Activities of Source Suppression for Improving Orbit Stability in Pohang Light Source

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POSTECH

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Sources of Orbit Drifts

Sources of Real Orbit Drifts:

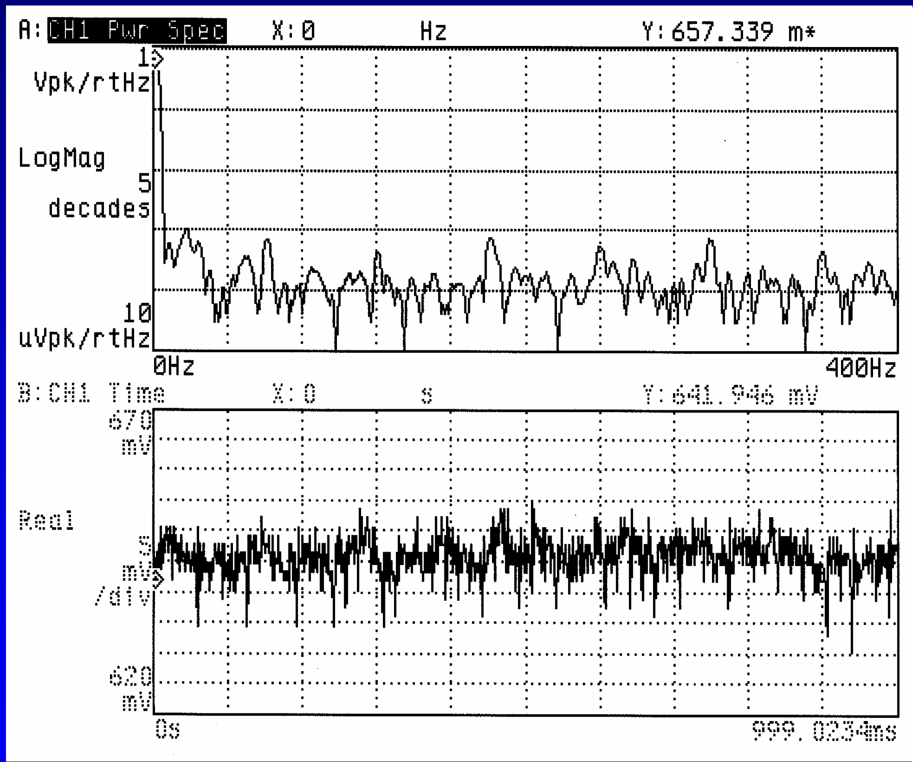
1. **Magnet Power Supplies**
2. **Cooling Water and Air**
3. **Atmospheric Temperature Changes (Day & Night, Seasonal,…)**
4. **Ground Settlement**
5. **Et Cetra : the Tide, Municipal Noises, …**
6. **And… : Operation Procedures, Uncorrected ID Gap Changes, Orbit Feedbacks based on Unstable BPM's, …**

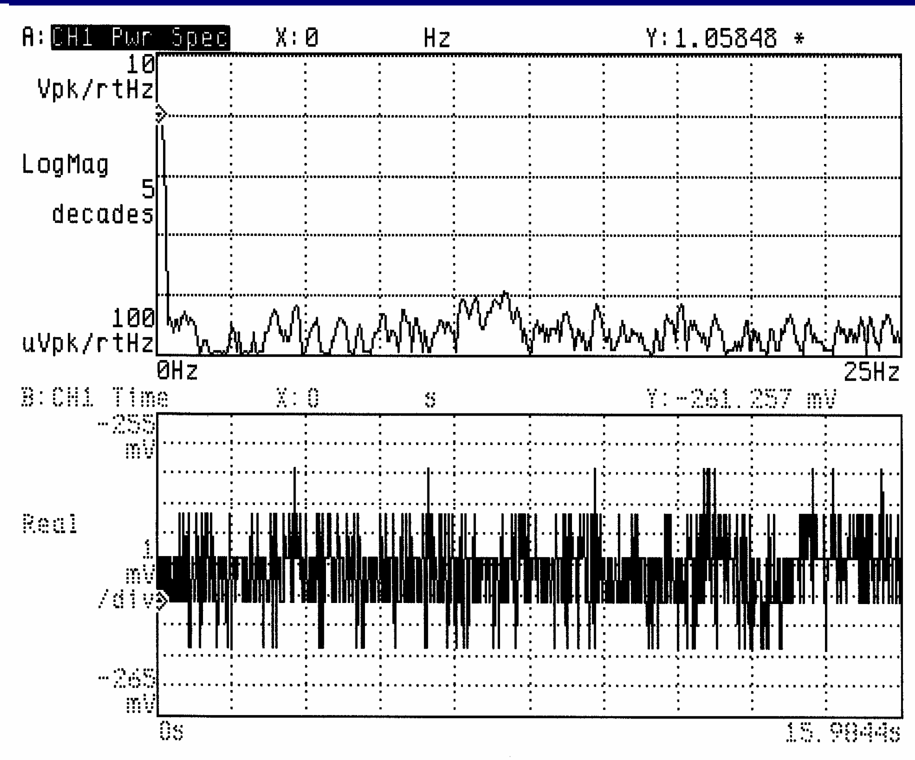
Sources of Apparent Orbit Drifts: largely due to BPM Instabilities

1. **Displacement of Vacuum Chamber**
2. **Thermal Drift and Intensity Dependency of BPM Electronics**
3. **TE modes**
4. **Aliasing of Beam Oscillations (Important for Multiplexing BPM's)**
5. **Cable Motions**

Measurement of Orbit Fluctuation

Measured by MX-BPM (Bergoz) – Horizontal Beam Position

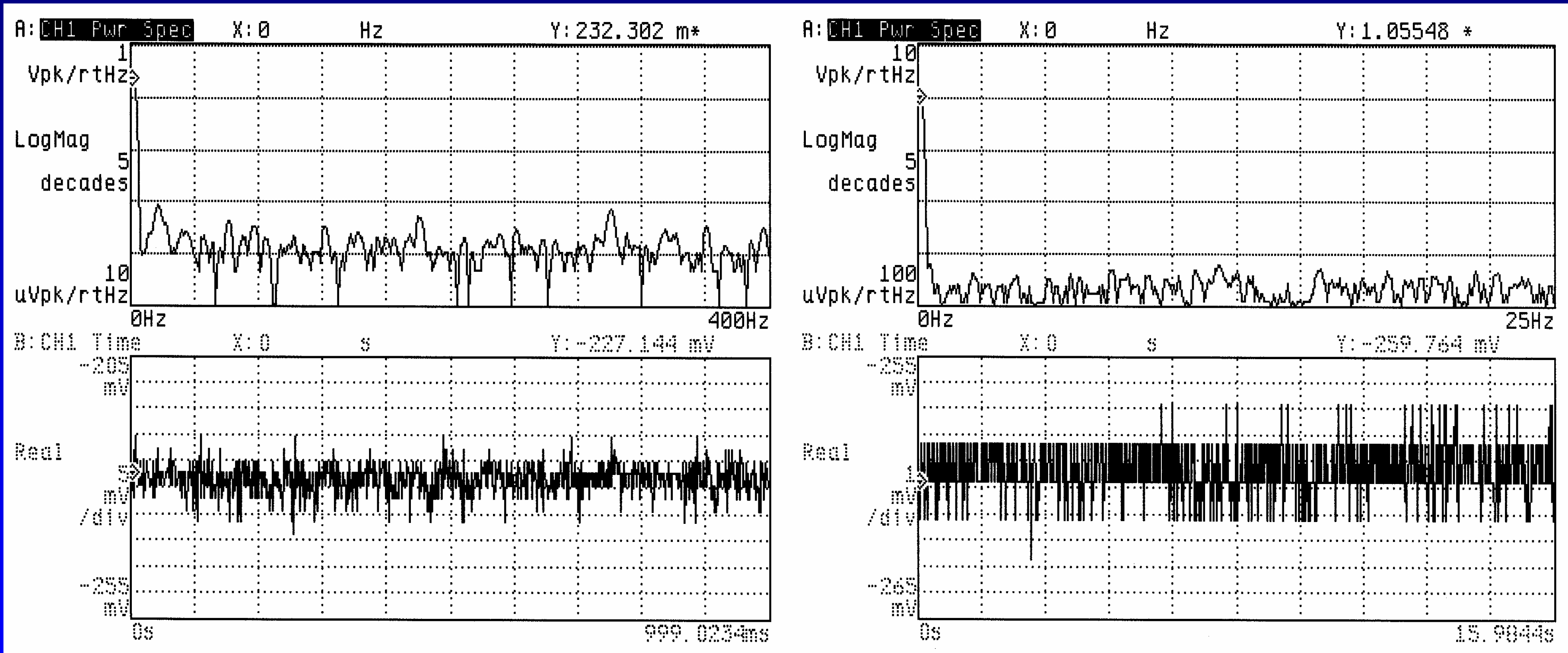




Note : Sampling Frequency of MX-BPM is 2 kHz and, as such, meaningful measurement can be done below ~ 1 kHz

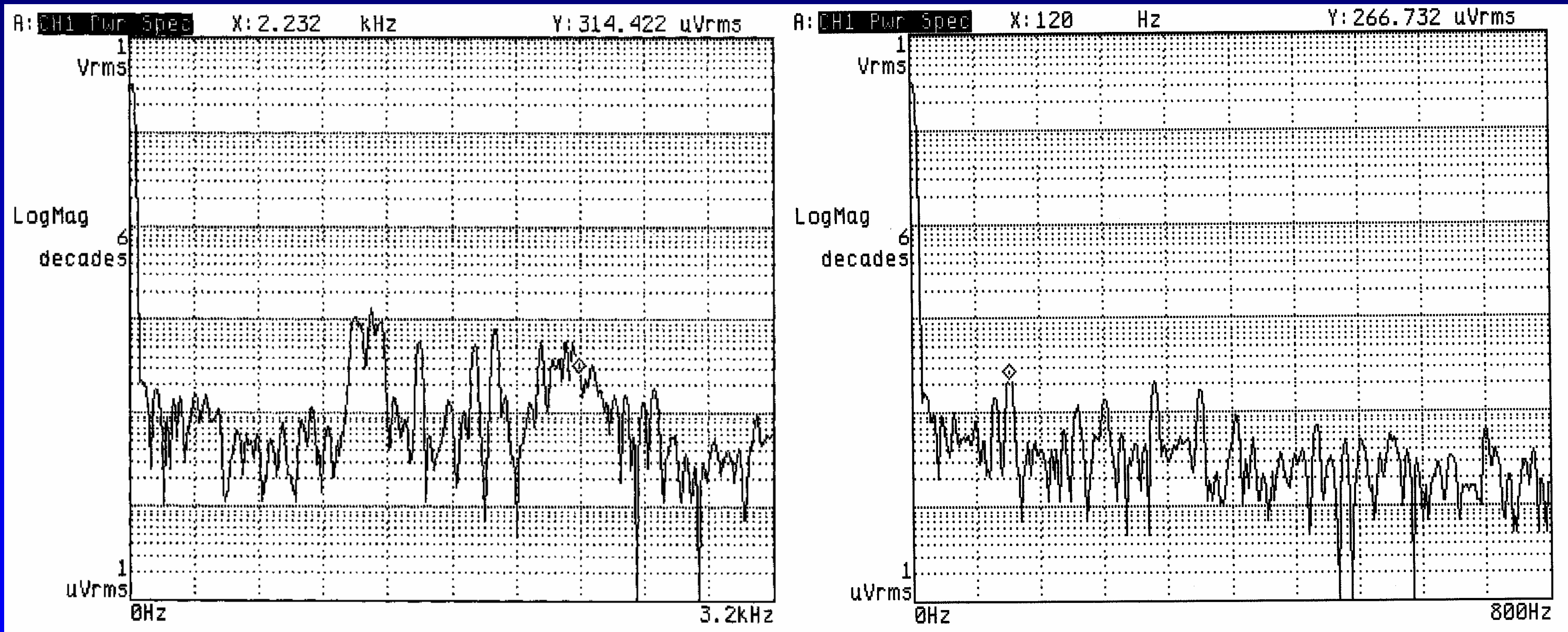
Measurement of Orbit Fluctuation

Measured by MX-BPM (Bergoz) – Vertical Beam Position



Measurement of Orbit Fluctuation by PBPM

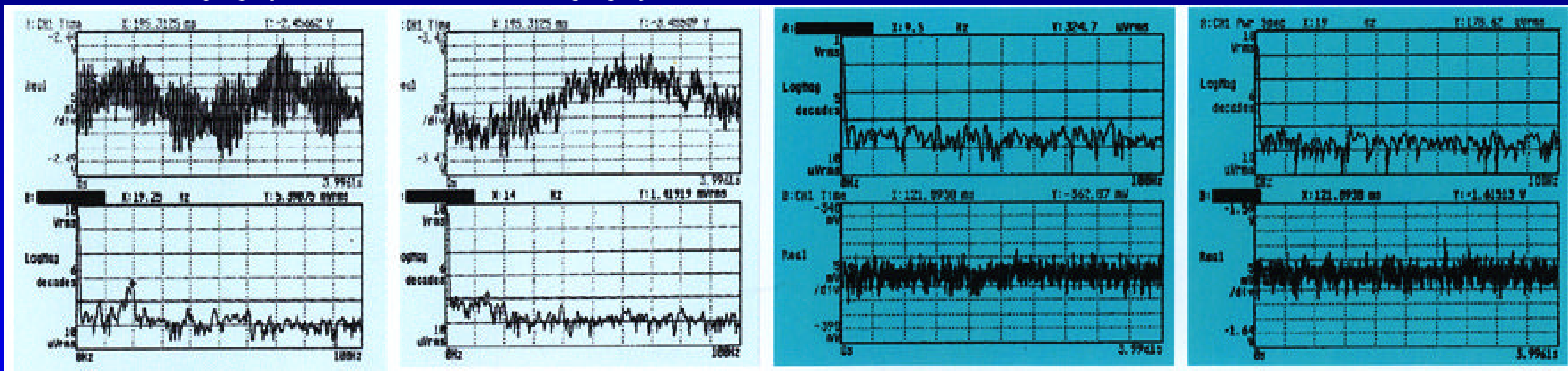
– Frequency Domain Measurement of Vertical Beam Position -



Note : 1. Bandwidth of Pre-AMP is several kHz, enabling measurement of kHz orbit fluctuation.
2. Orbit Fluctuation at frequencies > 1 kHz has been observed.

Improvement of MPS Stability

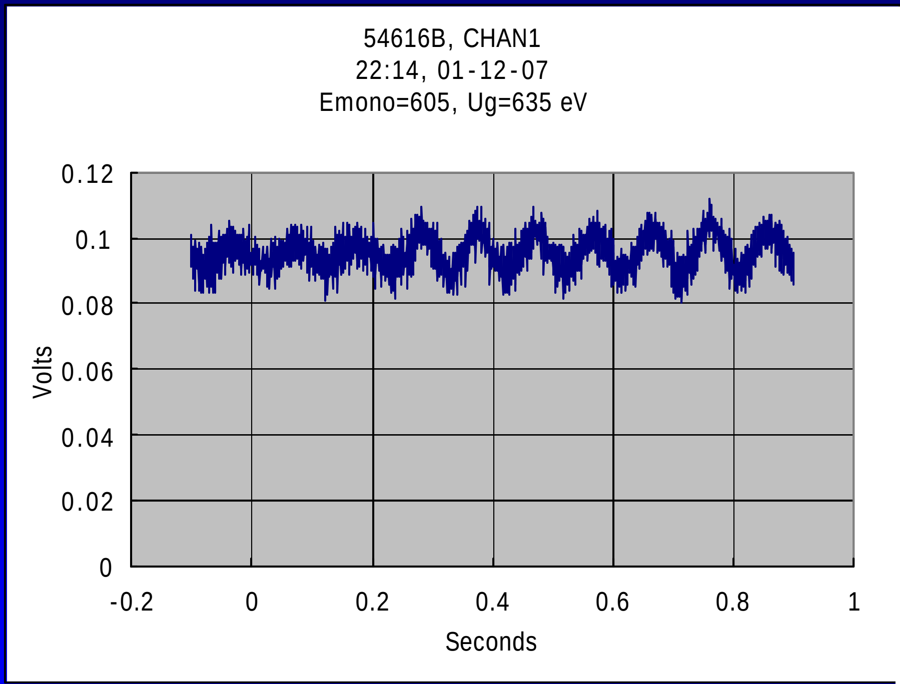
X orbit Y orbit X orbit Y orbit

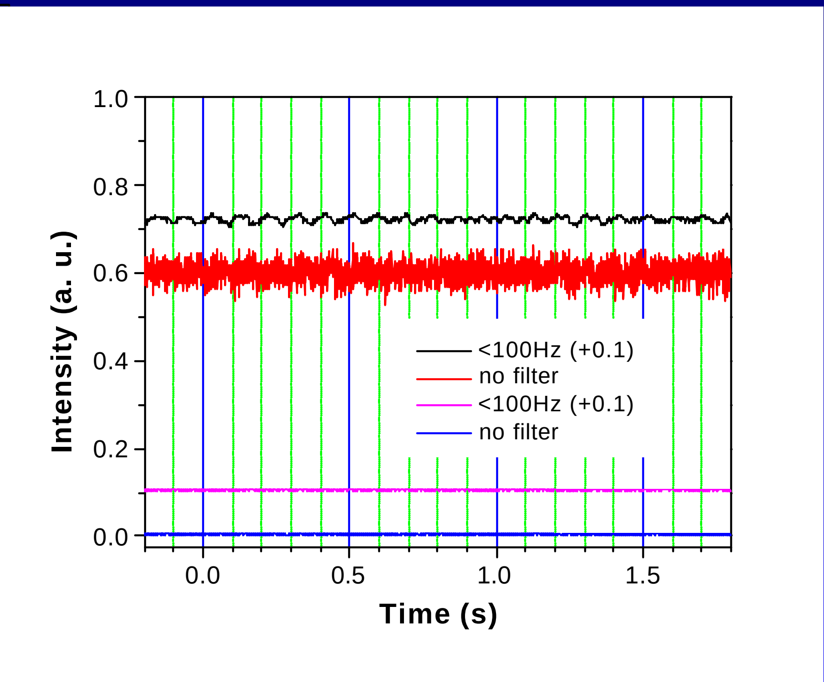


Comparison of closed orbit stability before and after MPS improvement. Left 4 graphs are time (top) and frequency (bottom) domain measurements of BPM signal before MPS improvement. Right ones are those after MPS improvement. Top and bottom graphs are frequency and time domain measurements respectively.

Improvement of MPS Stability

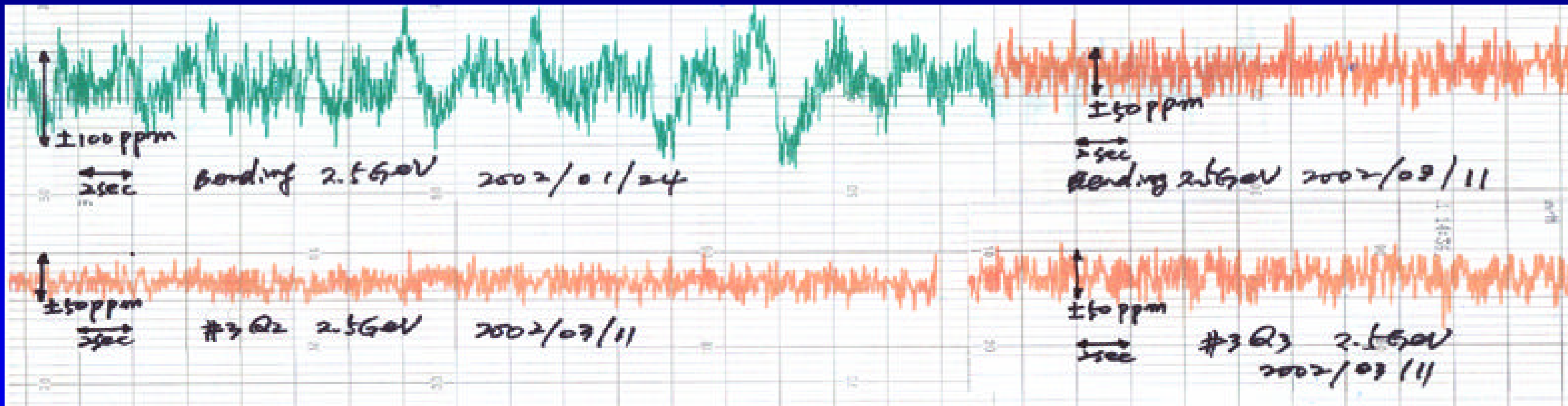
(Continued)





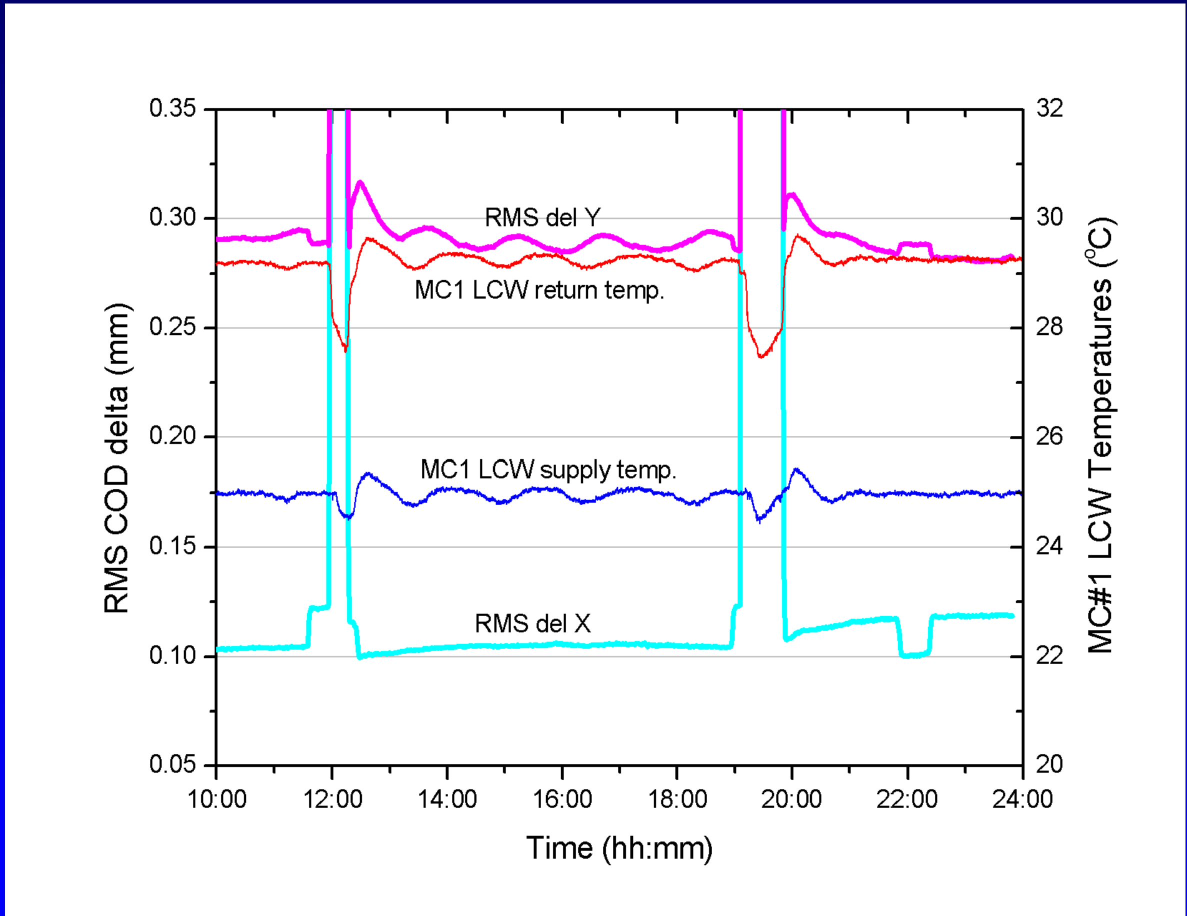
Comparison of U7 photon intensity fluctuations before (left) and after (right) MPS improvement.

Improvement of MPS Stability (Continued)



Comparison of MPS stability before and after improvement.

Effects of LCW Temperature Change on Orbit Stability



10/10/2002

Behavior of Mechanical Components in Machine Tunnel

1. **Displacements of magnets, girders, and vacuum chambers during machine startup and shutdown was as large as 100 μm. This was reduced < 5 μm after the machine reached steady-state operation. During normal operation, significant transients occur when beam injection.**
2. **During the de-ramping/ramping processes in beam injections, bending and quadrupole magnets moved as large as 20 and 10 μm respectively. After beam injection, the bending magnet promptly restored to its original position whereas the quadrupole did after 30 min - 1 hour. (See Fig. 1 & 2)**
3. **During normal operation, girder displacement was negligible. Vacuum chamber moved 8 - 10 μm vertically.**
4. **The above did not occur when the de-ramp/ramp are avoided (Fig. 3)**

Behavior of Mechanical Components in Machine Tunnel
(Continued)

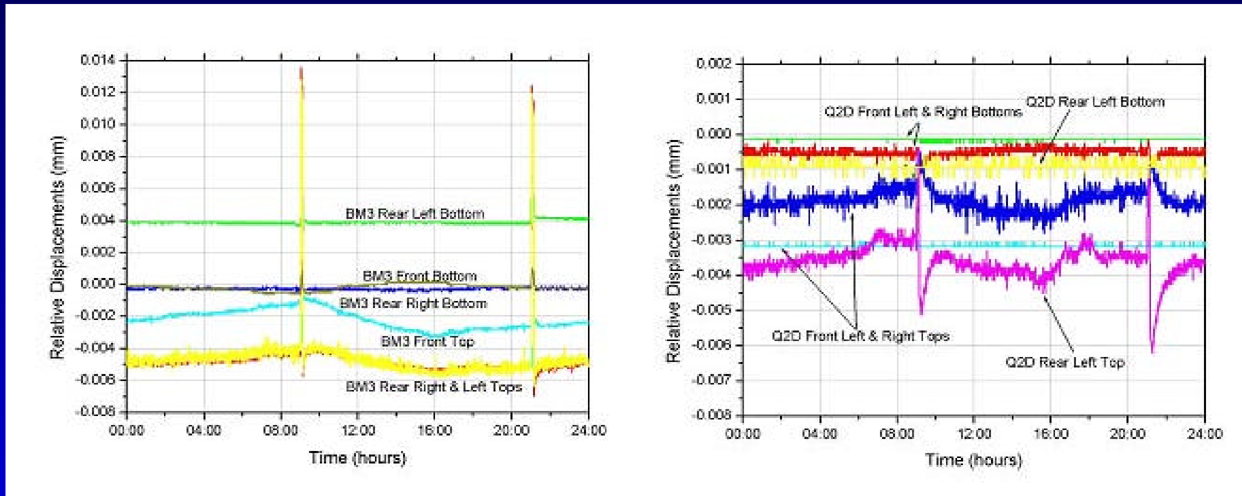


Fig. 1. Relative Magnet Displacements during Normal Operation. Left: BM, Right: QM

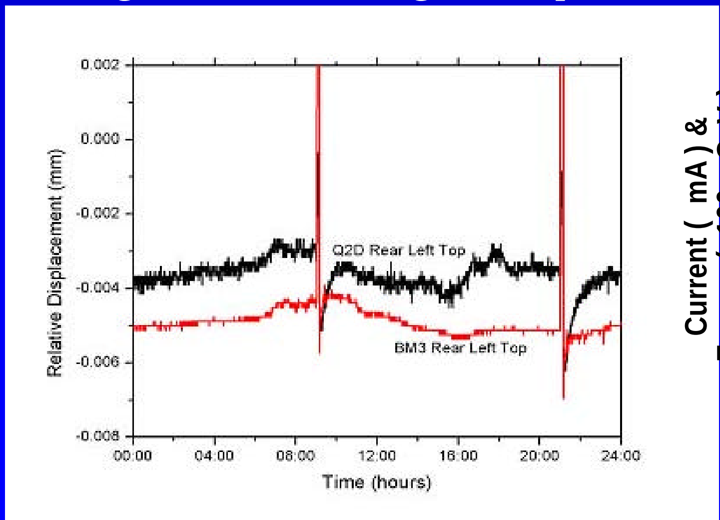


Fig. 2. Comparison of Magnet Displacements

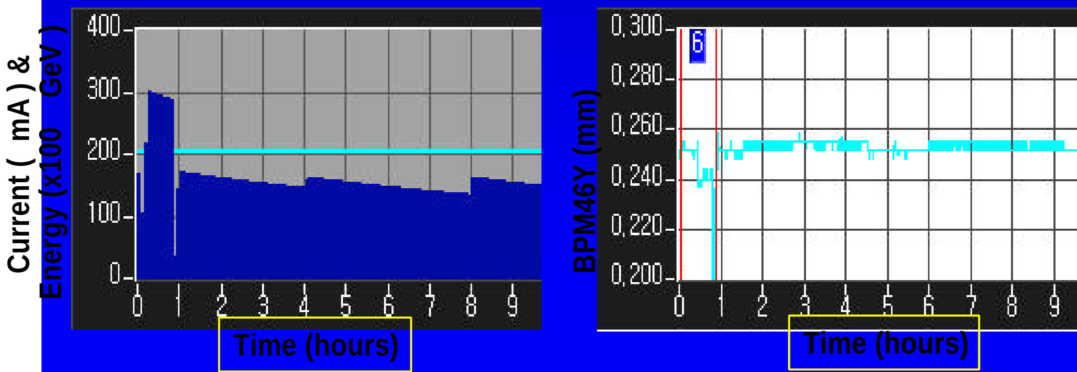


Fig. 3. Orbit was stable when there was no transients

Facts on Apparent Orbit Drifts (BPM Instabilities)

1. Displacement of Vacuum Chamber: BPM head that is installed on large vacuum chamber can move due the to thermal displacement of the vacuum chamber. Proper thermal stabilizing of the vacuum chamber can reduce this below 5 mm.

2. Thermal Drift and Intensity Dependency of BPM Electronics: For Bergoz MX-BPM, the thermal drift is negligible and the intensity dependency (linearity error) can be as high as 20 mm per 10-dB change if input signal strength. Due to unknown reason, the linearity error of the Bergoz MX-BPM Is larger in Y than X. This can be inverted by swapping two opposite buttons.

3. Aliasing of Beam Oscillations: Needs careful setting of sampling rate of MX-BPM. Low-pass filtering of the output signal of the MX-BPM is effective.

4. Cable Motions: This can cause orbit change as large as 10 mm. Cable must be carefully installed and maintained. Standing waves along the cable must be prevented.

Facts on Apparent Orbit Drifts caused by TE modes

1. **Only affects vertical orbit.**

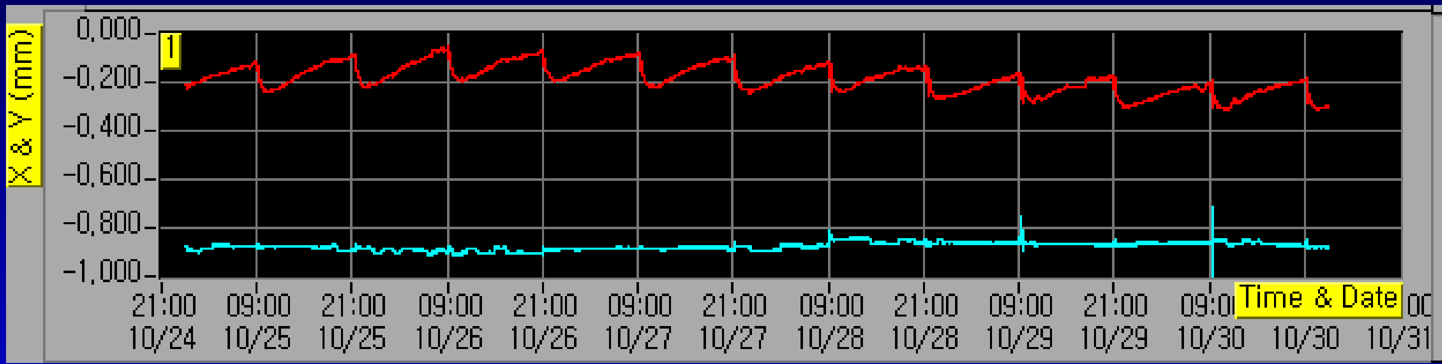
2. **In the APS, TE modes caused an order of magnitude higher systematic errors in vertical orbit readbacks than in horizontal ones.**

3. **In the PLS, some of ID BPM's have shown orbit drifts as large as 500 mm, which have smooth variation with time. In contrast to this, some set of arc BPM's have shown abrupt orbit jumps. All these occurred only in vertical orbit readbacks.**

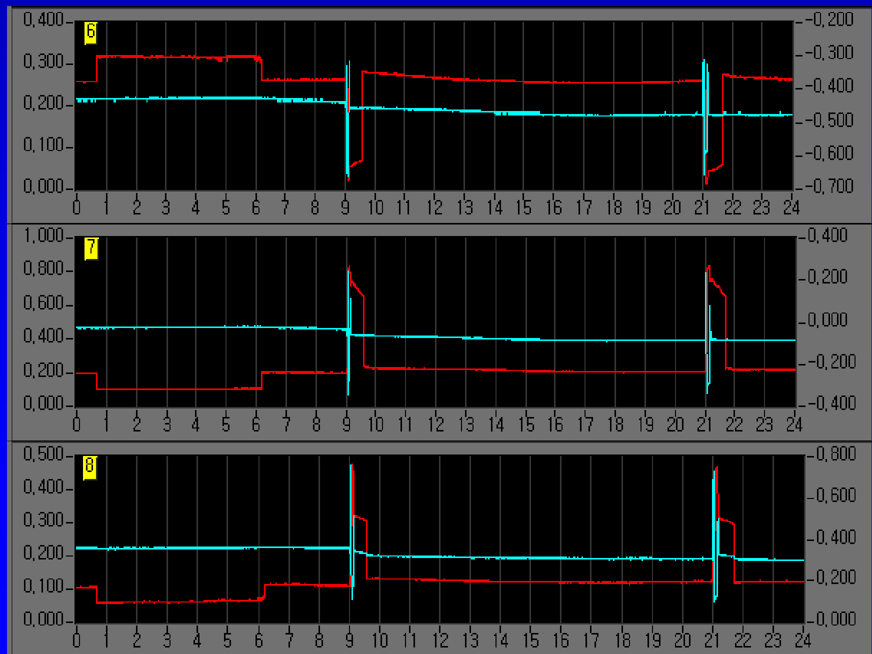
4. **TE modes degrade BPM performance only when their cutoff frequencies are lower than BPM center frequency. This was the case for APS, PEP-II, and SPEAR-3, but not for PLS. This is the mystery.**

5. **In PLS, BPM's installed in ID vacuum chambers show sharp peaks or dips in the button spectra of single-bunch beam, at frequencies lower than the cutoff frequencies of the vacuum chambers.**

Instabilities of ID and arc BPM's



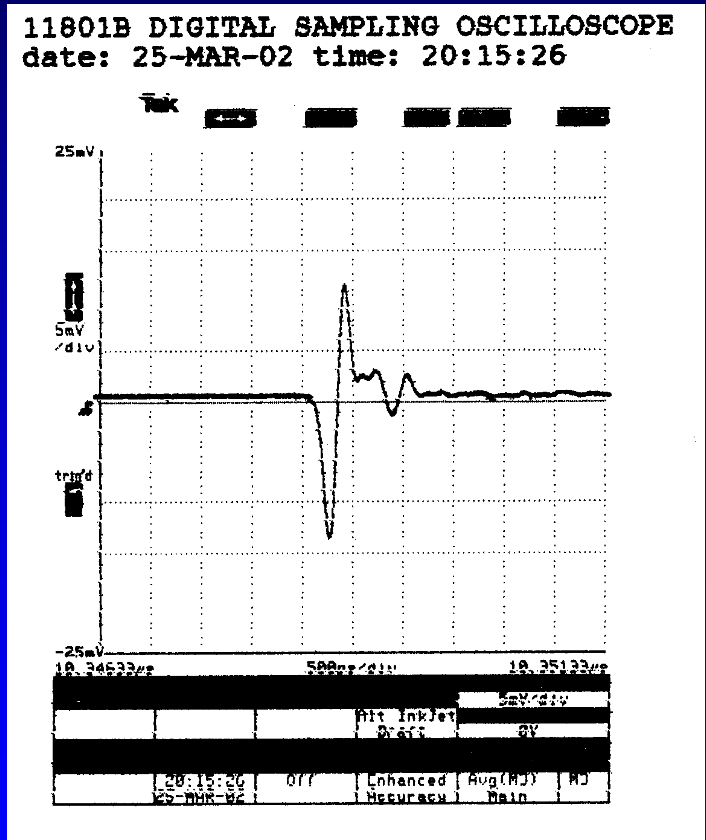
IDBPM81



arc BPM16 - 18

Measurement of Single-Bunch Spectrum using BPM Buttons - Time Domain Measurement -

Average Beam Current = 1.4 mA
(@ 2.5 GeV)



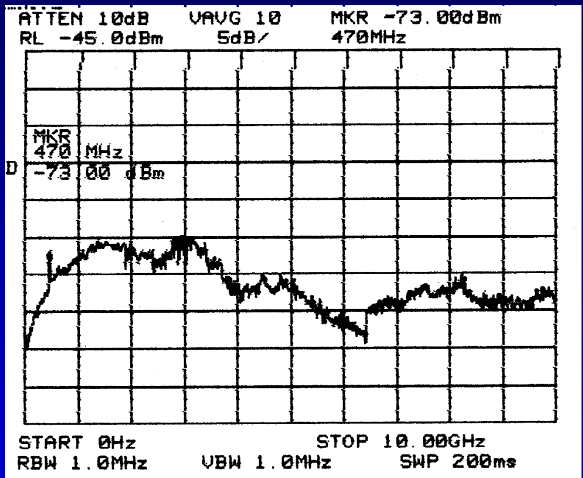
IDBPM81-A

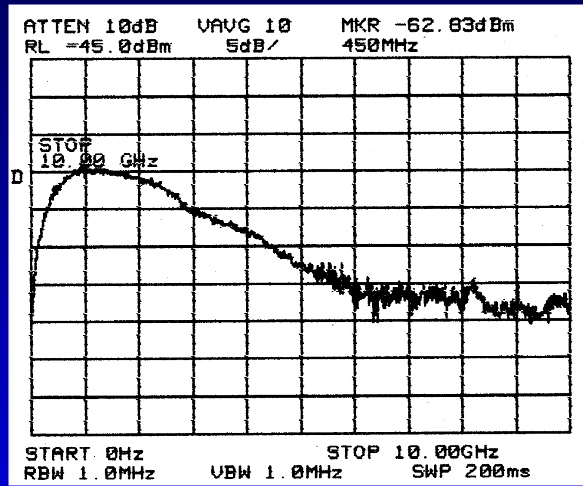
Cable Specification
- Length : ~25-m
- Model: Andrew HELIAX 1/4″ (FSJI-50)
- Attenuation: ~3.8 dB/25m @ 500 MHz

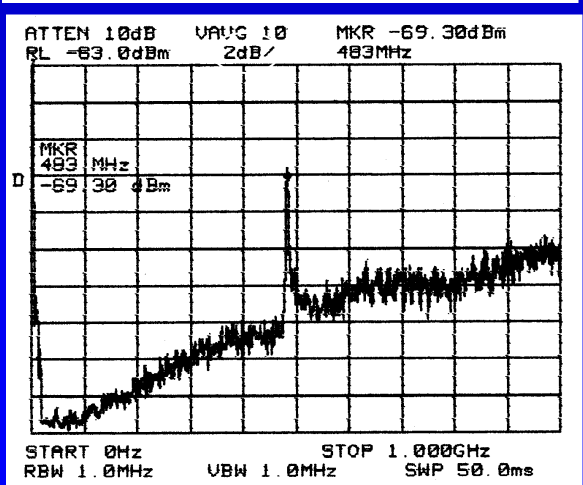
Description of Signal Chain:
10-mmϕ Button → 25-m 1/4″ HELIAX → 6-dB Attenuator → 9 dB Delay Line → 14-dB Attenuator → 11801B scope

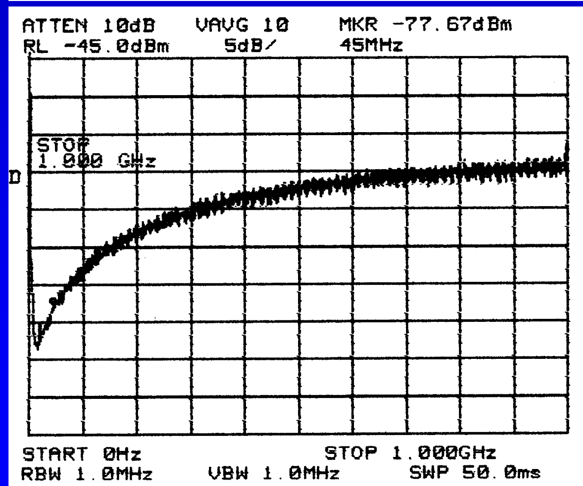
Single-Bunch Spectra from BPM Buttons

- Comparison between ID and Arc BPM's -









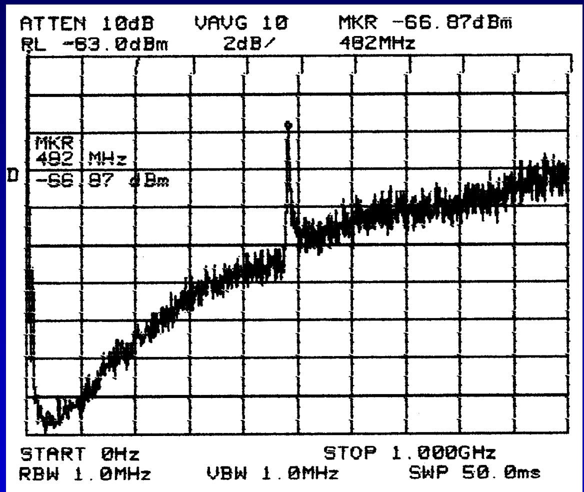
IDBPM81-A (10-mmϕ Button)

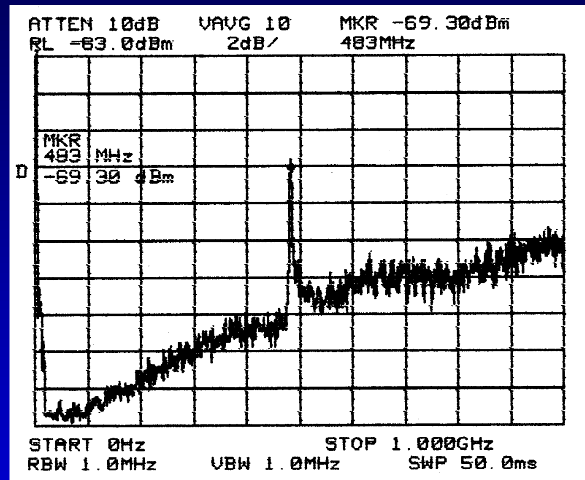
ArcBPM74-A (9.5-mmϕ Button)

Single-Bunch Spectra from IDBPM Buttons

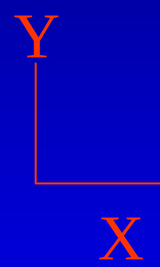
- Comparison between Upper and Lower Buttons -

IDBPM81-C

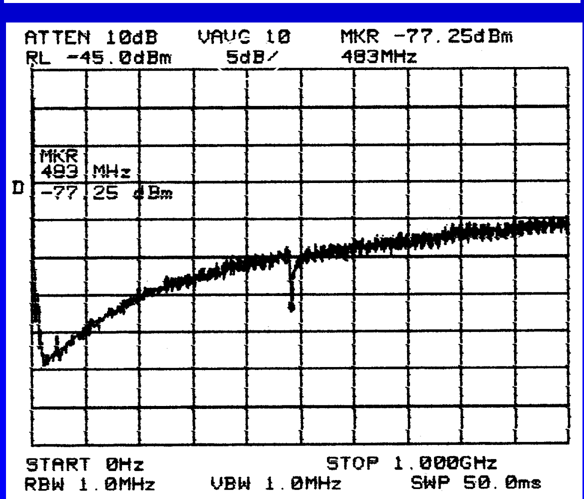


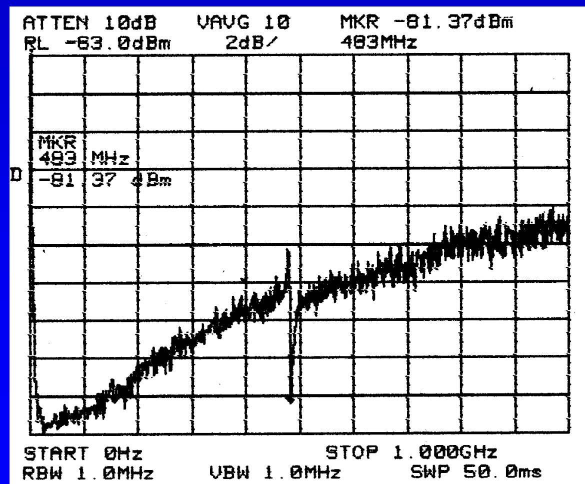


IDBPM81-A



IDBPM81-D





IDBPM81-B

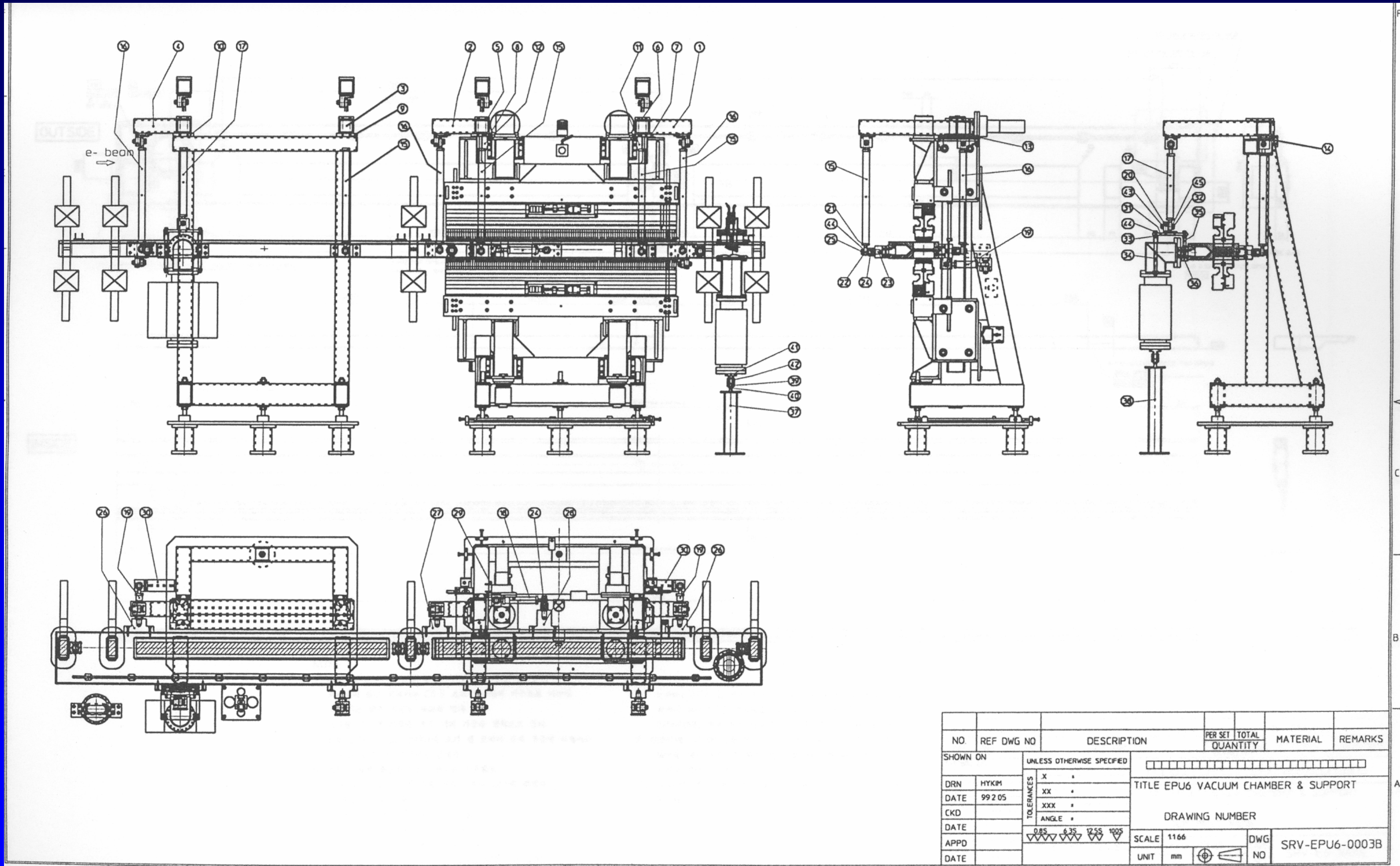
Button arrangement is as shown in the above

Location of peaks and dips for ID BPM buttons in different ID vacuum chambers

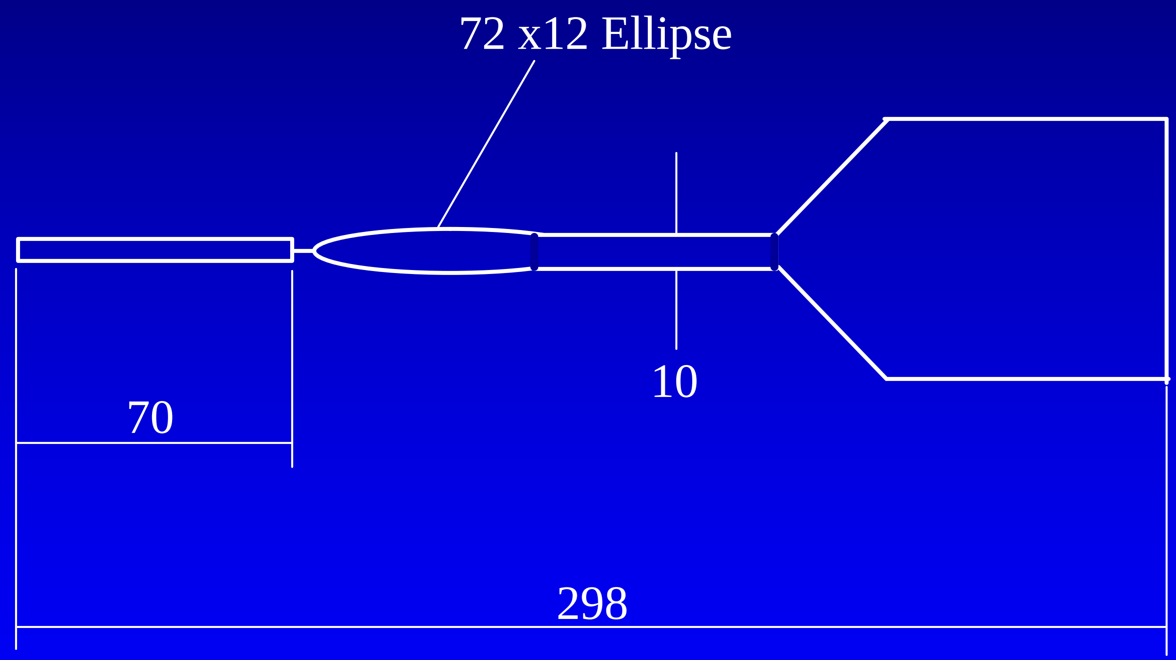
[Units = MHz]

BPM # \ ID type	U7 (fc = 538 MHz)	EPU6 (fc = 557 MHz)
#1	483	517
#2	805	-
#3	NA	532
#4	NA	577

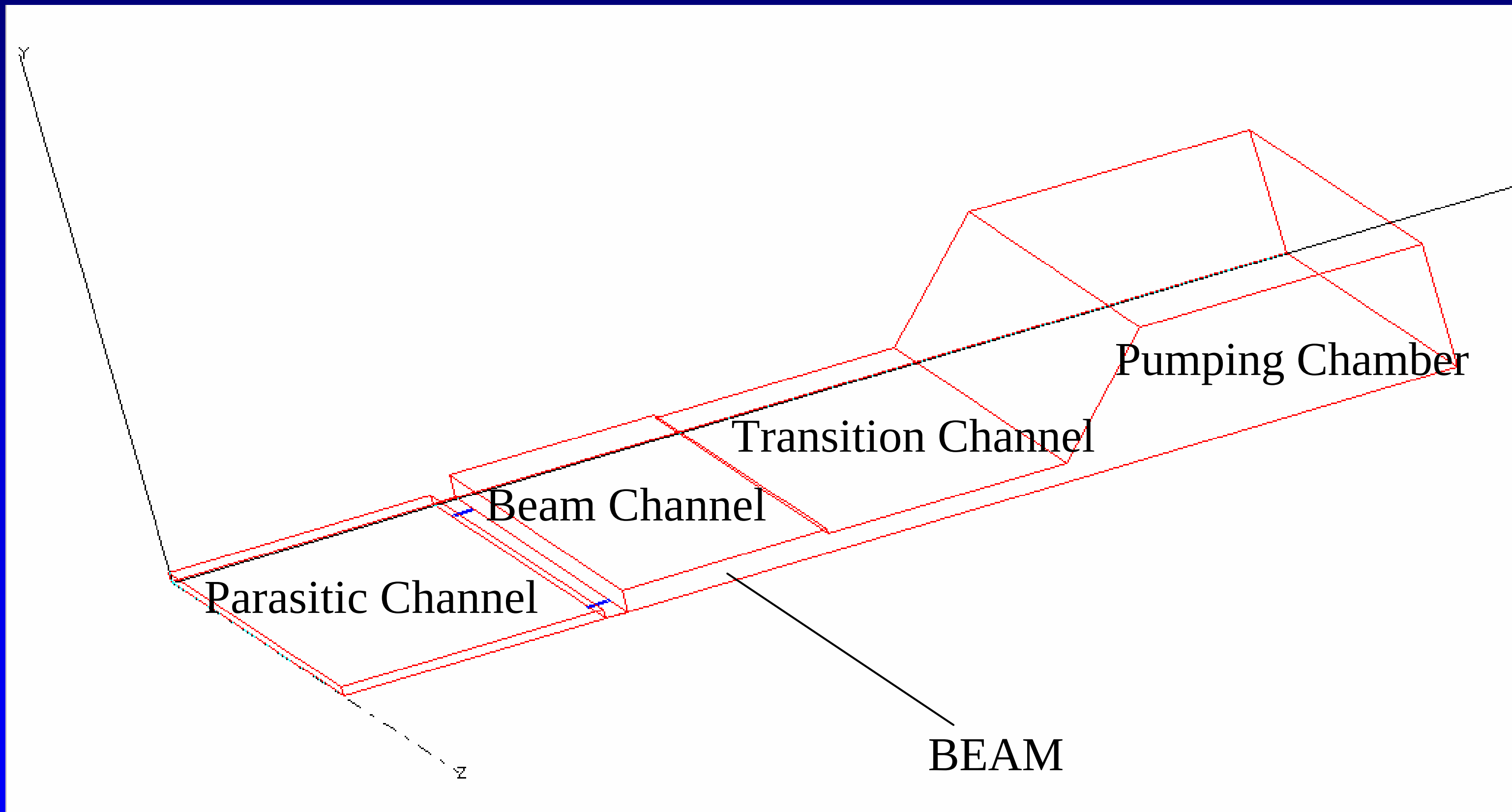
Appearance of EPU6 Insertion Device



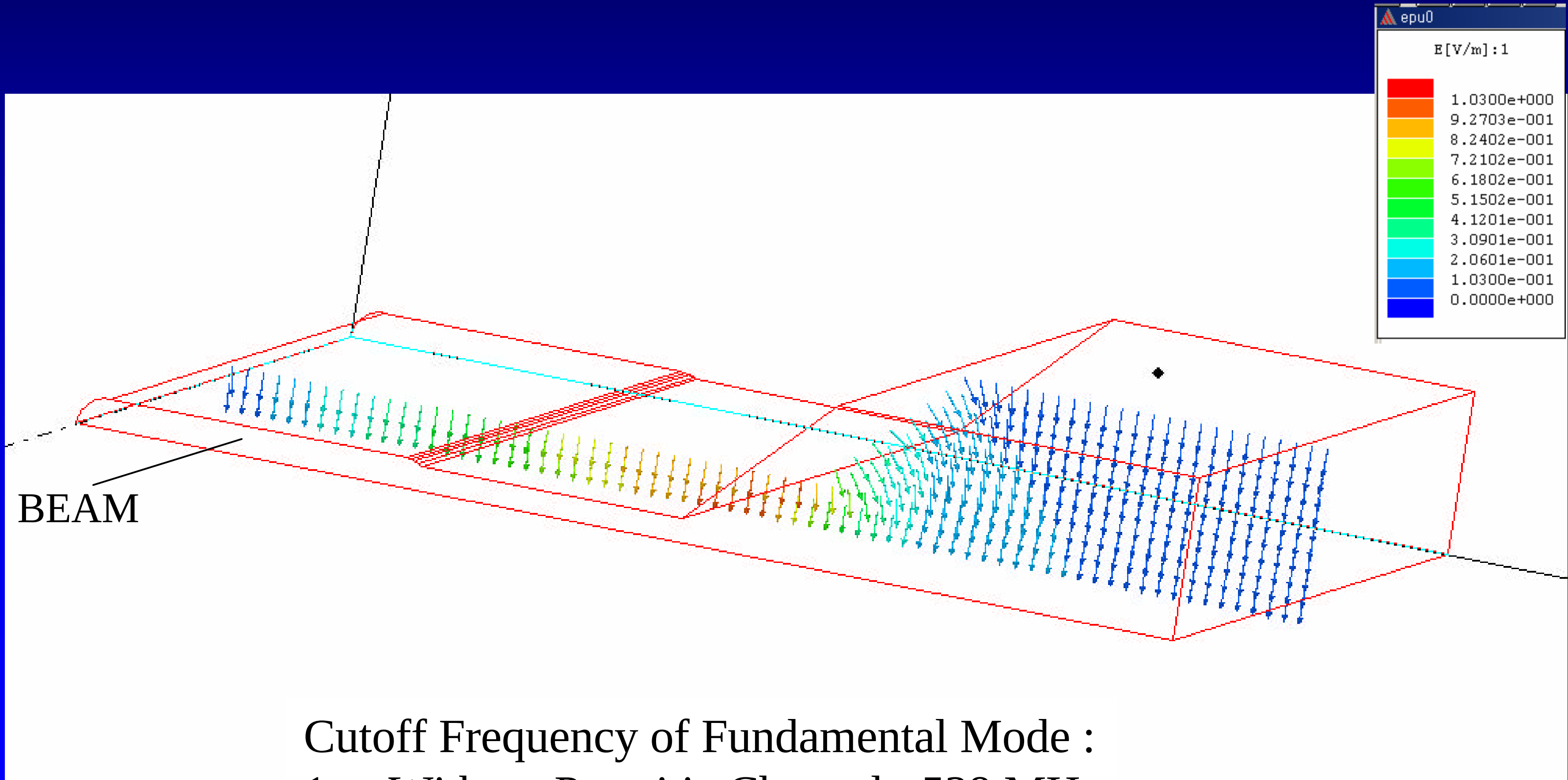
Cross Section of U7 Vacuum Chamber



3D Model of U7 Vacuum Chamber



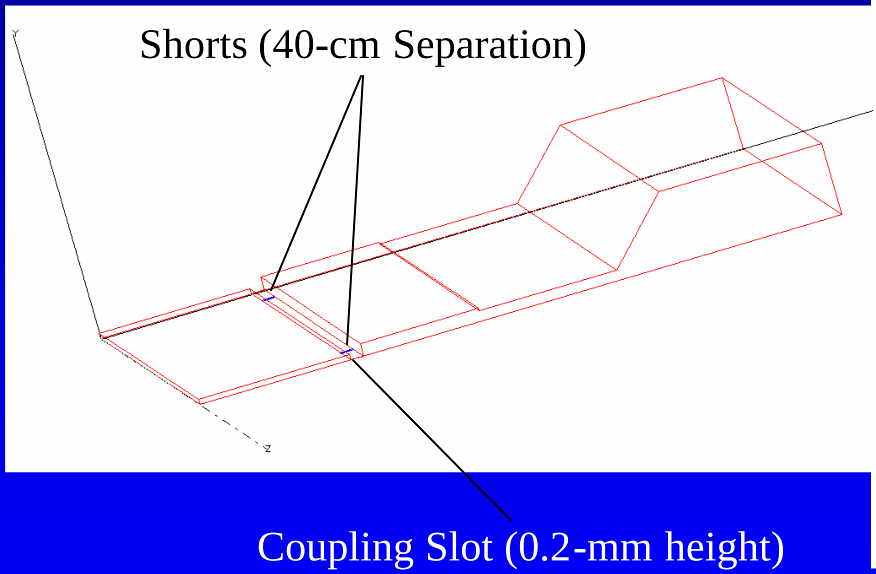
Electric Field Distribution of Fundamental Propagating TE Mode in ID Vacuum Chamber

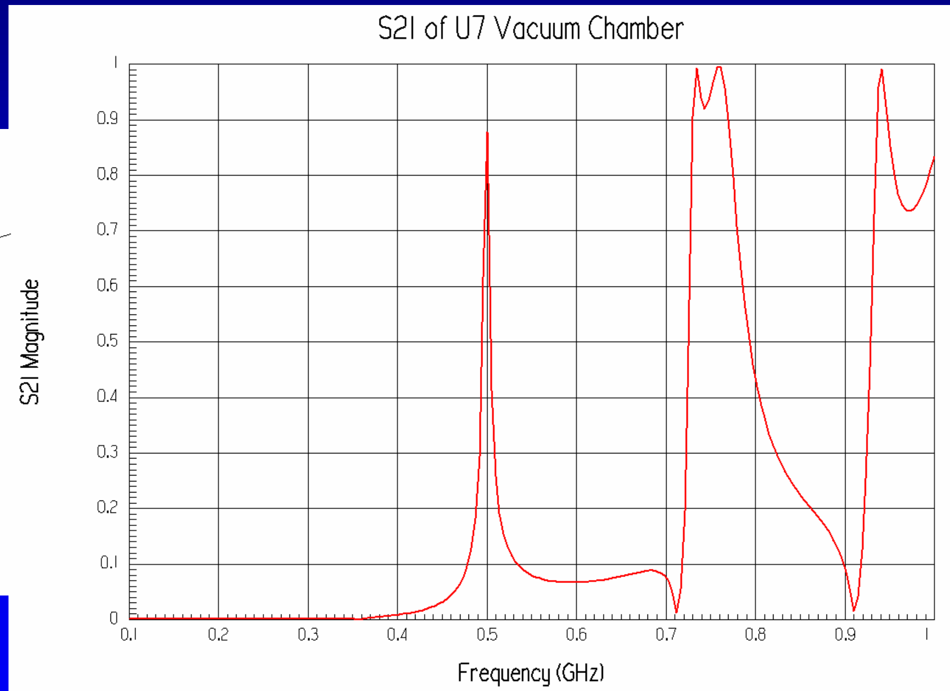


Cutoff Frequency of Fundamental Mode :

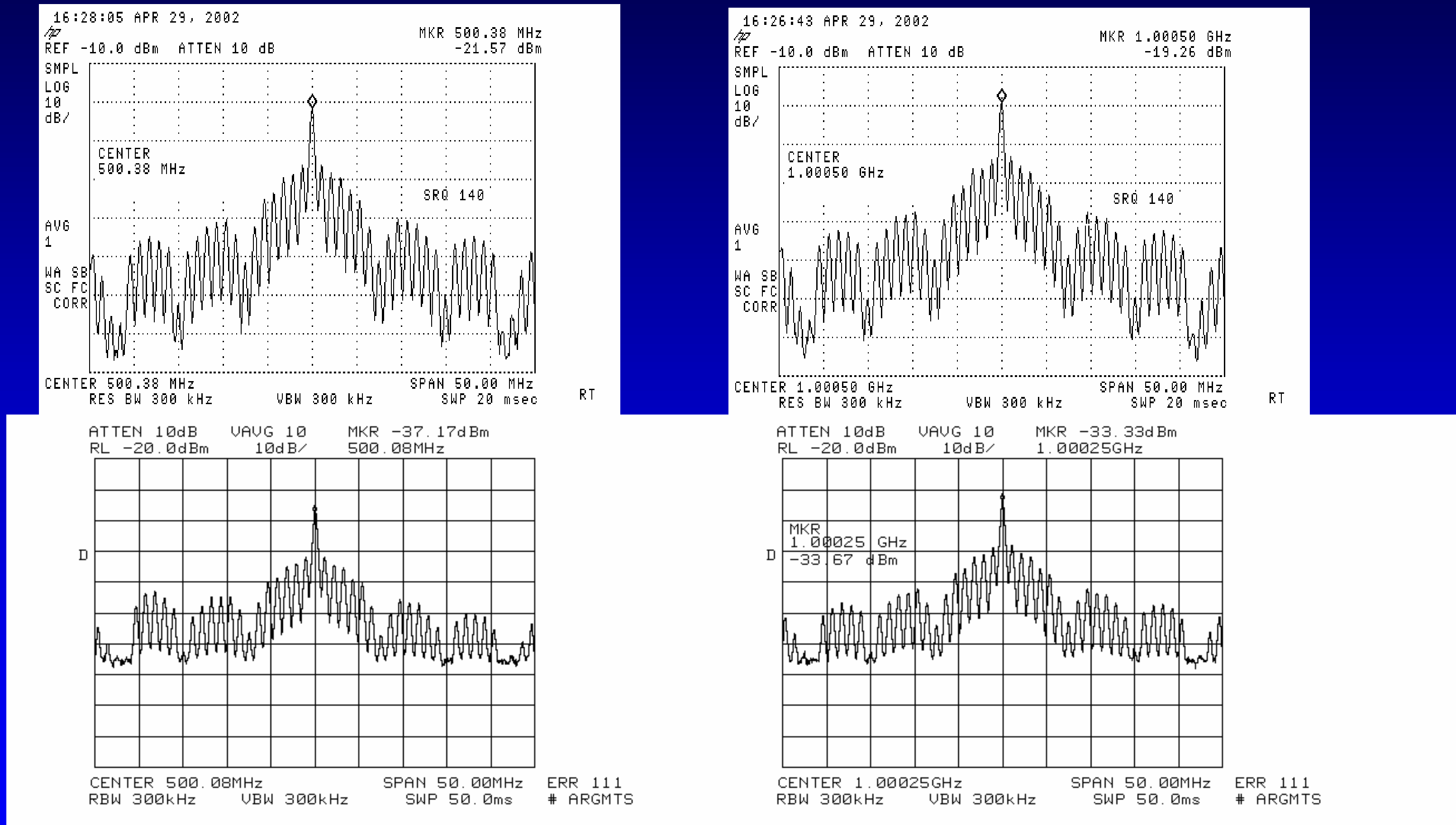
1. Without Parasitic Channel : 538 MHz
2. With Parasitic Channel : ~300 MHz

Calculation of S21 of U7 Vacuum Chamber with Parasitic Channel and two Shorts



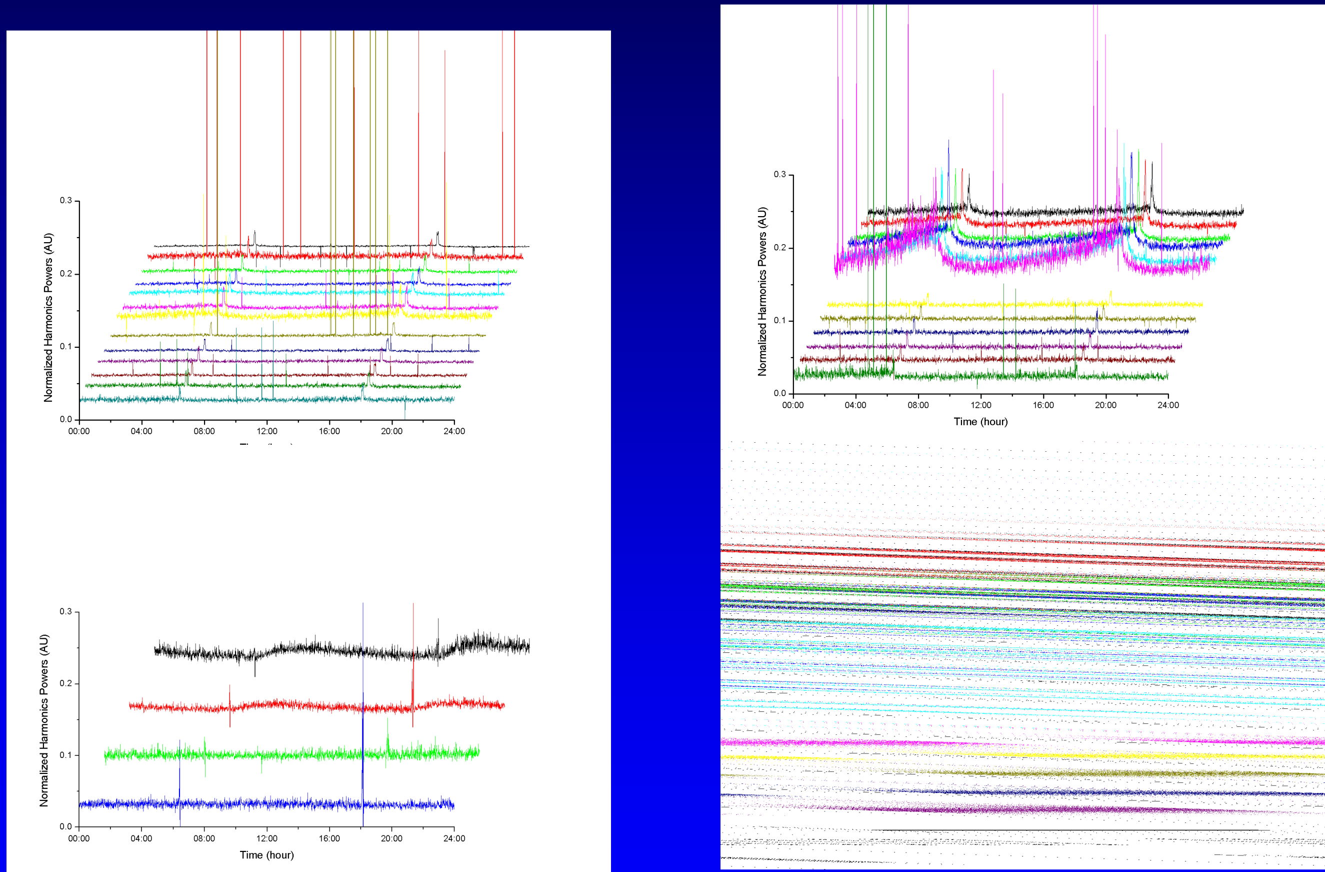


Measurement of Button Spectra from Multi-Bunch Beam



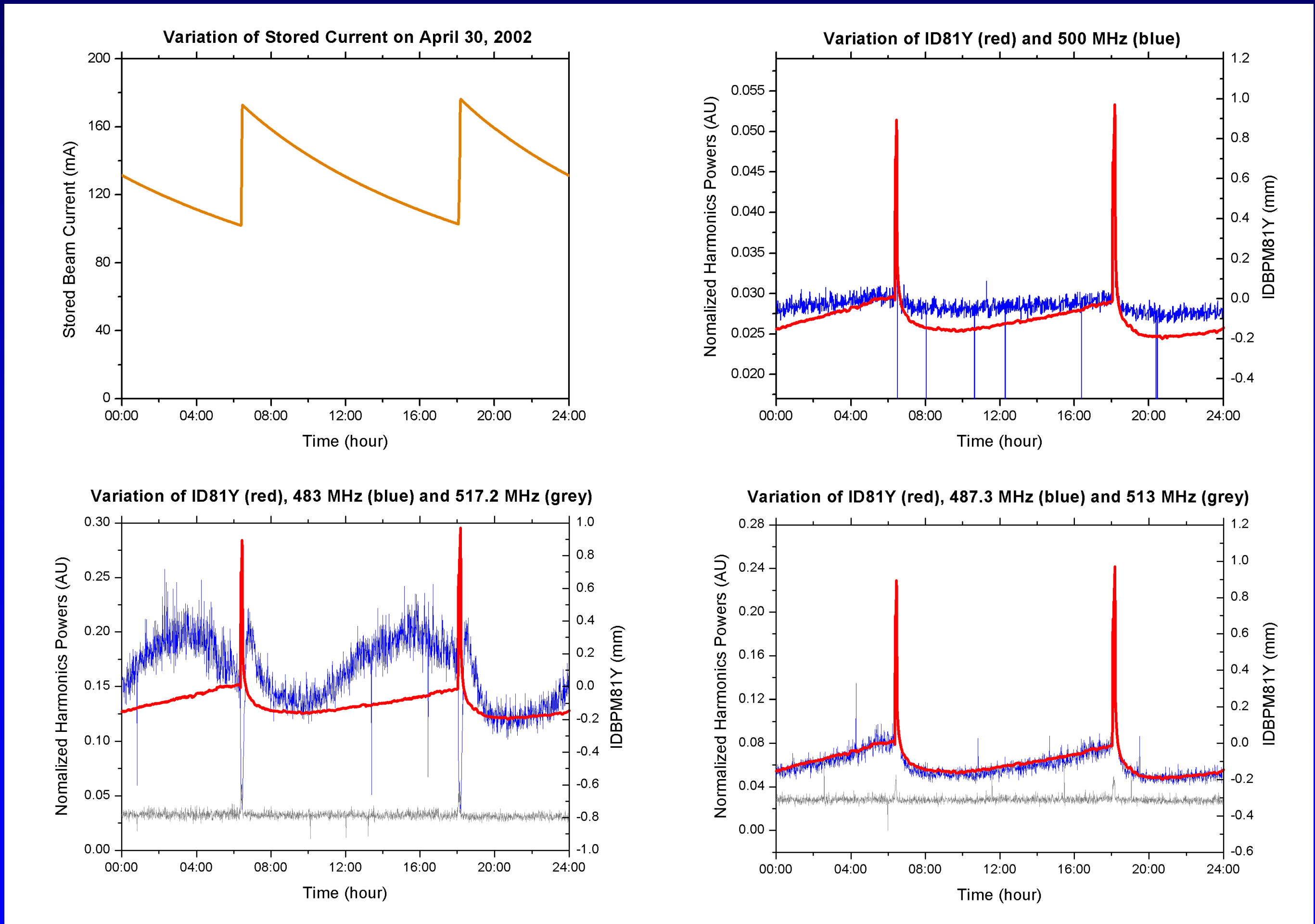
Comparison of Bunch Spectra around 500 MHz (Left) and 1 GHz (Right)
(Top traces are reference spectra measured at arcBPM79 and
bottom traces are from IDBPM81)

Measurement of Button Spectra from Multi-Bunch Beam (Continued)



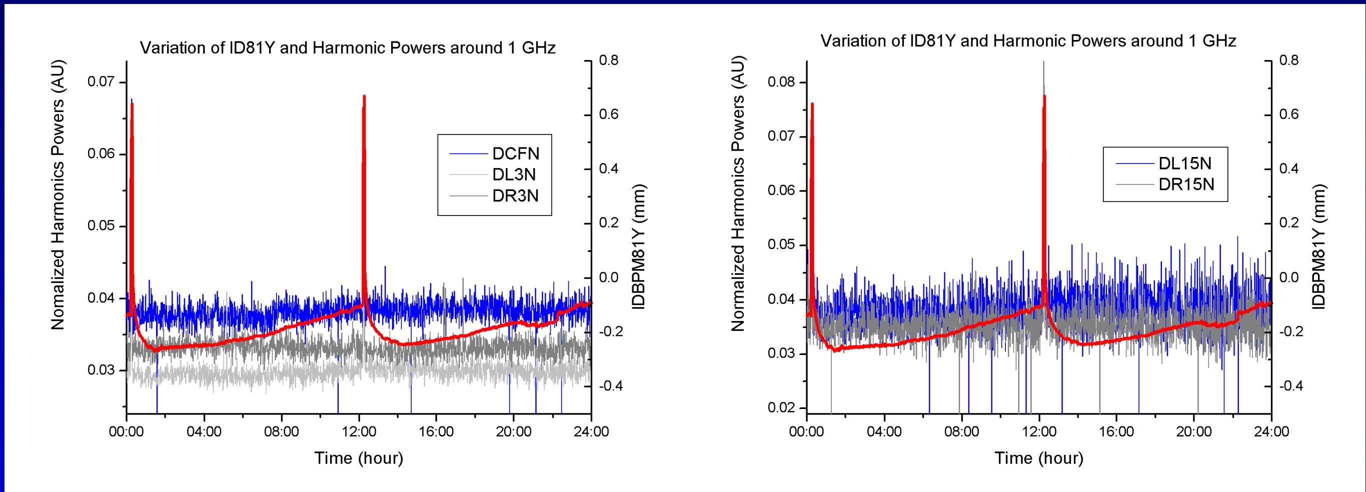
Variation of Normalized Harmonic Amplitudes around 500 MHz
(From upper-left graph in clockwise sequence, 1st to 6th, 8th to 13rd, 15th to 19th, 22nd to 23rd rotation harmonics amplitudes)

Measurement of Button Spectra from Multi-Bunch Beam (Continued)



Comparison between IDBPM81Y and Harmonics around 500 MHz

Measurement of Button Spectra from Multi-Bunch Beam (Continued)



Comparison between IDBPM81Y and Harmonics around 1 GHz

Notes :

1. For the PLS, operation of BPM's at 1 GHz seems to be a quick solution for the TE-mode problem. (Complete solution would be achieved by providing dedicated chambers for BPM's.)
2. Recent tests of this have yielded promising results. Bergoz MX-BPM tuned at 1 GHz was proved to be effective, in spite of increased linearity errors, which can be easily compensated for.

Concluding Remarks

1. Ripples in Magnet Power Supplies were identified as the main cause of short-term orbit fluctuations and reduced below 50 ppm. Additional efforts are going on to further reduce this.

2. Stability of cooling water was found to strongly affects the orbit stability. Stabilities of cooling water and tunnel air have been improved better than +/- 0.1 ^{o}C.

3. Source of apparent orbit drifts is largely due to BPM instabilities. Owing to intensive efforts for understanding and overcoming these, the BPM instabilities are in the stage of overcoming.