentum compaction factor	***0.00678***
Damping time	
Horizontal	***6.959 ms***
Vertical	***9.372 ms***
Longitudinal	***5.668 ms***
Betatron tunes horizontal/vertical	***7.18/4.13***
Natural chromaticities	
Horizontal	***-15.292***
Vertical	***-7.868***
Synchrotron tune	**$1.06*10^{-2}$ (SRF, $1.52*10^{-2}$)**
Bunch length	**9.2 mm (Doris Cavities, 800 kV)**
	6.5 mm (SRF, 1.6 MV)
Radiation loss per turn (dipole)	**128 keV**
Nominal stored current (multibunch)	**200 mA (~2004), 300~400 mA (2005~)**
Number of stored electrons (multibunch)	**$5*10^{11}$ (SRF cavity, 10^{12})**

Efforts to Improve Beam Stability

Coupled-bunch instability :

RF gap voltage modulation (~ October 2004)

Superconducting RF (December 2004 ~)

(to accompany double the stored beam current).

Coupled bunch feedback system

Orbital stability:

Source Elimination

Ambient temperature, Water temperature, Enhance data acquisition system, Vibration elimination, Power quality improvement , Power supply improvement …etc.

Orbit feedback system

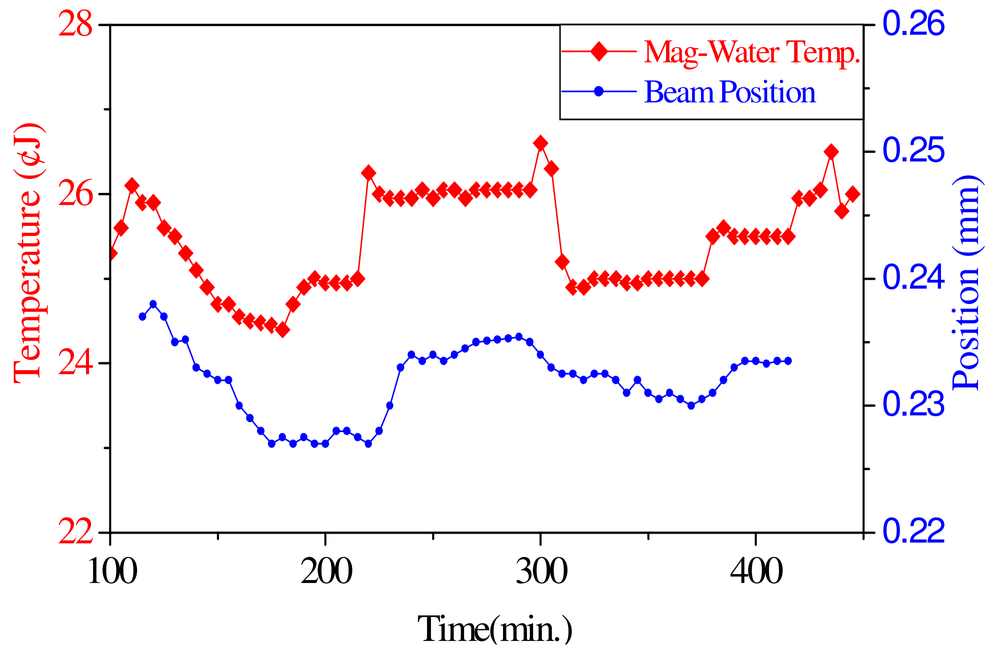
Top-up injection

Mechanical Related Source Elimination

Program initiation	1997	1998	1999	2000	2001	2002	
Performance, T orbit Io/Io	> 1 (drift>50 m) >1%	~ 0.25	< 0.2 (drift~20 m)	~ 0.15 <3 m rms ~0.5%	< 0.1 (drift<5 m)	< 0.1 <1 m rms <0.3%	(2003) ~ 0.06%
1. Utility Capacity Improvement	CTW, CHW Stability			Utility building #2 construction CHW capacity improved			
2. Heat Source Stabilization	Global effect studies (air/water temp., cable heat)	Injector energy upgrade full energy injection		EPU air temp. Power supply heating		U5 air temp.	
3. Thermal-Mechanical Effects				Girder, thermal insulator , vacuum chamber, SR heat mask BL-, RF-DIW temp.	I monitor		
4. Vibration	AHU, crane vibration pre-reduced		Damping study		Floor meas.	Piping improv.	
5. Sensors Implementation	Air temp. sensors		Position sensors	SCADA implementation electrical sensors			
6. Control System	Water control system upgrade VF controller implementation Utility data archive system				AHU controller upgrade AHUs reorganized		

(J. R. Chen, et. al.)

Magnet (Water Temperature)



Caused by the temperature fluctuations of magnet cooling water

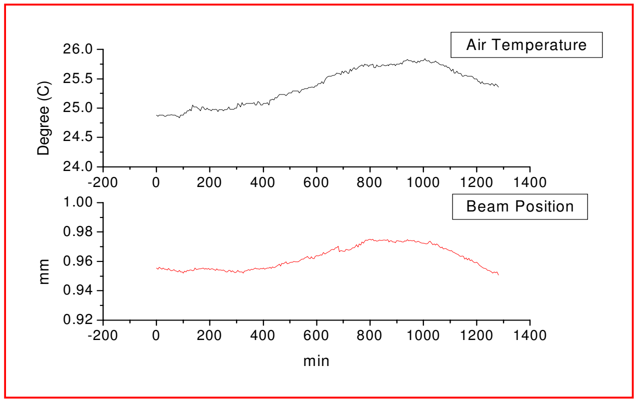
Magnet deformed ~ 10 m/

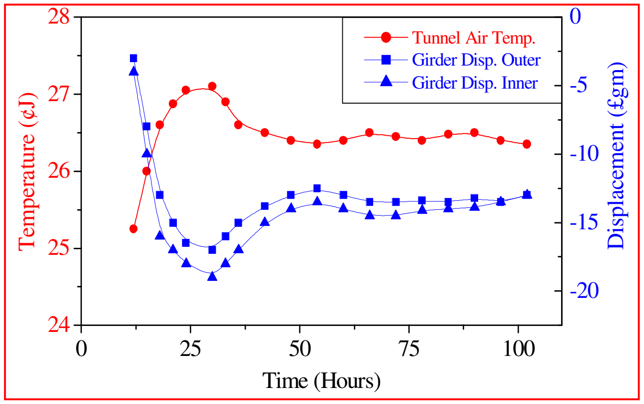
Induced beam orbit drift: 5 ~ 50   m /

Current status

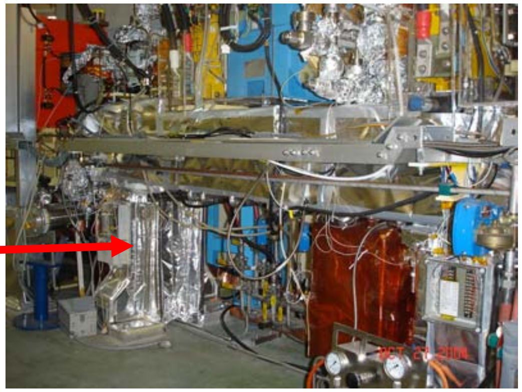
Cooling water temp.: ~   0.1

Girder Displacement





- Main cause: air temperature
  Sensitivity to air temp.: ~10 m /
  Induced beam orbit drift: 20-100 m /
- Current status: < 0.1 m per 8 hr shift
  Air temp. : < 0.1
  (utility control system improved)
  Thermal insulator jacket



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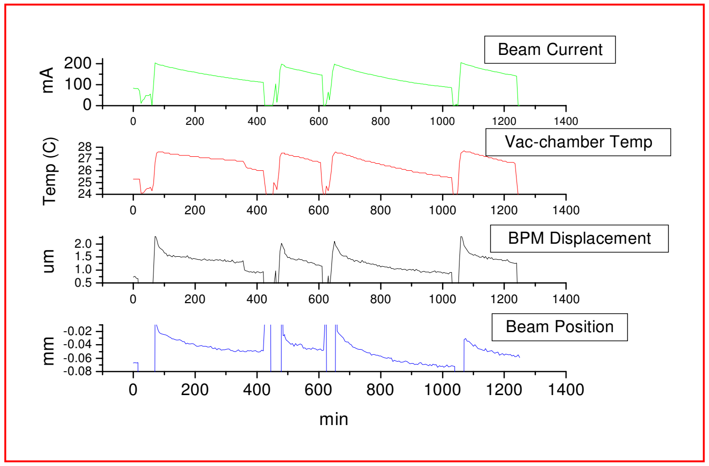
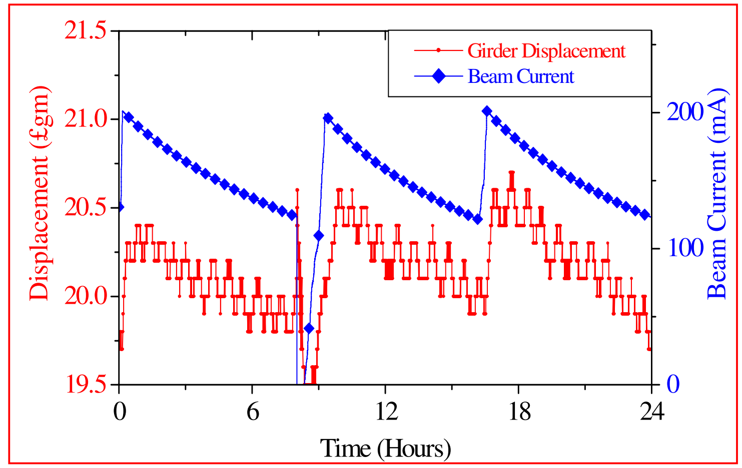
Expansion of Vacuum Chamber



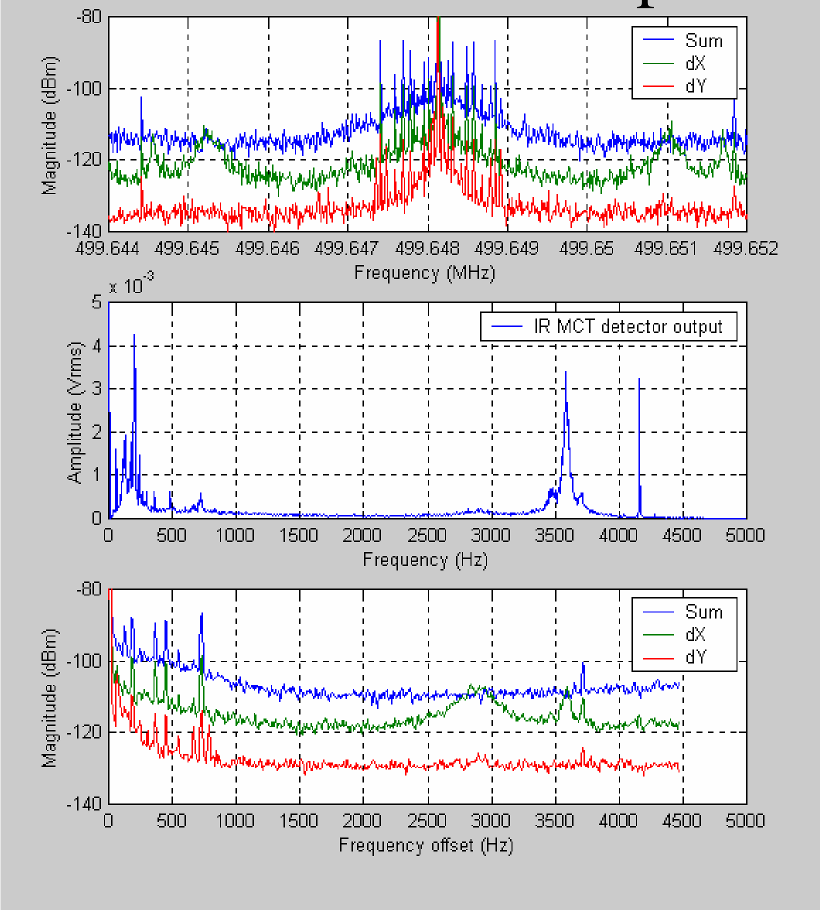


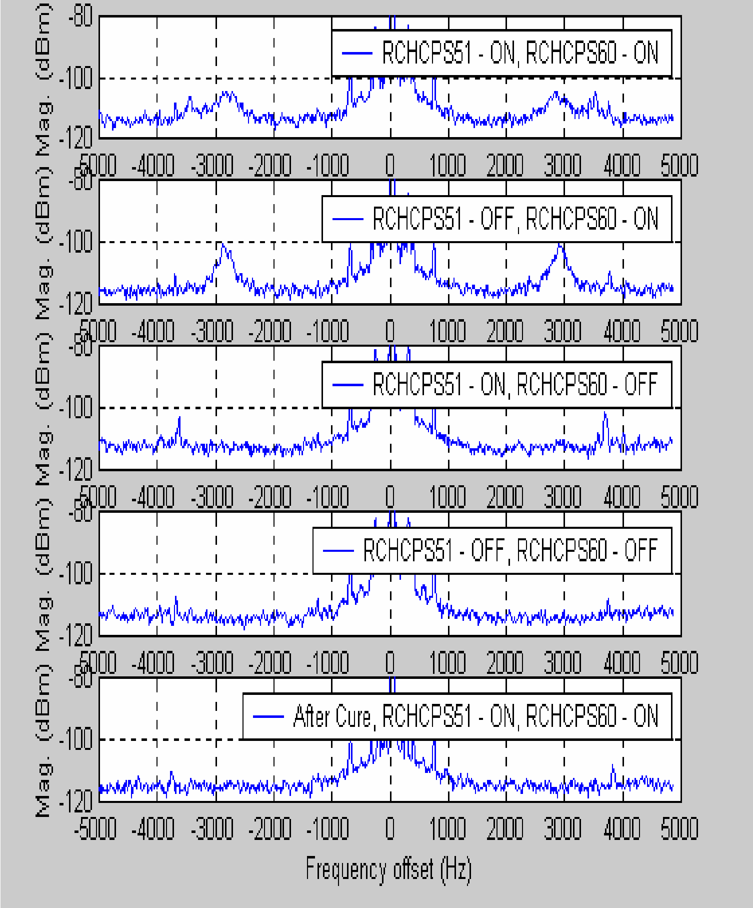
- Caused by synchrotron light irradiation.
  Sensitivity to water temp.: ~ 10   m /
  Move the girder (~ 0.3   m/   ) and BPM (~ 1   m/   )
  Induced beam orbit drift: ~10-30   m /

- Current status
  Vacuum cooling water temp.: ~   0.5

Power Supply Related High Frequency Orbital Noise (Source Elimination)

Beam Spectrum Observation

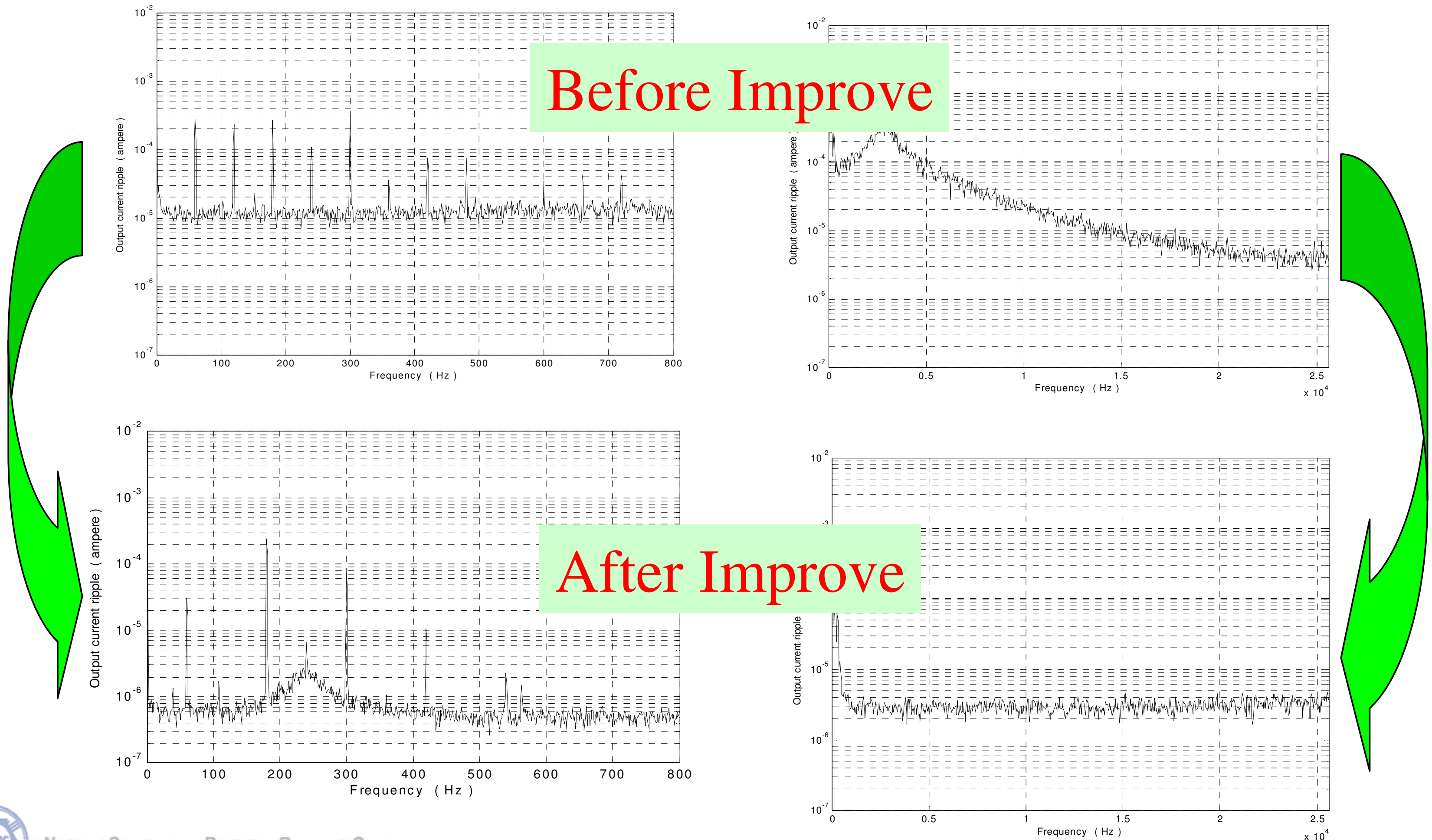




@ 136 mA (August 22, 2001)

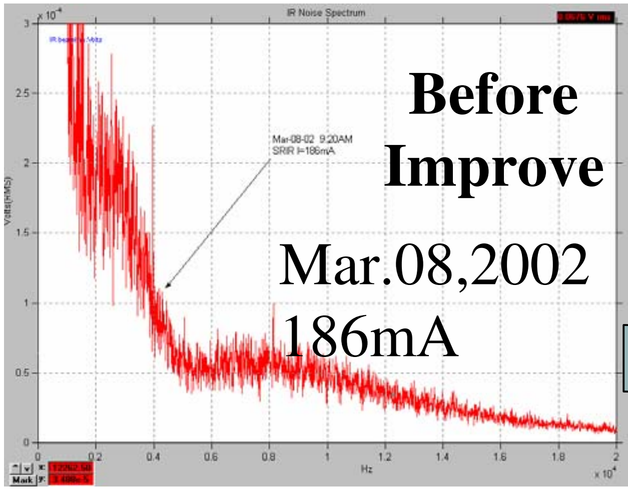
High Frequency Corrector Power Supply Noise

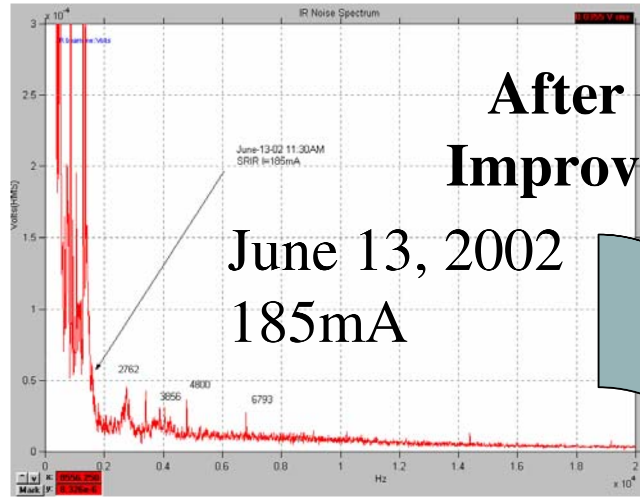
Typical Corrector Spectrum



(K.B. Liu et al.)

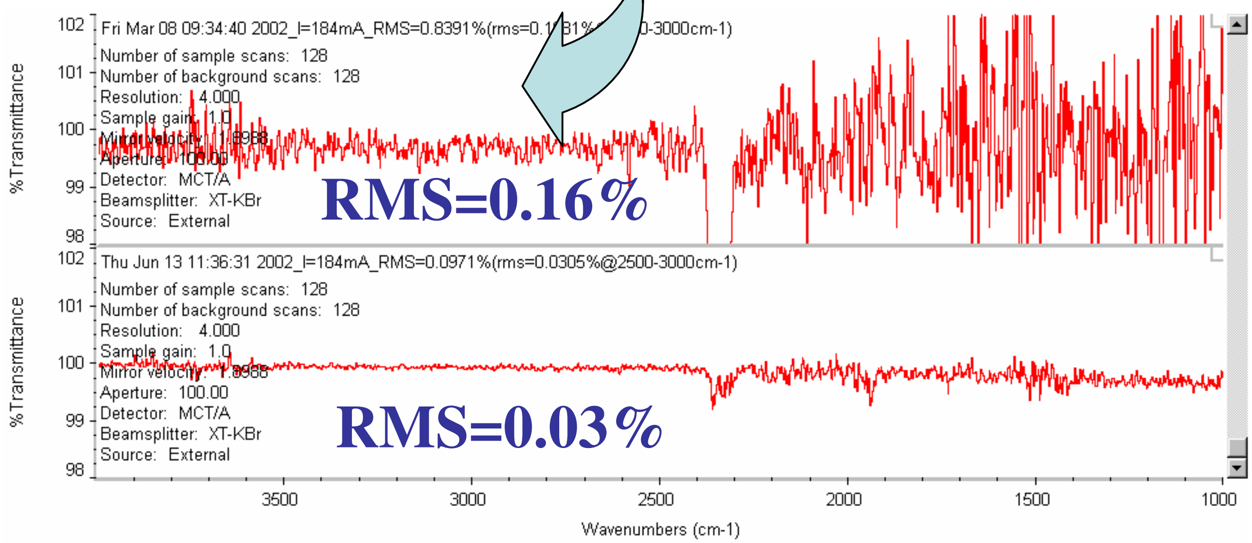
Observation at Infrared Beamline





Before Improve

After Improve



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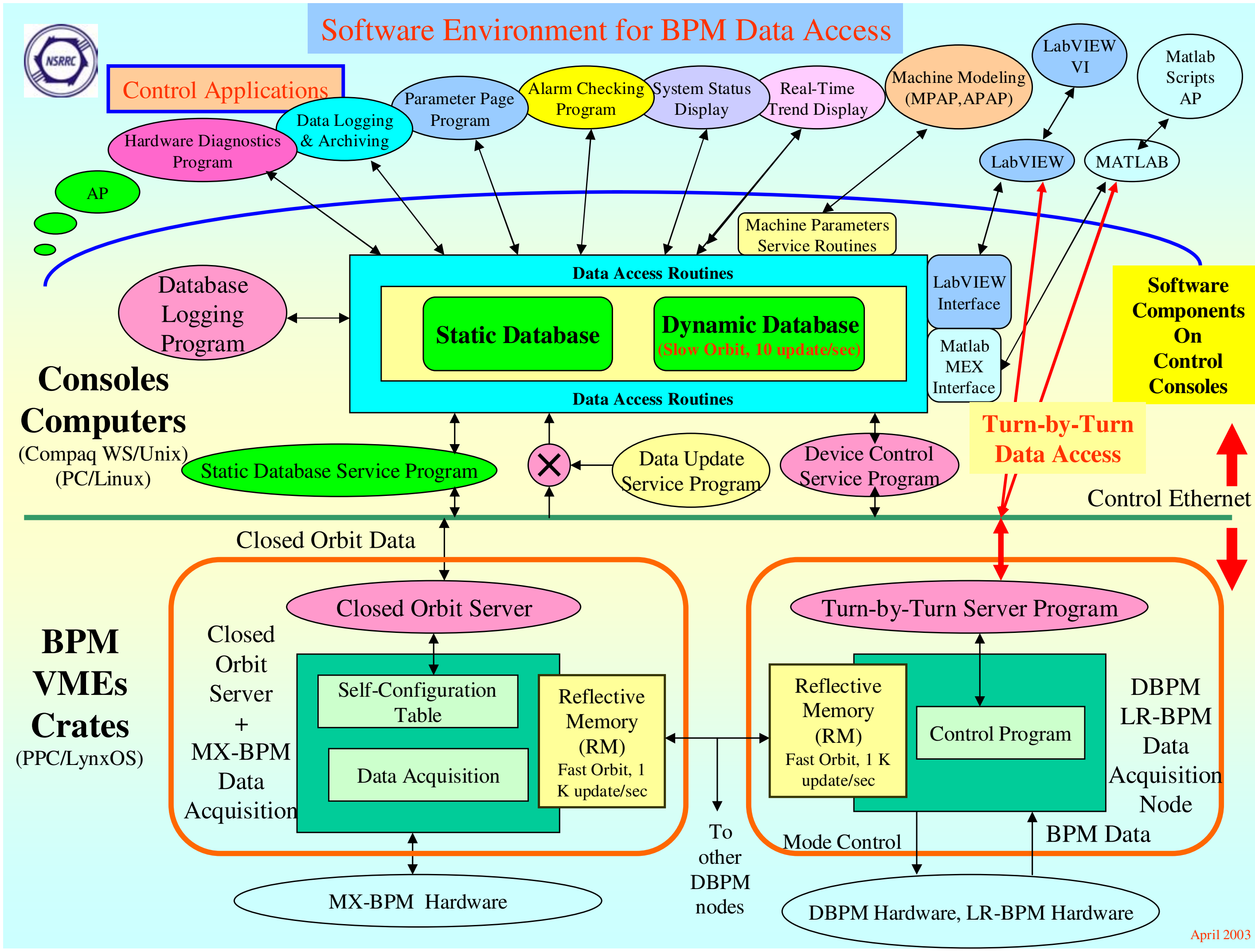
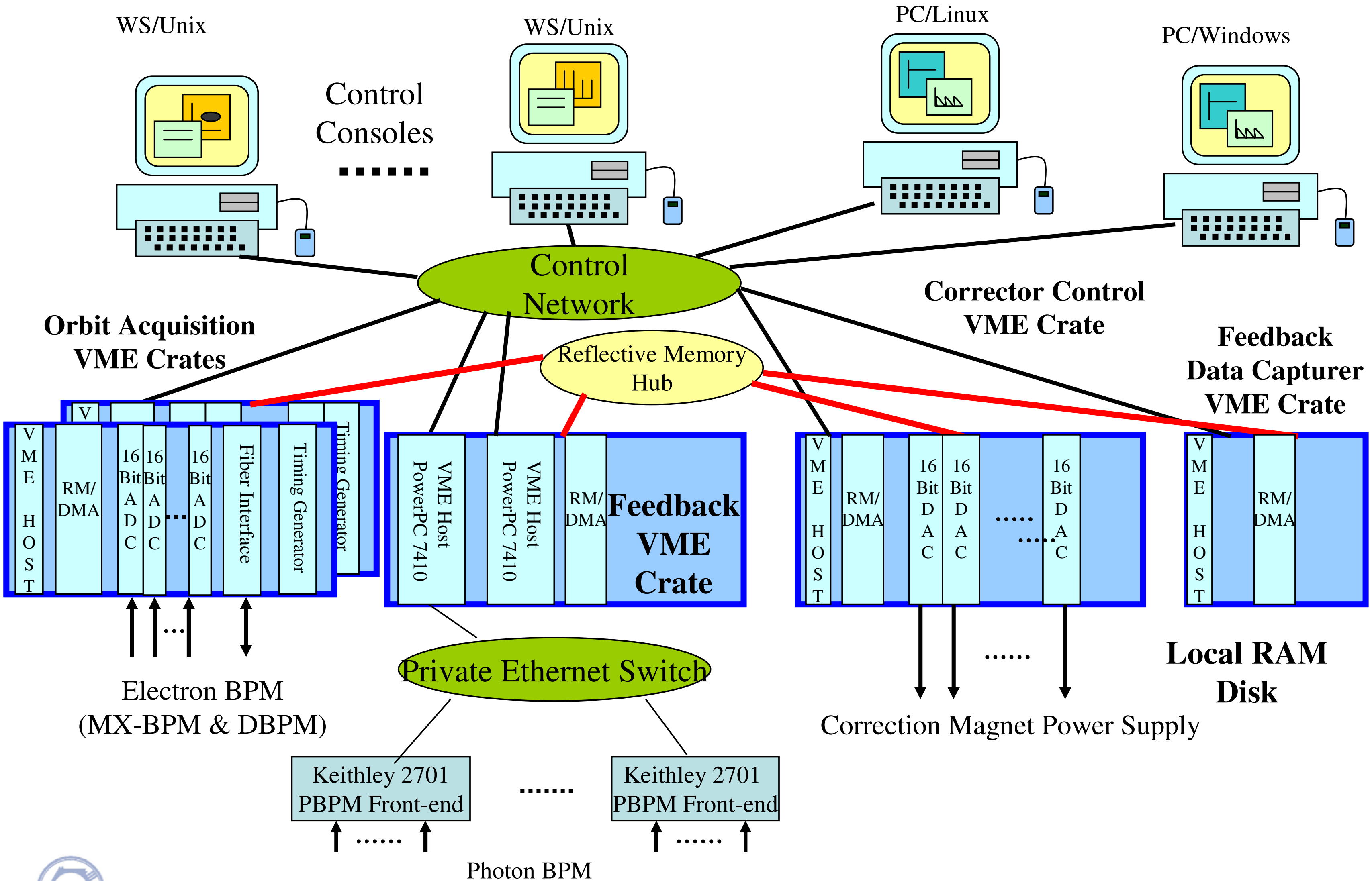
(Y. C. LO, et al.)

Environment of BPM System



Orbit Feedback System Architecture



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Orbit Feedback System Summary

* 22 correctors + 30 BPMs for both plane
* Using measured response matrix
* Singular Value Decomposition (SVD) approach to invert the response matrix
* Proportional, Integral and Derivative (PID) control algorithm
* Orbit acquisition rate 1 kHz
* Loop bandwidth is about 5 Hz now (30 Hz before December 2003)
* Unified system for global feedback and local feedback system
* Remote enable/disable of the feedback loop
* Orbit excursion reduced to less than ~ um level for ID operation
  - U5, U9 and EPU5.6
* Suppress orbit leakage due to non-ideal dynamic local bump
  - EPBM
* Prototype local feedback loop by using e-BPMs

Orbit Feedback System Summary (cont.)

* DSP feedback engine was replaced by general purpose PPC module
    - User friendly development environment
    - Lift maintenance difficults
    - Slightly increase jitter < 50 μsec (DSP < 10 μsec)

* Robustness enhancement of the feedback loop
    - BPM Check
        - RMS, data change rate, …etc
    - Limited correct setting range

Problems and Plan of the Orbit Feedback System

Major Problems :

* Loop bandwidth is too small right now
  - => cannot eliminate mechanical related oscillation
  - => Limited gap/phase changing speed of IDs

Short-term Plans:

* Increase sampling rate o 2 kHz to 4 kHz
* Modify corrector power supply regulation loop
* Increase loop bandwidth > 100 Hz

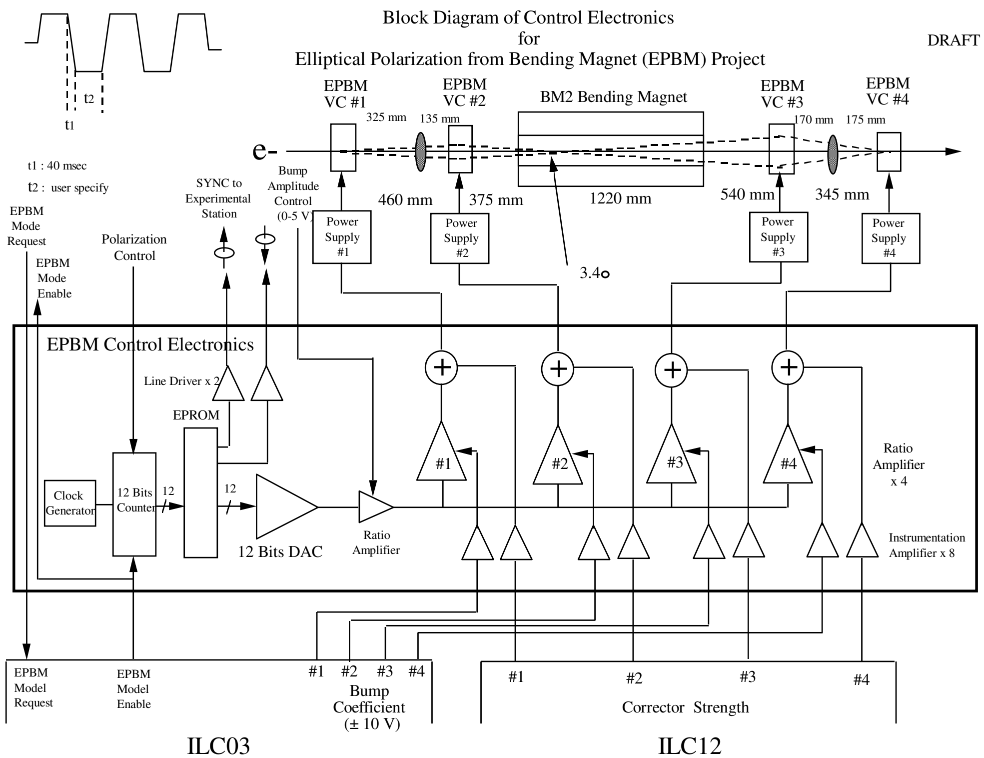
Closed Orbit and Orbit Stability

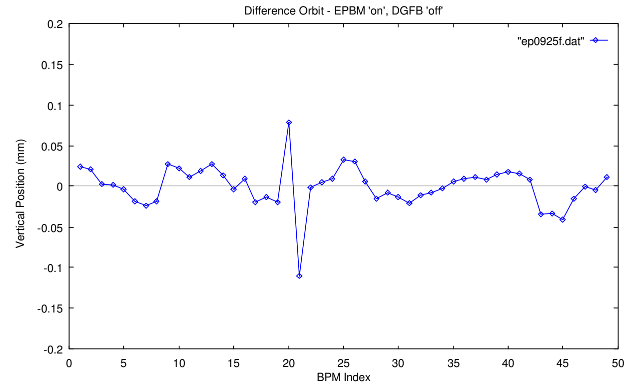
Closed Orbit : ~10 μm rms with DC correction schemes. (Peace Chang et al.)

Orbit distortions: < 10 μm rms during insertion gap scan can be compensated for using look-up correction tables. (Peace Chang et al.)

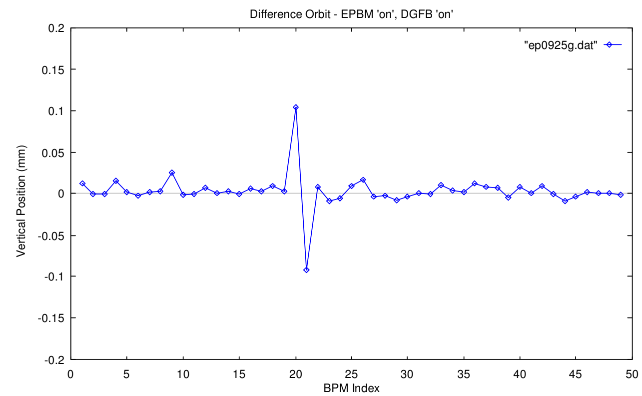
Beam orbit stability: *a few* μm *level (peak-to-peak)* with a global feedback system. (C. H. Kuo et al.)

Eliminated Orbit Leakage for EPBM Operation





EPBM flip bump without feedback



* EPBM dynamic bump with feedback

(C.H. Kuo et. al.)

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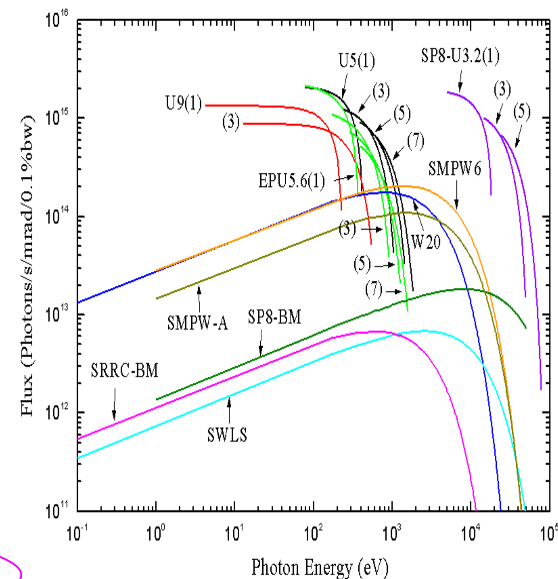
Insertion Devices in the TLS Storage Ring

Insertion Device		SWLS	EPU5.6	U5	SW6	W20	U9	IASW
Location Section		S1	S2	S3	S4/RF	S5	S6	Arc 2,4,6
Type		SC	Pure	Hyb.	SC	Hyb.	Hyb.	SC
Magnet Length (M)		0.835	3.9	3.9	1.404	3.0	4.5	0.85
Period Length (cm)		25	5.6	5	6	20	9	6
(Min.) Gap (mm)		55	18	18	18	22	18	18.5
Number of Periods		1.5	66	76	16	13	48	7.5
Maximum By (Bx) Field (Tesla)		6	0.67 (0.45)	0.64	3.2	1.8	1.25	3.5
Photon Energy (eV) [Used Range]	Min.	4000	80	60	5000	800	5	5000
	Max.	38000	1400	1500	14000	15000	100	14000
Defection Parameter Ky (Kx)		190.5	3.52 (2.37)	2.99	17.9	33	10.46	19.6
Vertical Tune Shift (Horizontal Tune Shift)		0.0504 (-0.014)	0.011 (-0.012)	0.008	0.036	0.036	0.033	0.05
Installation Date		Apr. 2002	Sep. 1999	Mar. 1997	Dec. 2003	Dec. 1994	Apr. 1999	2005

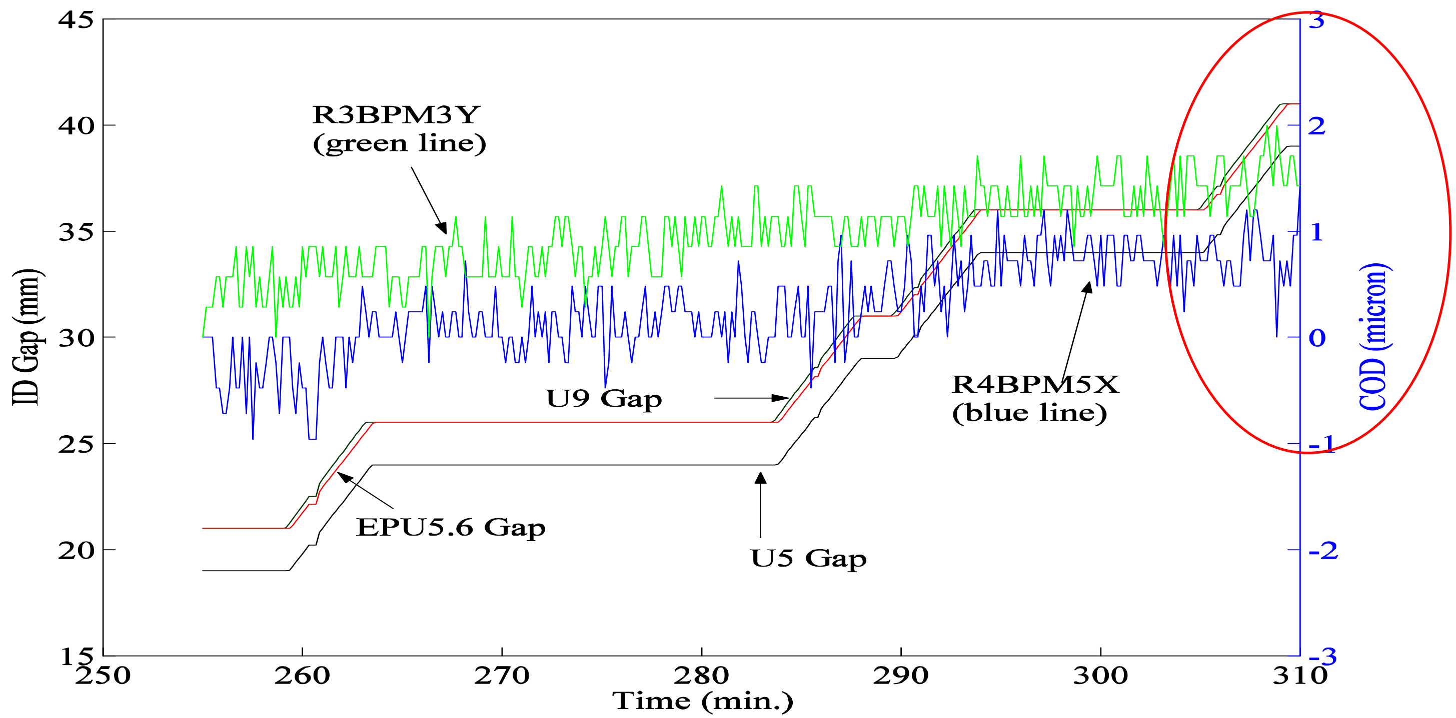
without Feed-forward Tune Correction

with Feed-forward Tune Correction



The photon flux vs. photon energy of bending magnets and IDs at TLS. Two Taiwan beamlines, SP8-BM and SP8-U3.2, at Spring 8 are also depicted

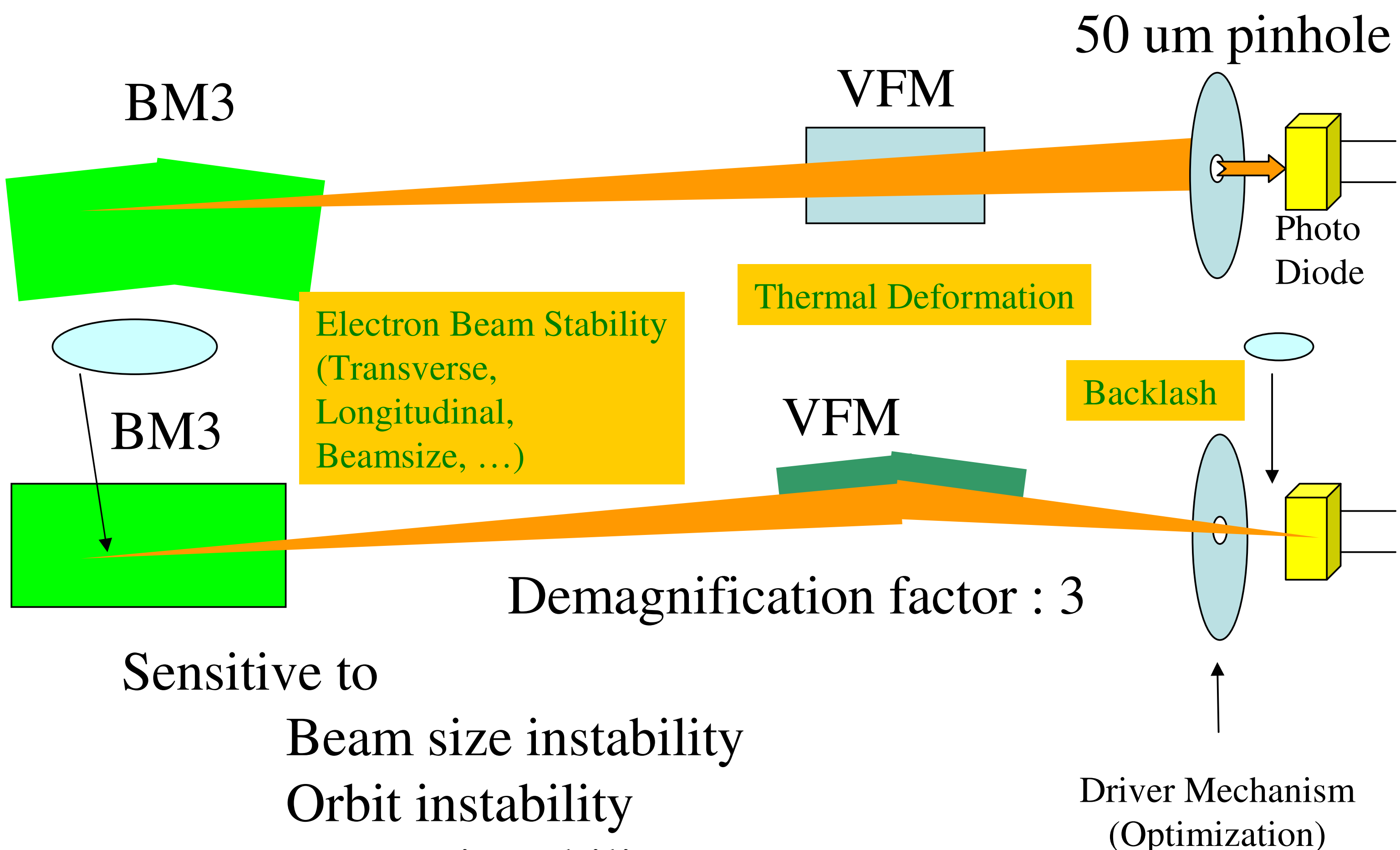
Orbit stability of the NSRRC Storage Ring



With the follow-gap look-up table and global orbit feedback system, the orbit drift of the field scan of U5, U9 and EPU5.6 can be reduced from a few hundred microns to *a few microns*. When the gaps of U5, U9 and EPU5.6 are scanned from 19, 21, and 21 mm to 39, 41, and 41 mm, the closed orbit distortions indicated by the R4BPM5X (blue) and R3BPM3Y (green), those are used in the faster orbit feedback system, are within 2 microns in both horizontal and vertical planes.

(Peace Chang, et. al.)

Photon Beam Stability Monitor (ΔI_o / I_o)

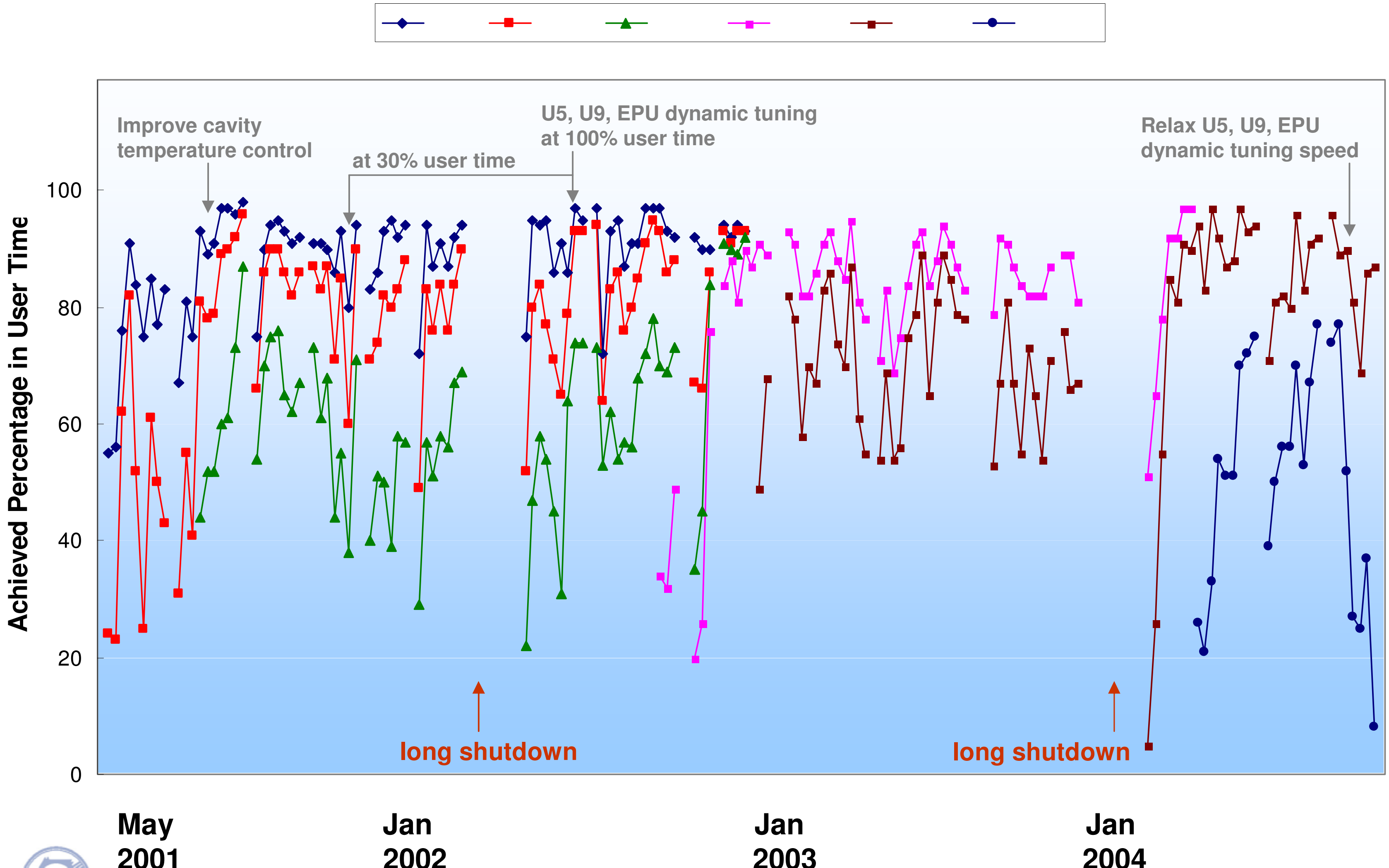


Sensitive to

- Beam size instability
- Orbit instability
- Energy instability

Signpost of overall beam stability form users' viewpoints

History of the Photon Beam Stability ($\Delta I_0/I_0$)



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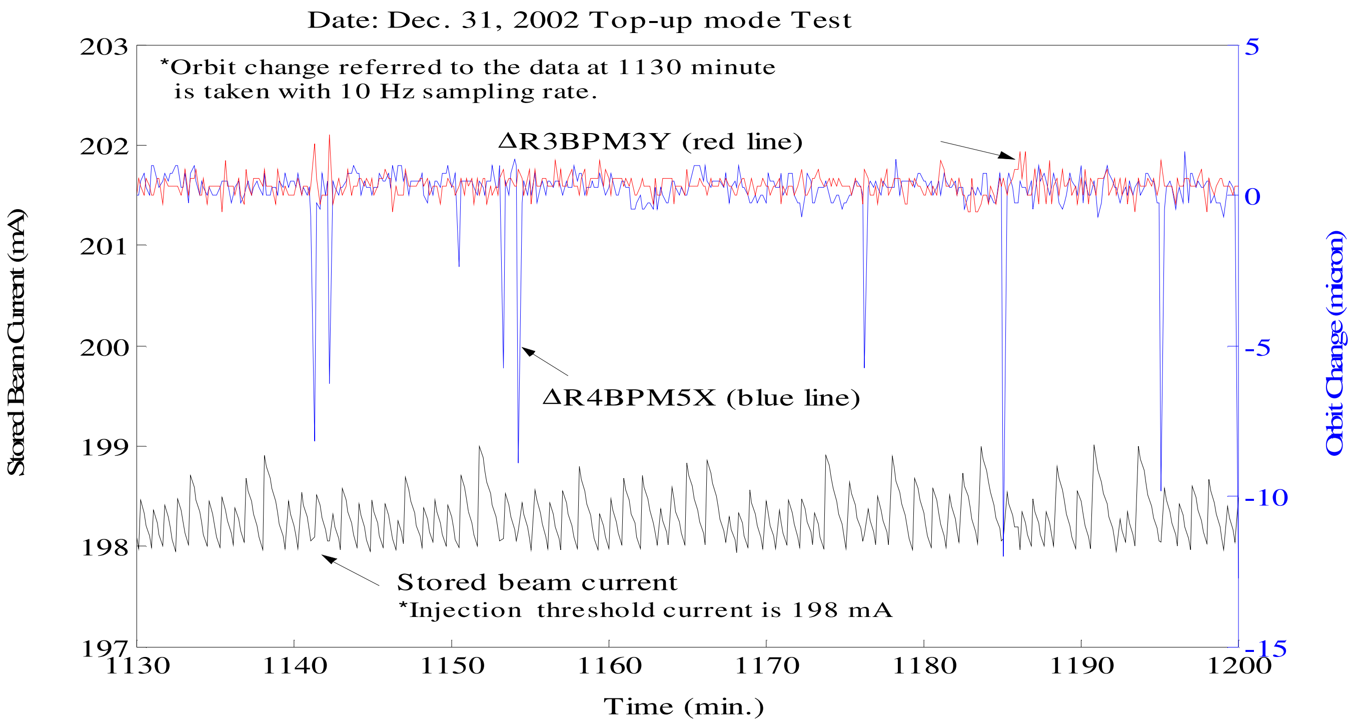
(K.K. Lin et. al.)

Top-up Injection Project

Top-up injection scheme planned.
Feasibility demonstrated.

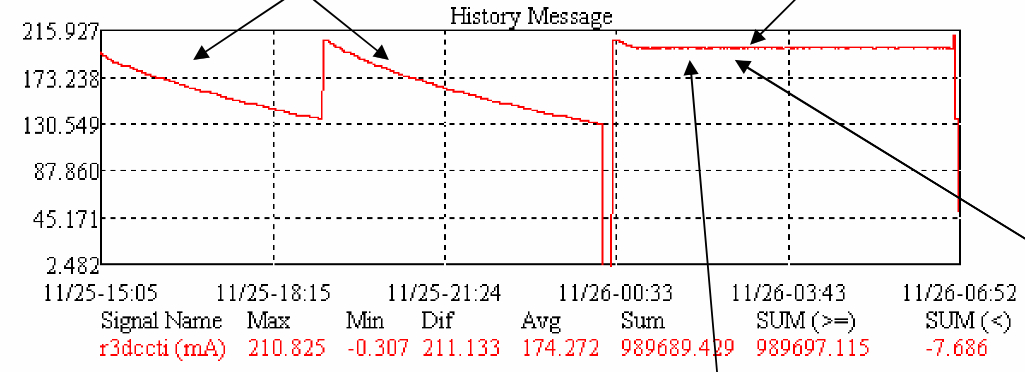


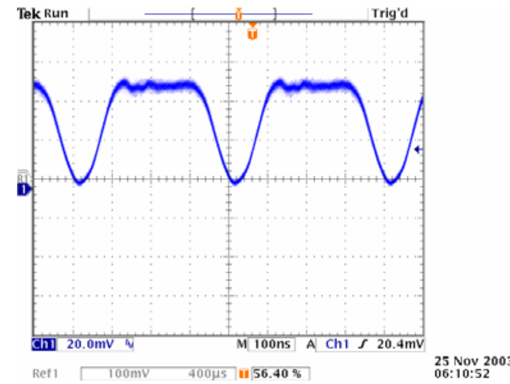
(G.H. Luo et. al.)

Experiment of Top-up injection

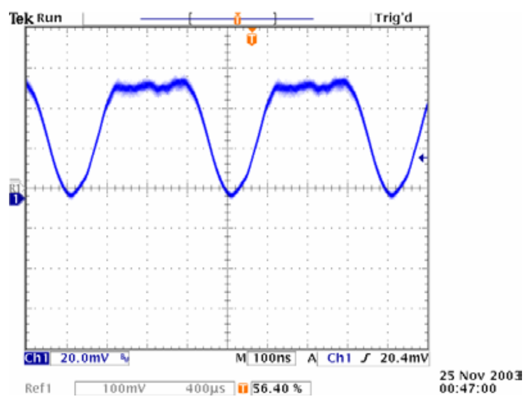
User's shift decay mode

Test of top-up mode

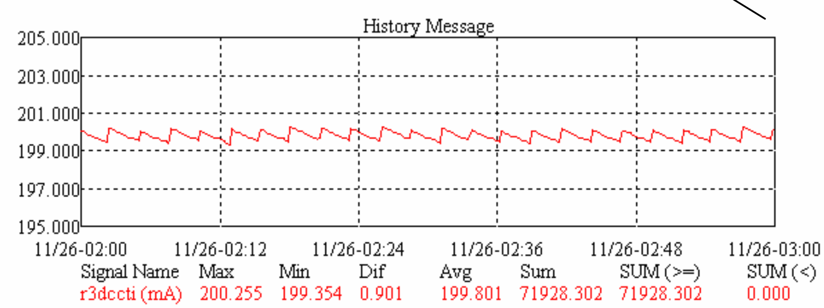




Filling pattern at the end of top-up injection



Filling pattern at the beginning of top-up injection



Zoom in, injection interval 2 min.

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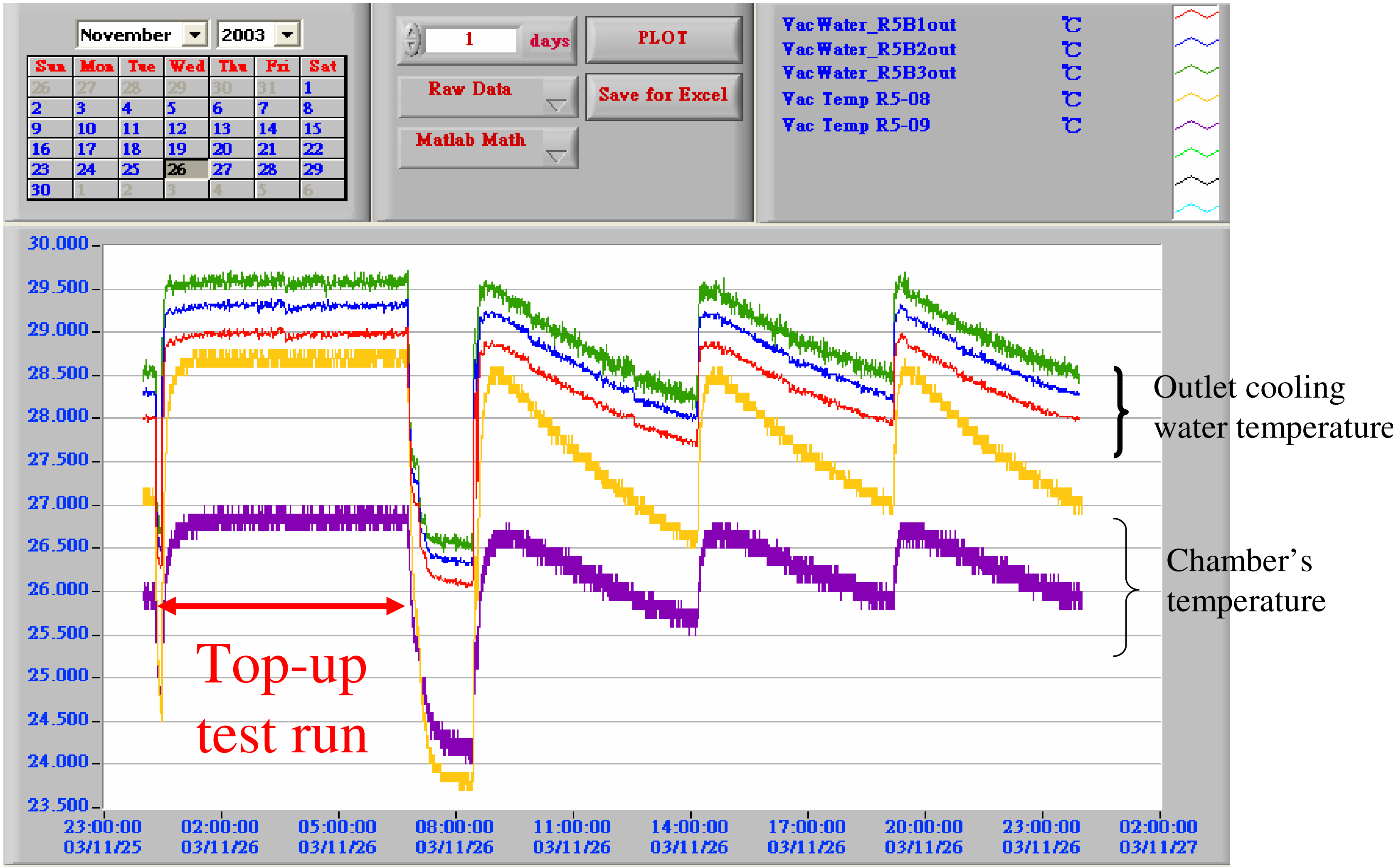
(G.H. Luo et. al.)

Cooling Water and Chamber Temperature



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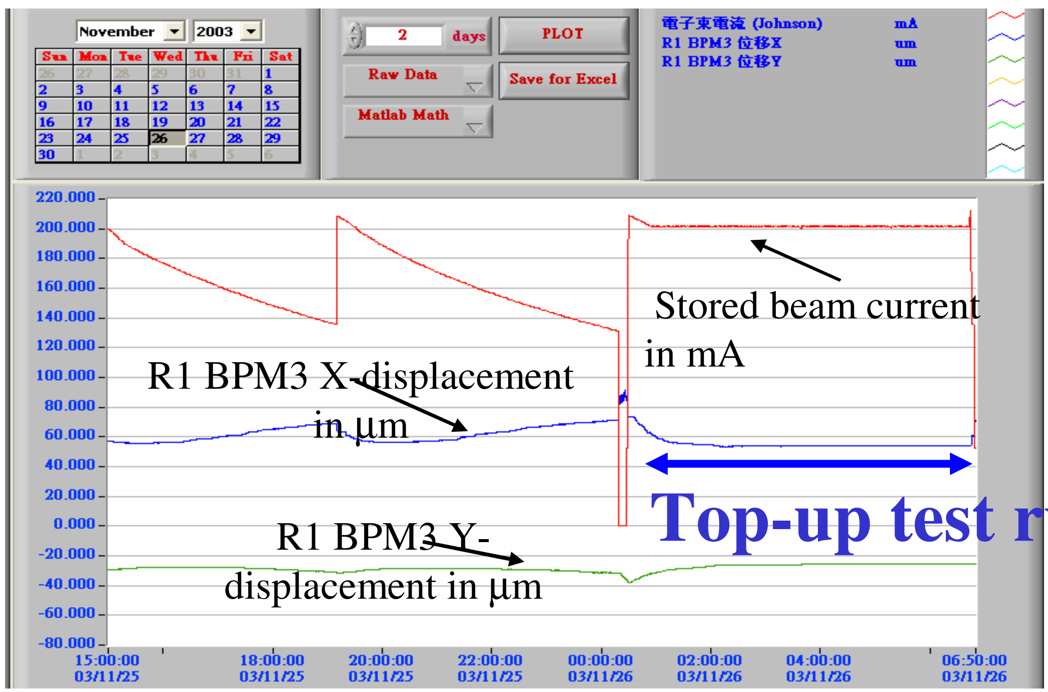
(G.H. Luo et. al.)

Compound Displacement of the of Beam Position Monitor Reading

-Intensity dependency of BPM electronic and BPM support fixtures (~ µm)
-Filling pattern dependency of BPM electronics (~ µm)
-RF gap voltage condition variation
-BPM support structure (~ 10 µm)
-Thermal related (~ 10 µm)

δx ~15 µm

δy ~5 µm



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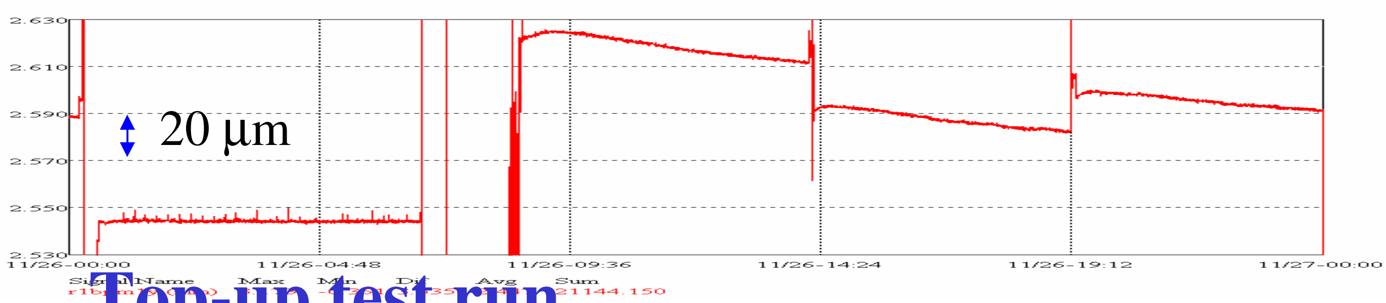
(G.H. Luo et. al.)

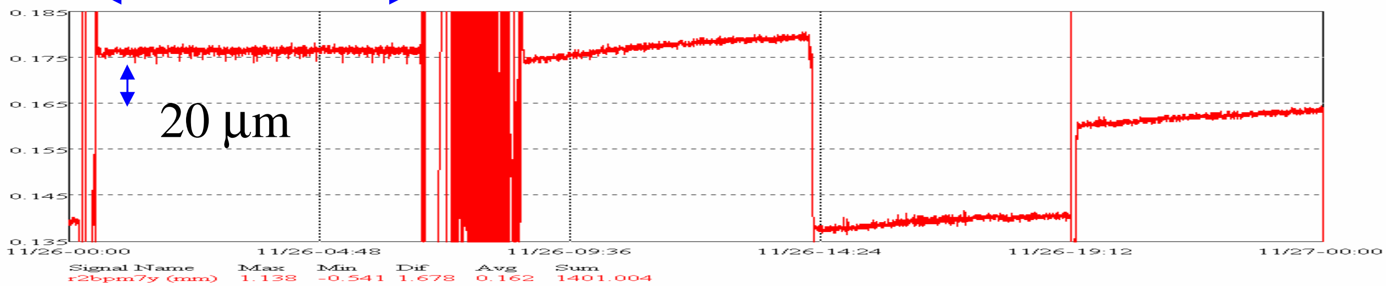
Vertical Beam Position Variation

R1BPM1Y

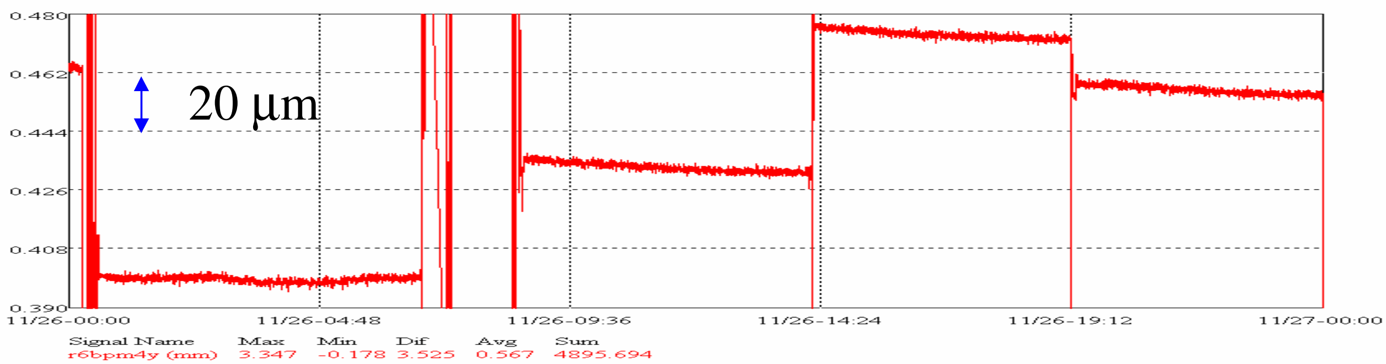


Top-up test run

R2BPM7Y

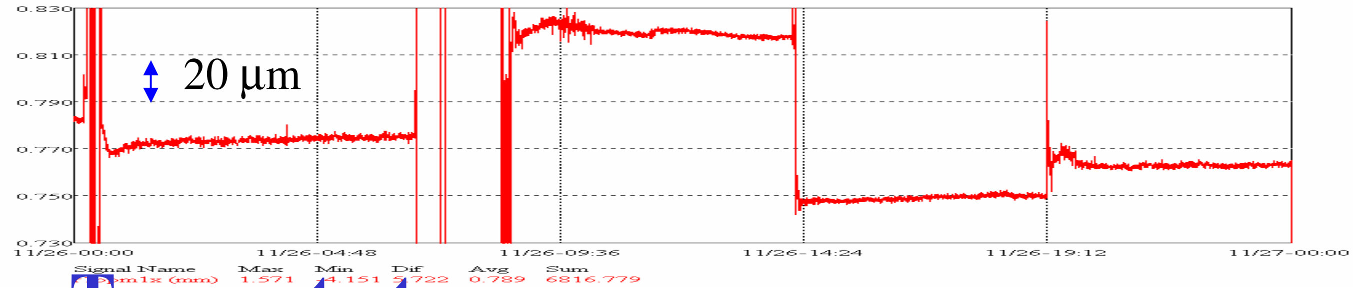


R6BPM4Y



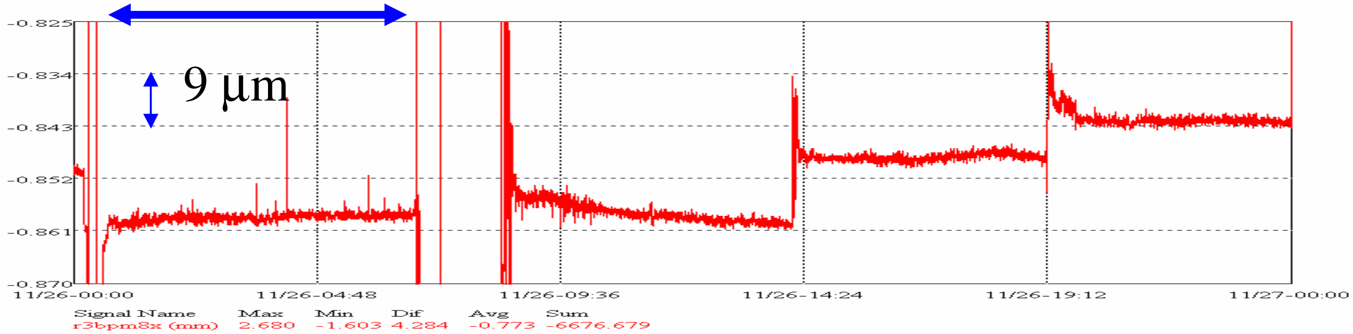
Horizontal Beam Position Variation

R1BPM1X

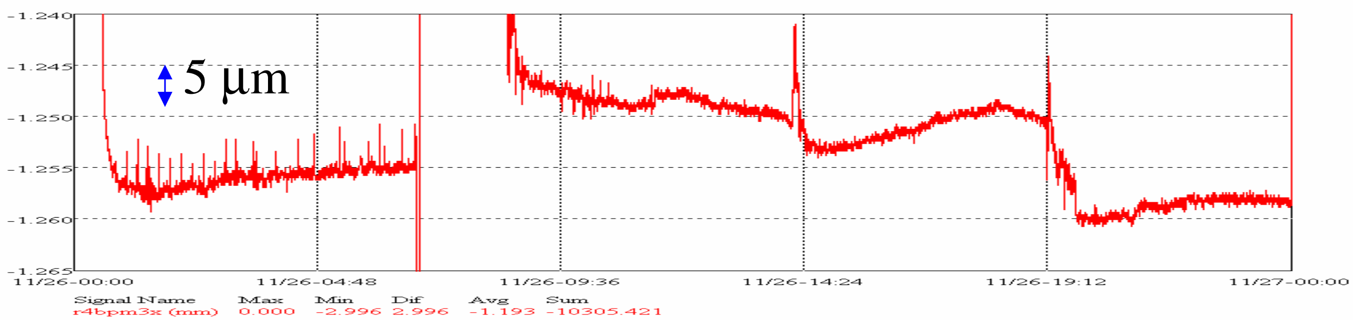


Top-up test run

R3BPM8X



R4BPM3X



Top-up Injection Plan

Renew 1.5 μsec half-since injection kicker to reduced jitter and to improve waveform matching .

Gate of the orbit feedback loop is a provincial solution to remedy mismatching problem of the injection kickers.

User experiment with injection gate and without is performed, acceptable results get up to now.

Improve gun pulser and linac performance to improve filling pattern control.

Studies of the injector reliability, injection efficiency, and minimization of orbit perturbation during injection, etc., are ongoing.

Top-up operation is scheduled in late 2005.

Parameters of the Proposed Taiwan Photon Source

Electron Energy	**3 ~ 3.3 GeV**
Current	**400 mA at 3 GeV or 300 mA at 3.2 GeV (Top-up injection)**
SR Circumference	**518.4 m (h = 864 = $2^5 \cdot 3^3$, dia.= 165.0 m)**
BR Circumference	**499.2 m (h = 832 = $2^6 \cdot 13$, dia.= 158.9 m)**
Lattice	**24-cell DBA**
Straight-section	**10.5 m x 6 ($_v$ = 10.5 m, $_h$ = 160 m)** **6 m x 18 ($_v$ = 8 m, $_h$ = 110 m)** **3 m x 12 ($_v$ = 4.5 m, $_h$ = 250 m; In-achromat)**
Bending-section	**x 12**
Emittance	**< 2 nm·rad at 3 GeV (Distributed dispersion)**
Coupling	**1 %**
RF Frequency	**500 MHz**
RF Max. Voltage	**4.8 MV (4 SRF cavities)**
RF Max. Power	**720 kW (4 SRF cavities)**
Site	**NSRRC in Hsinchu Science Park , Taiwan**
Building	**223 m OD (700 m circumference)** **139 m ID (437 m circumference)**

Sub-μm orbital performance is one of a design goal.

Summary

* To achieve μm (sub-μm) orbital performance is a short term goal at TLS.
* Further develop of fast orbit feedback system is needed in following area:
  • Corrector PS improvement
  • High sampling rate (~ 2 KHz/4 KHz)
  • PS control interface
  • BPM system improvement in engineering as well as software functionality.
* Top-up operation mode is scheduled, beam orbit stability will be improve further.
* Sub-μm orbital performance is one of a challenge for the newly proposed 3 ~ 3.3 GeV Taiwan Photon Source

Thank you for you attention