KEKB Accelerator Review Committee, 23-25 February, 2001

BEAM INSTRUMENTATIONS OF KEKB

KEKB Beam Monitor Group
S.Hiramatsu

1. Beam Position Monitors
2. SR Monitors
3. Bunch-by-bunch Beam Feedback System

*Outline and performance of all beam instrumentations are reported at the previous committee. Here we report 3 topical themes.

1. Beam Position Monitors

- Electrostatic pickup with 4 buttons (12mmϕ)
  454 BPMs @ LER / 443 BPMs @ HER
  detection freq. =1GHz
- Processing time for COD measurement of 2 rings is ~2sec.
- Resolution measured by 3-BPM correlation method;
  average 2-4 μm for $I_b > 10$mA
  (limited by orbit vibration at 0.47/ 0.25Hz and 11-13Hz)

- Completed beam based calibration of BPM center offset by Quad/BPM-response method.
  COD : 0.3-0.4 mm(rms)
- Background by HOM wake field
  BPM which has the aperture with the waveguide mode cutoff frequency <1GHz picks up the HOM signal and causes offset error.
  → Cured by changing the detection frequency from 1GHz to 509MHz.

MEASUREMENT ERROR DUE TO HOM SIGNAL

Table: Comparison of 1018 MHz and 509 MHz detection

	1018 MHz detection		508 MHz detection	
QMag	X[mm]	Y[mm]	X[mm]	Y[mm]
QC4RE	-0.351	4.497	-2.168	-0.230
QC3RE	1.159	-3.860	-0.042	-0.897
QC2LE1	-0.868	1.849	-1.527	-0.237
QC2LE2	0.391	3.014	-0.298	-0.165

- Construction of single-pass BPM system is on going program.
  120BPMs of each ring will be changed in dual mode (COD/single-pass) operation.
  The 1st turn orbit will be monitored whithin the error of 0.5mm --- helpfull for injection tuning.
  Precise determination of the betatron phase advance around IP is expected.

2. Synchrotron Radiation Monitors

- SR monitors are working well and indispensable to collision tuning.
- Primary SR beam from the week bend extracted by a Be mirror is divided into 3 lines.

(a) Beam image - focused onto CCD camera

(b) Streak camera and/or high speed gated CCD camera

- bunch profile observation
- measurement of bunch length and structure

Optical system of the streak camara for multibunch observation is on going program.

(c) Double-slit interferometer

- automatic beam size measurement (σ_x and σ_y)

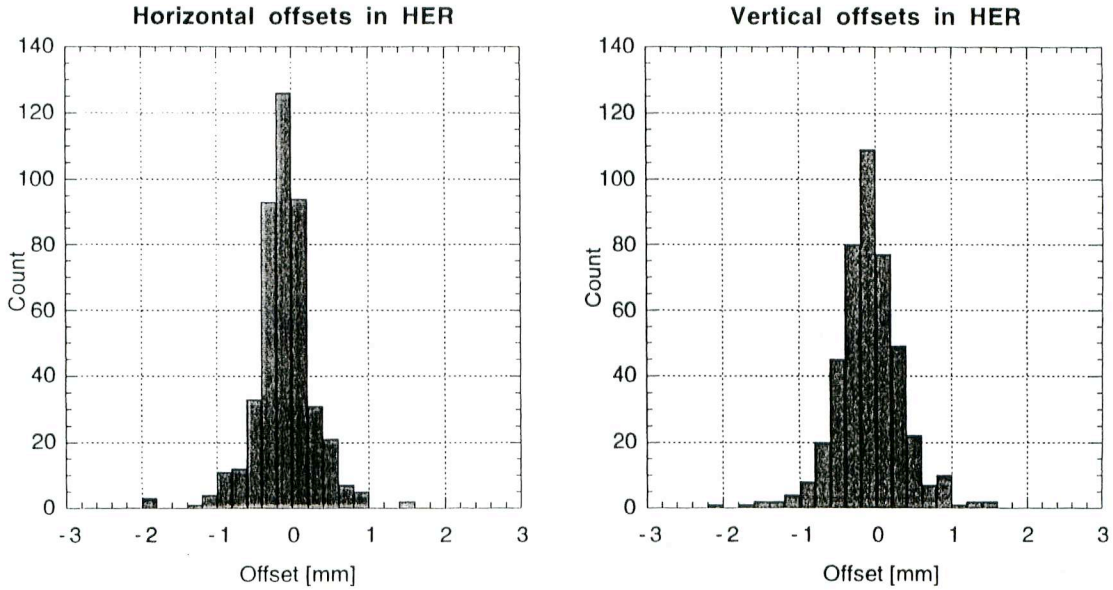
- Surface distortion of the extraction mirror and change of the optical line cause the error in the beam size measurement.
  - Effective optical path length between the source point and the slit plane is changed by surface distortion of the extraction mirror by SR heating.
    → Surface distortion was measured with the multi-hole array screen.
  - Tilt and displacement of the extraction mirror by beam heating change the optical line.
    → Optical line was stabilized by the feedback to the 2nd mirror rotation.

3. Bunch-by-Bunch Beam Feedback System

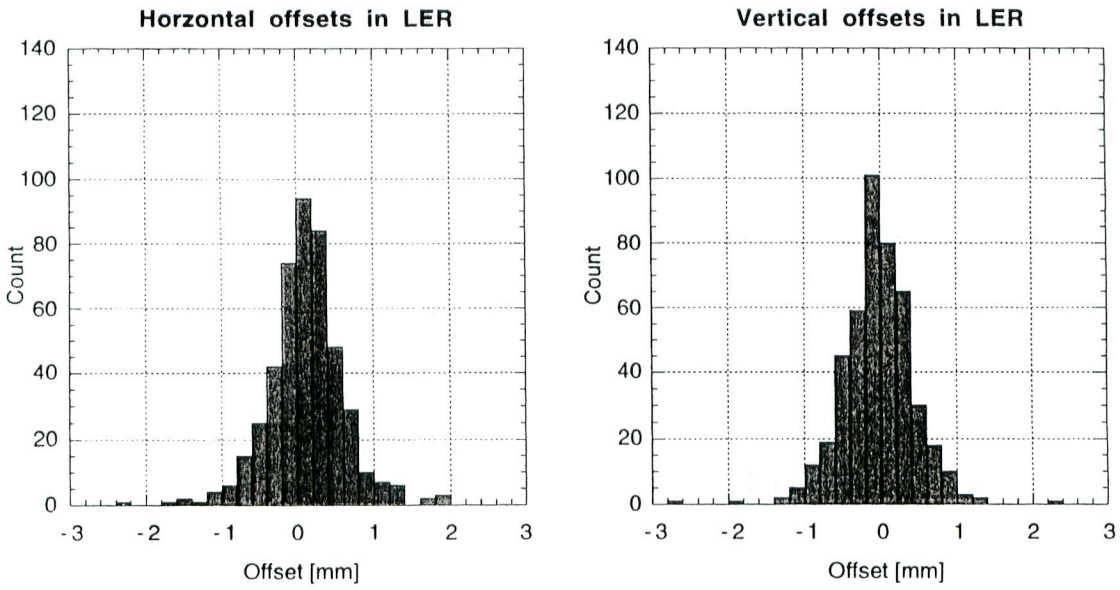
4. Others

Fast beam loss monitors with PIN diode detectors will be installed in this April.
It can provide the interlock signal for beam abort within one revolution time to ptotect moving masks.

Beam based calibration for the BPM

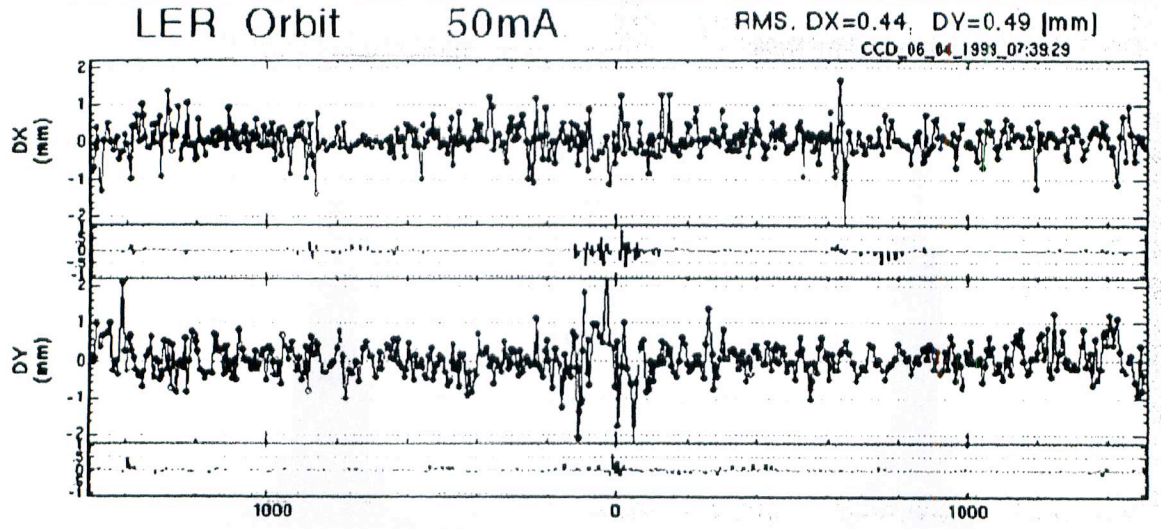


Histogram of offset measured by beam based alignment in HER

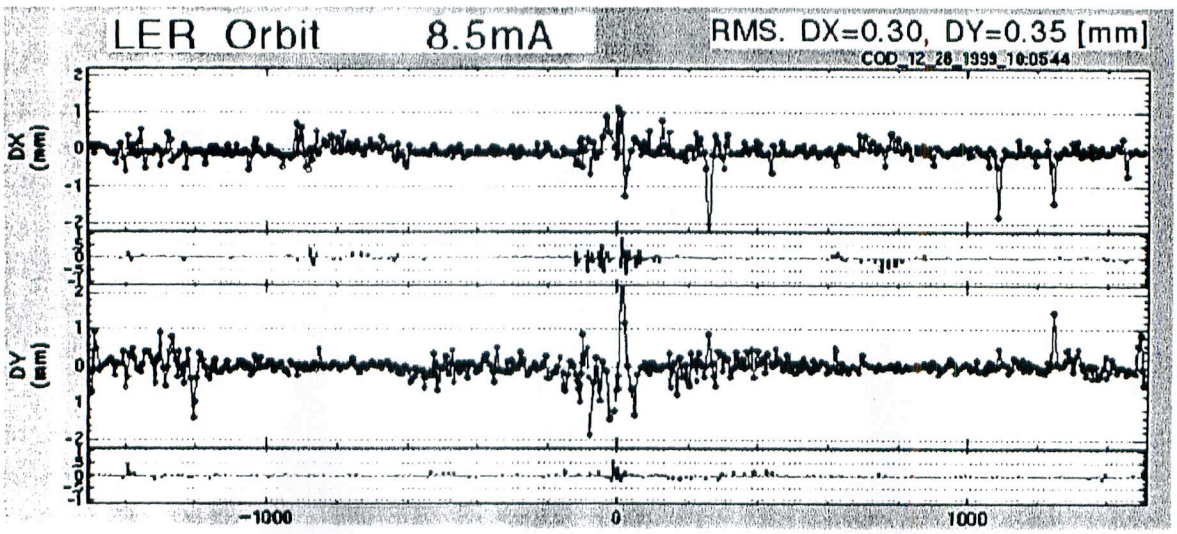


Histogram of offset measured by beam based alignment in LER

Improvement of closed orbits

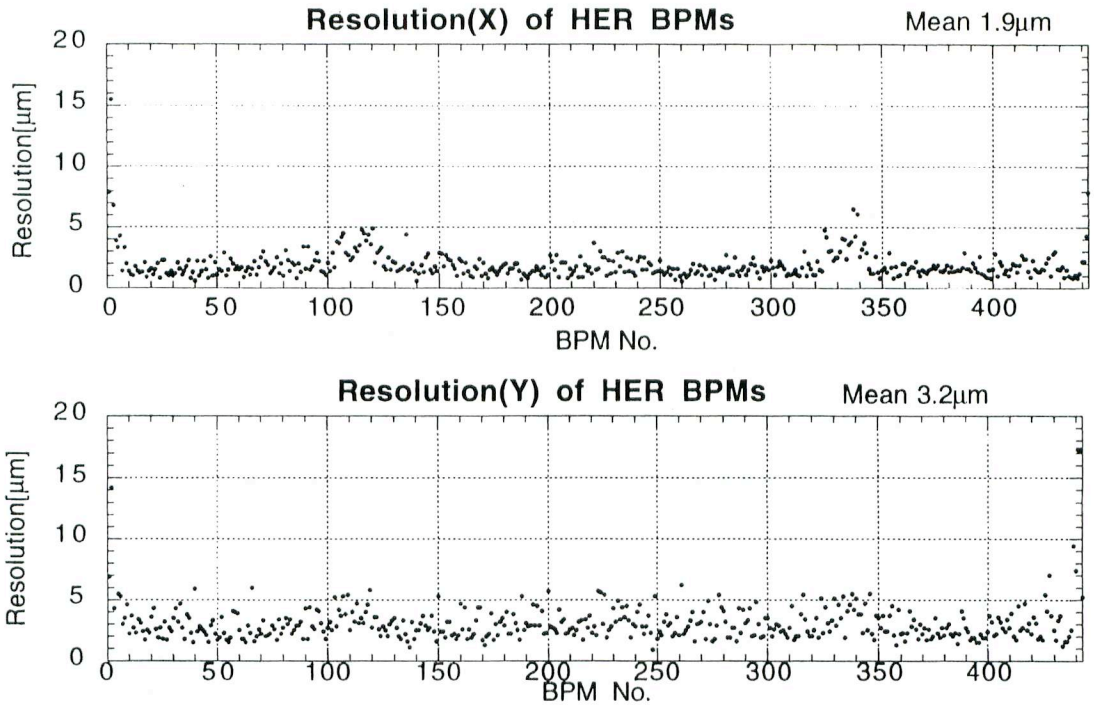


LER closed orbit before offset correction

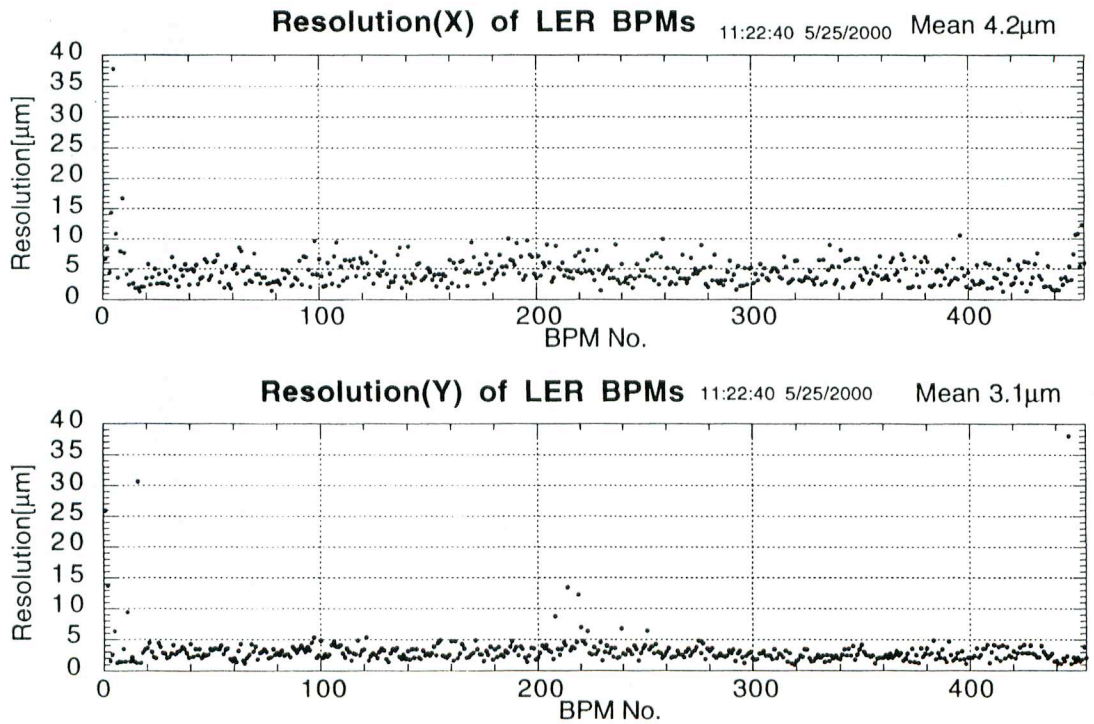


LER closed orbit after offset correction

Position resolution by three-BPM method

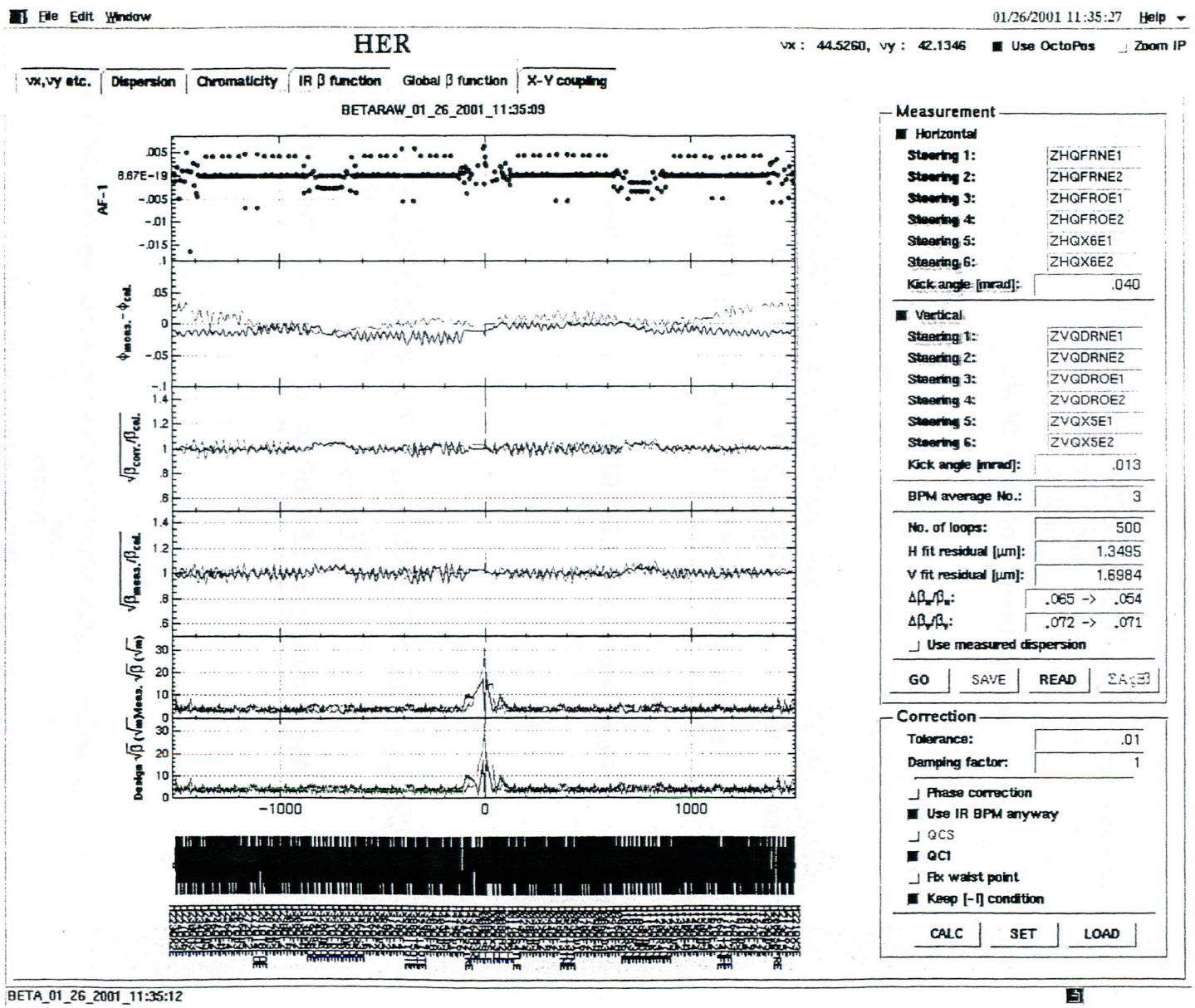


Distribution of all BPM resolutions in HER

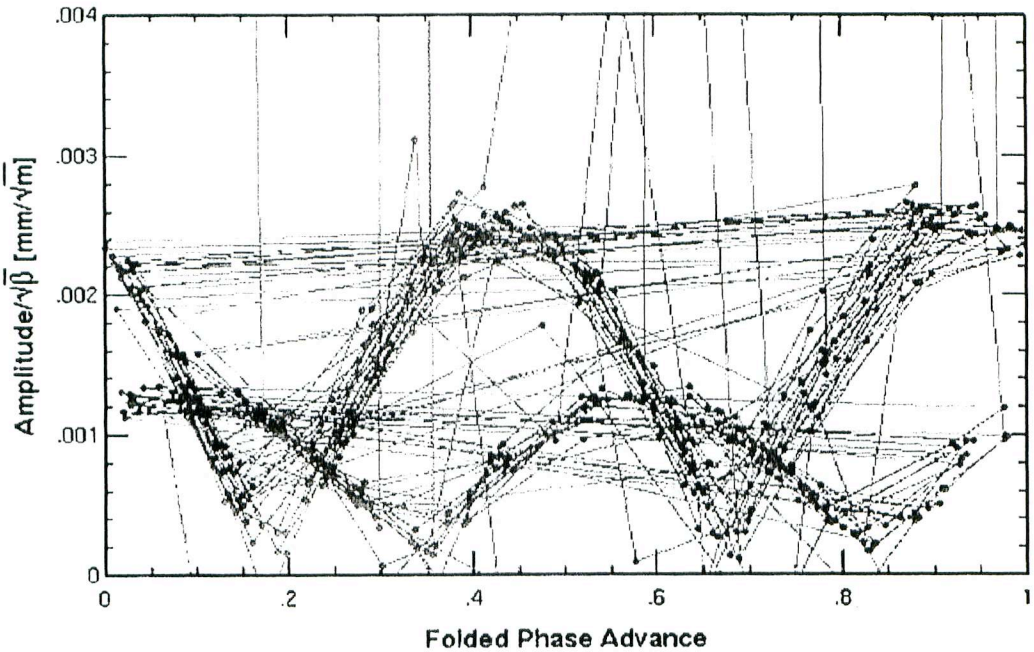


Distribution of all BPM resolutions in LER

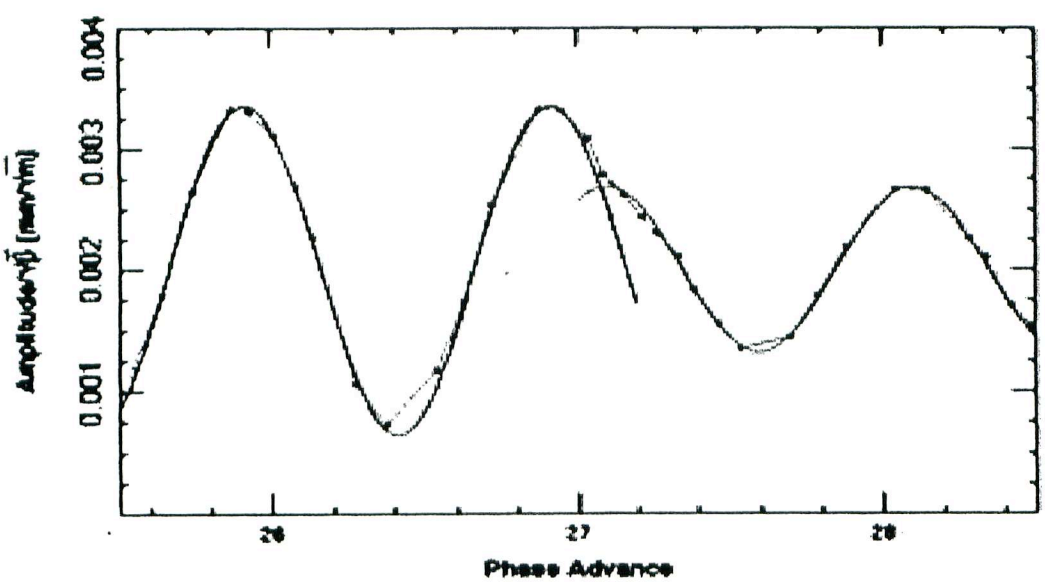
Optics function measured by BPM system



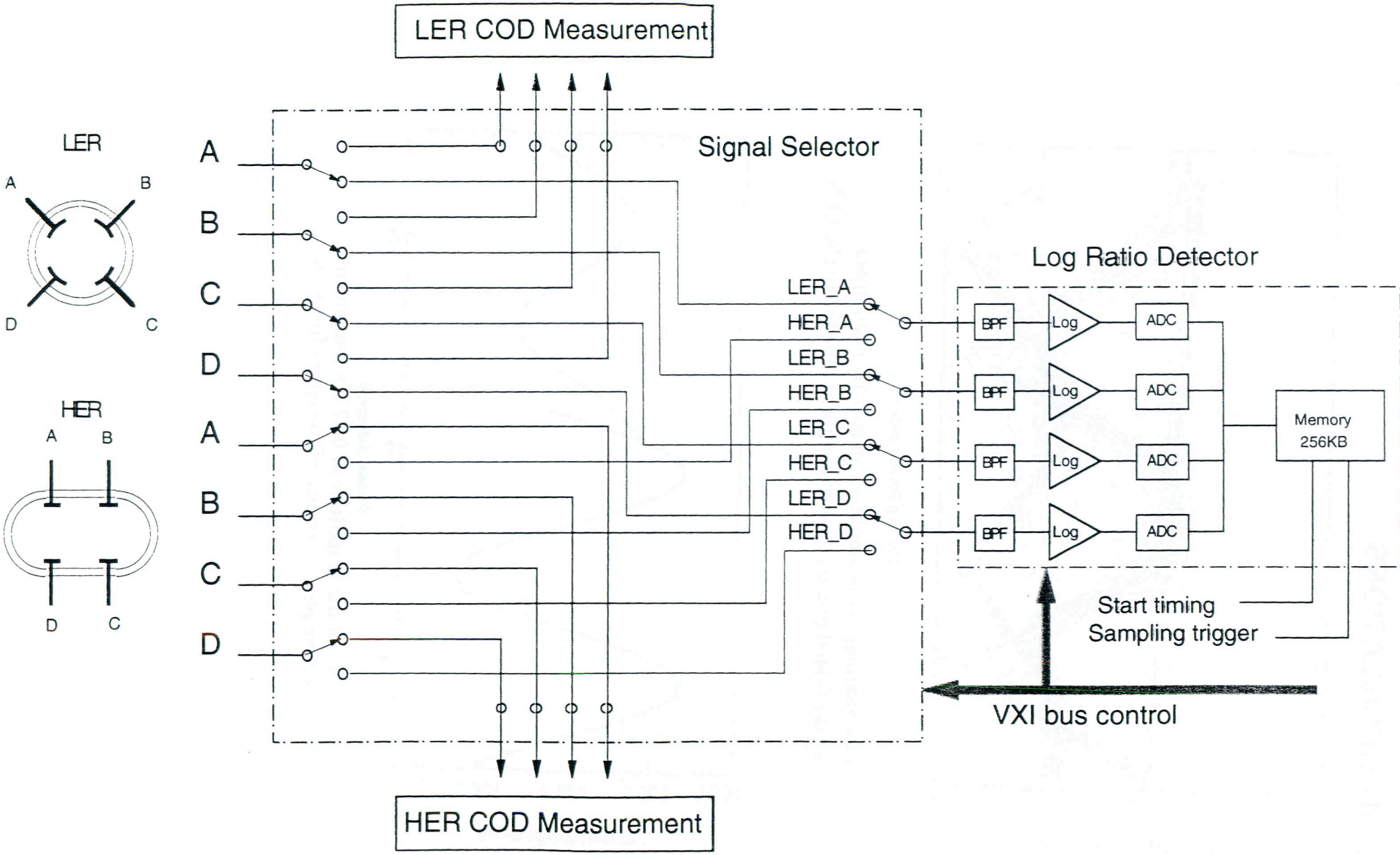
ORBIT OSCILLATIONS



Overlapping of the amplitude of 0.47 Hz component on the folded phase advance of optical function in the LER

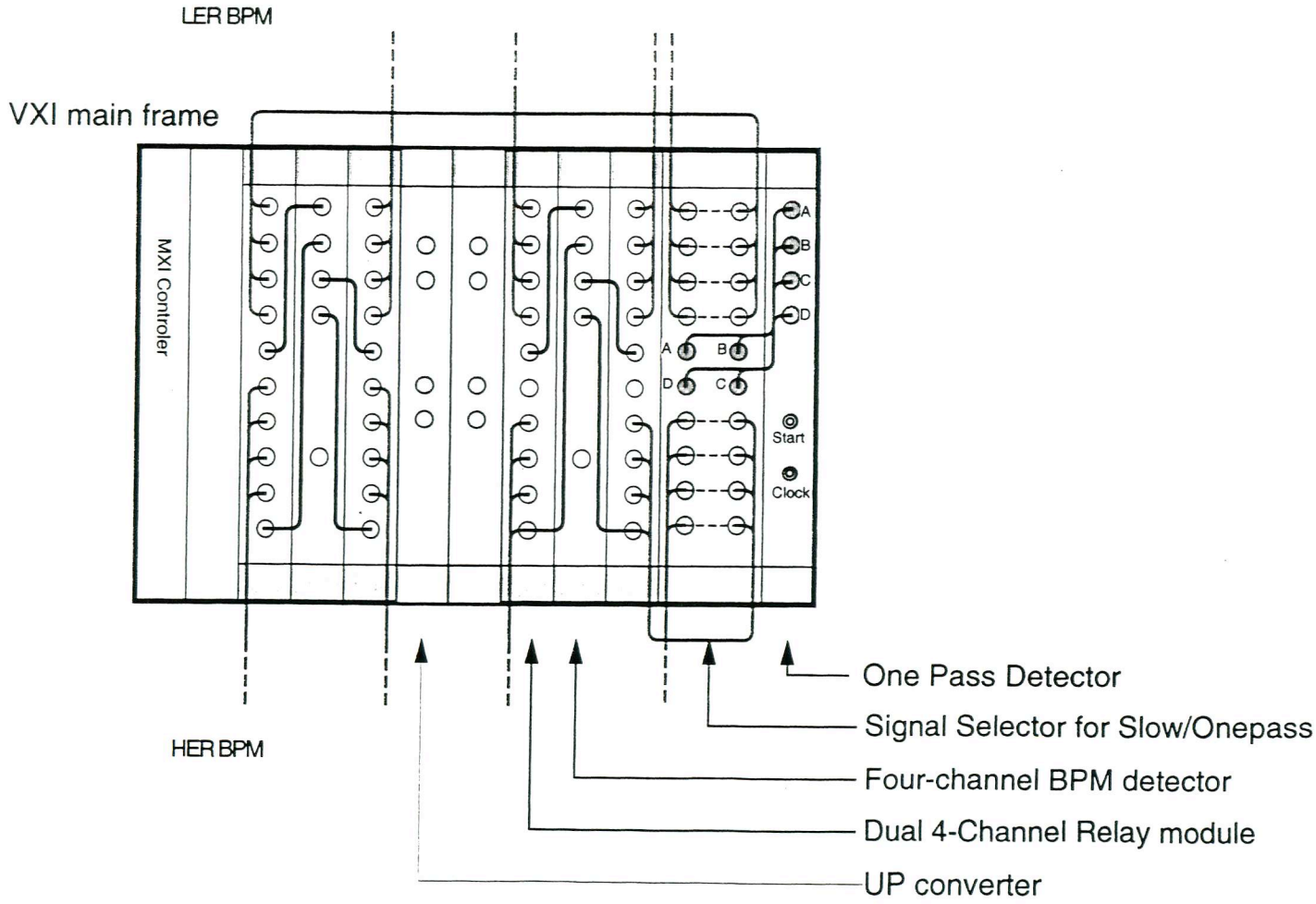


Trace of the amplitude of 0.47 Hz component over the phase advance of the optics function.

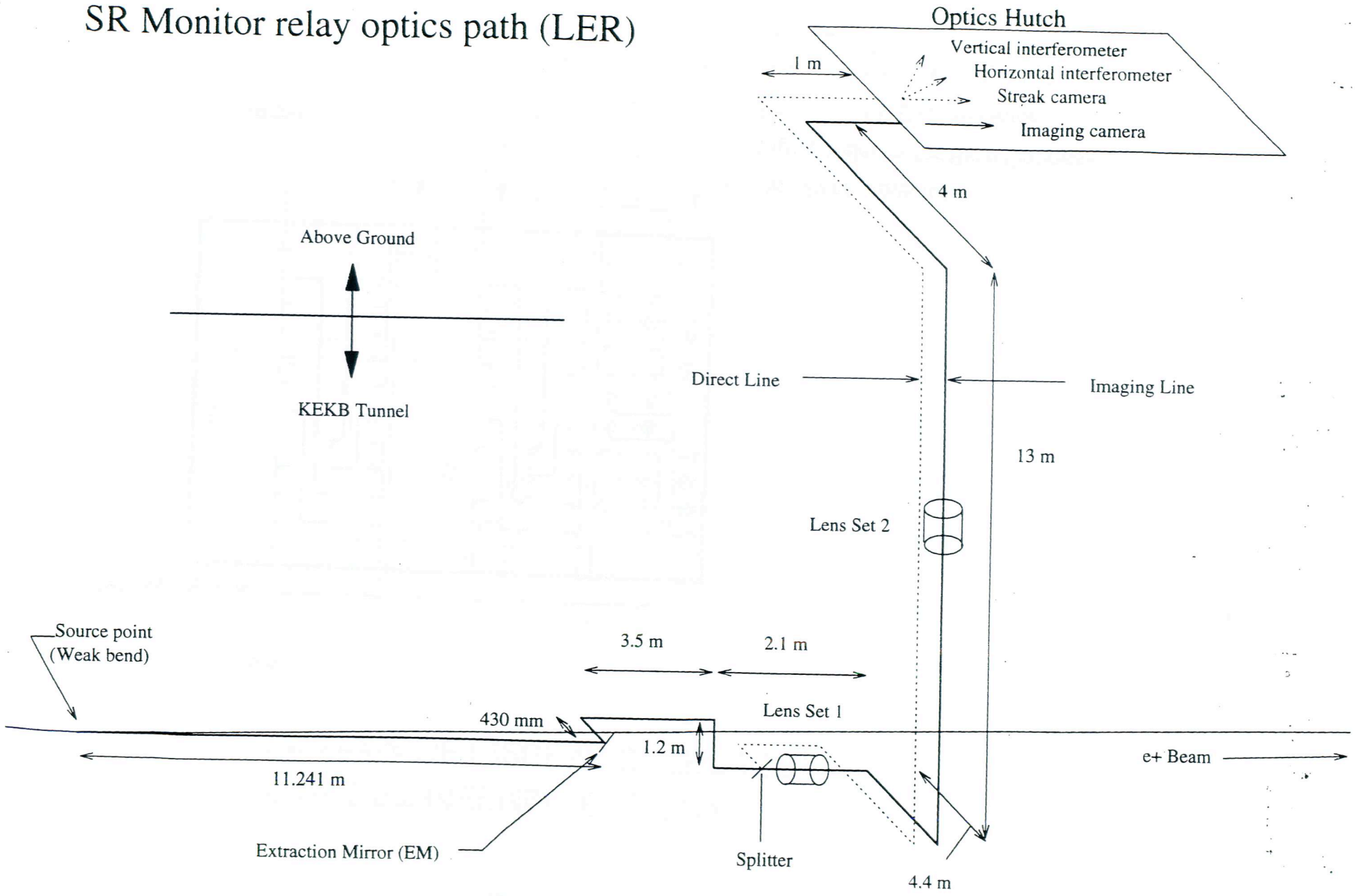


Electronics of One Pass BPM for KEKB

Slow DET.(4BPMs/DETECTOR)
One pass DET.(2BPMs/DETECTOR)



SR Monitor relay optics path (LER)



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LER Synchrotron Radiation Monitor

σ_y (μm)	σ_y @ IP (μm)	σ_x (μm)	σ_x @ IP (μm)	$\varepsilon_y/\varepsilon_x$ (%)
15.1 Normal	3.91 Normal	643 Normal	129. Normal	9.1 Normal

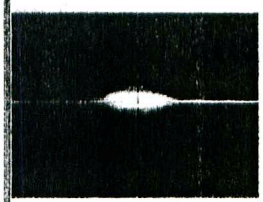
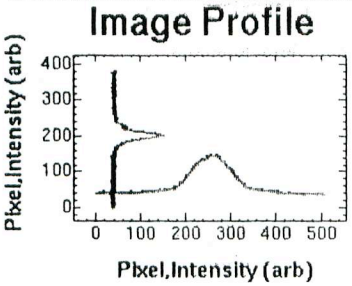
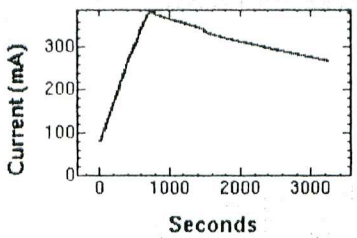


Image Profile

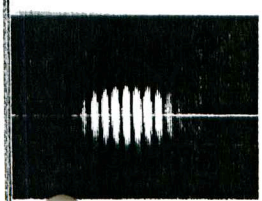


Beam Current

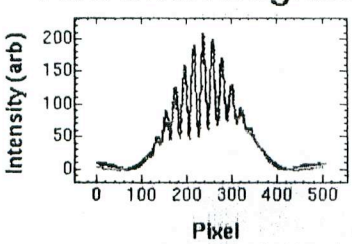


$\varepsilon_y, \varepsilon_x, \sigma_y^*, \sigma_x^*$ Measurement

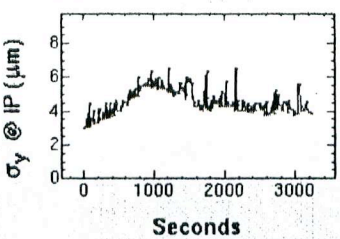
β_y (m):	15.0620
β_x (m):	24.6284
η_y (mm):	0.0000
η_x (mm):	0.6000
β_y^* (m):	0.0100
β_x^* (m):	1.0000



Vert. Interferogram

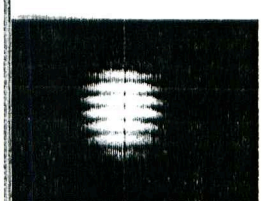


Vert. Beam Size

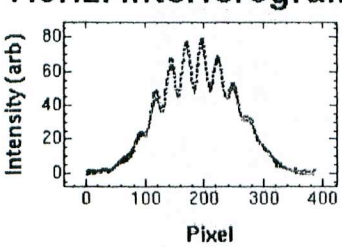


σ_y Measurement

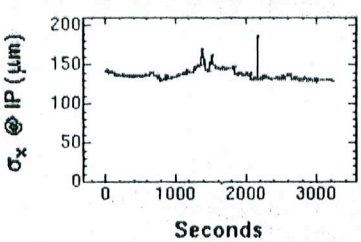
Eff. Path (m):	40.7630
Slit Sep. (mm):	26.2000
Wavelength (nm):	513.2400
Magnification:	0.9173
Visibility:	0.5480
$\sigma_{visibility}$:	0.0019
Fit χ^2/d.o.f.:	14.87



Horiz. Interferogram



Horiz. Beam Size



σ_x Measurement

Eff. Path (m):	34.5168
Slit Sep. (mm):	20.5000
Wavelength (nm):	513.2000
Magnification:	0.3604
Visibility:	0.2414
$\sigma_{visibility}$:	0.0036
Fit χ^2/d.o.f.:	1.16

Main Application Area

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HER Synchrotron Radiation Monitor

σ_y (μm)	σ_y @ IP (μm)	σ_x (μm)	σ_x @ IP (μm)	$\varepsilon_y/\varepsilon_x$ (%)
134 Normal	3.79 Normal	146 Normal	13.1 Normal	8.2 Normal

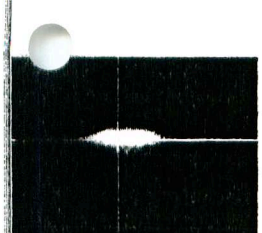
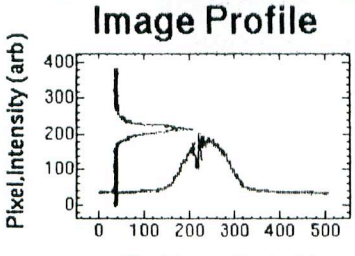
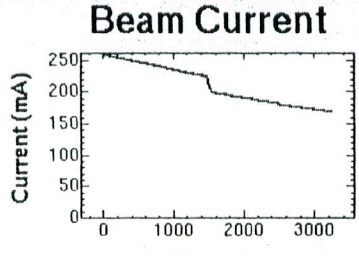


Image Profile

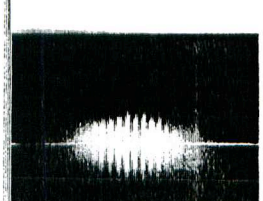


Beam Current

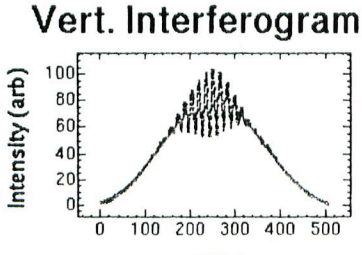


$\varepsilon_y, \varepsilon_x, \sigma_y^*, \sigma_x^*$ Measurement

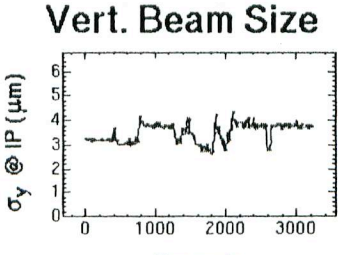
β_y (m):	12.4934
β_x (m):	32.0376
η_y (mm):	0.0000
η_x (mm):	4.7000
β_y^* (m):	0.0100
β_x^* (m):	1.0000



Vert. Interferogram

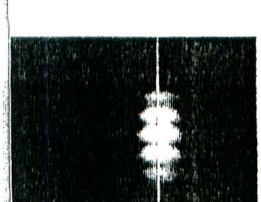


Vert. Beam Size

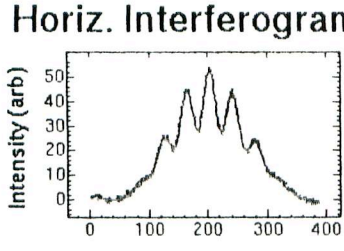


σ_y Measurement

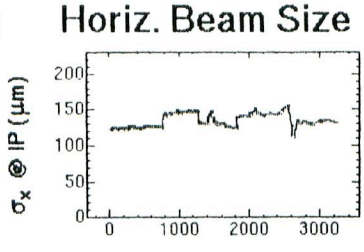
Eff. Path (m):	37.6000
Slit Sep. (mm):	38.2000
Wavelength (nm):	513.1900
Magnification:	0.9180
Visibility:	0.3088
$\sigma_{visibility}$:	0.0033
Fit χ^2/d.o.f.:	1.51



Horiz. Interferogram



Horiz. Beam Size

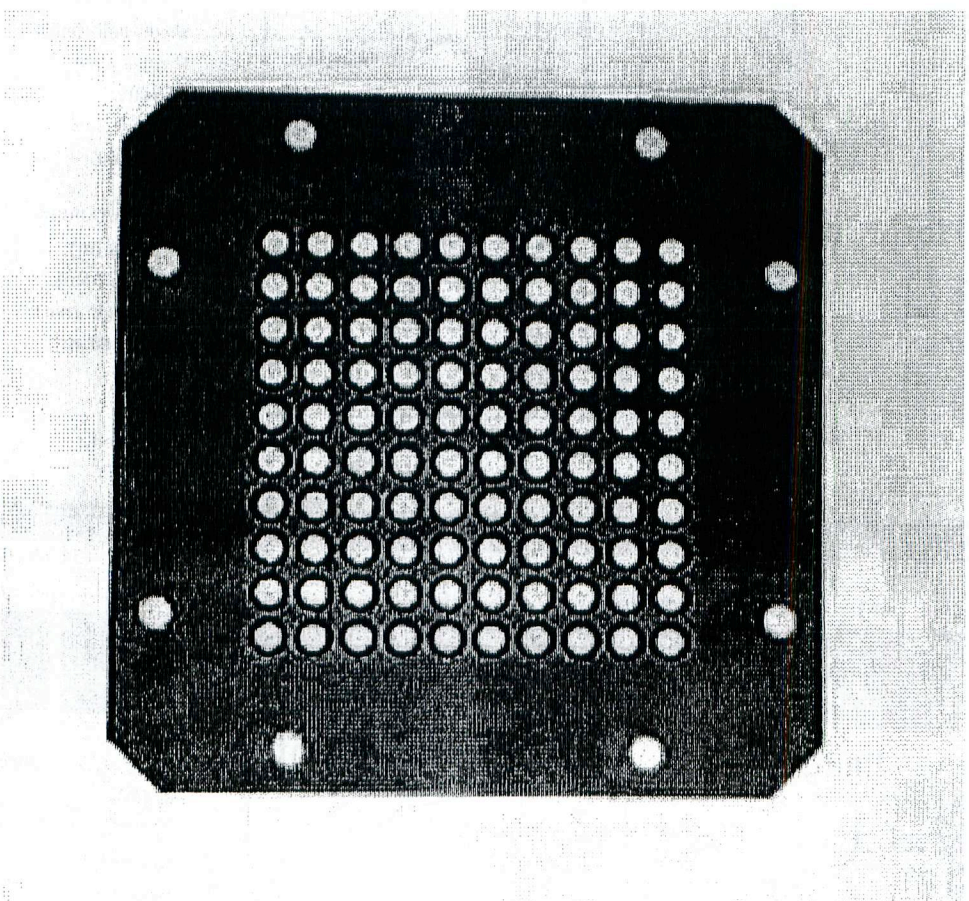


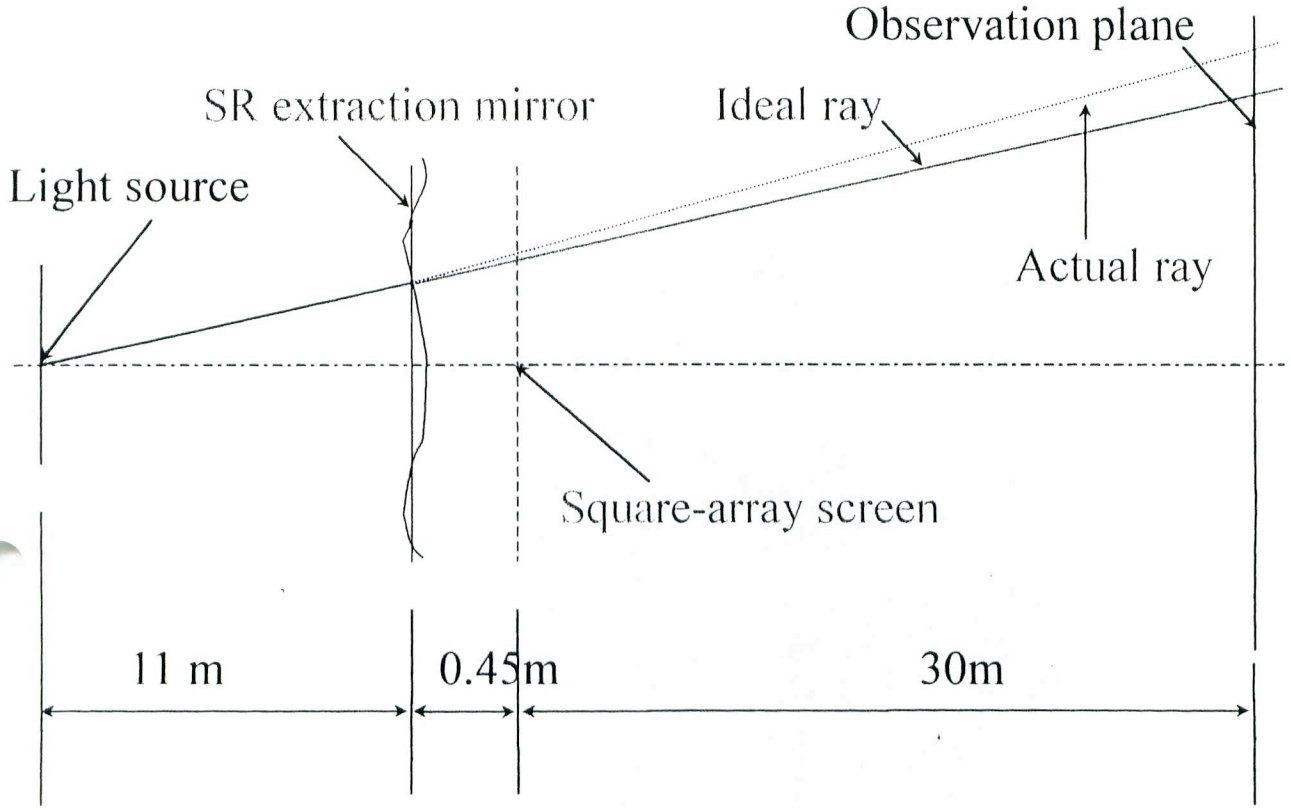
σ_x Measurement

Eff. Path (m):	37.6000
Slit Sep. (mm):	8.0000
Wavelength (nm):	510.4900
Magnification:	0.8000
Visibility:	0.2945
$\sigma_{visibility}$:	0.0055
Fit χ^2/d.o.f.:	0.30

A 100-hole square-array screen.

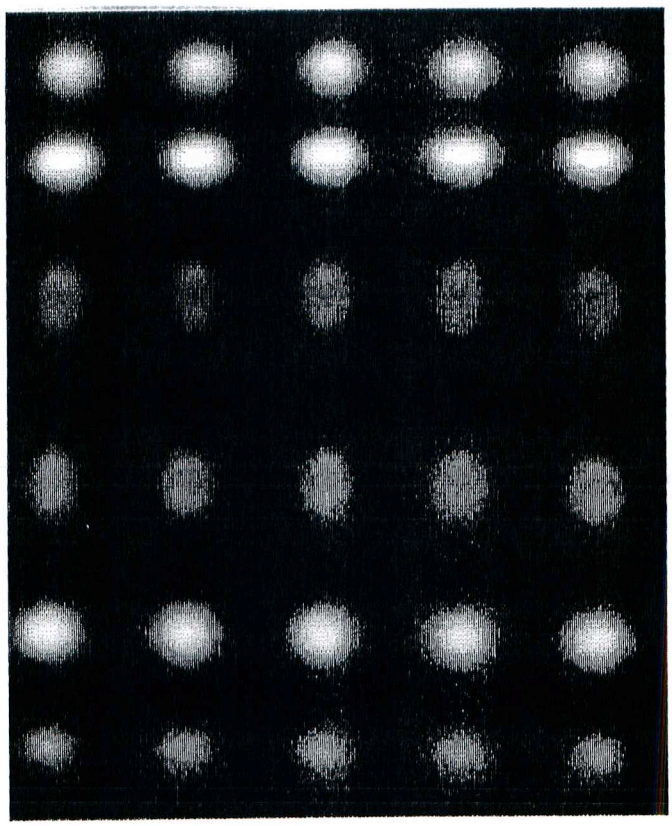
The hole size is 2.7mm, and the hole interval is 5mm.



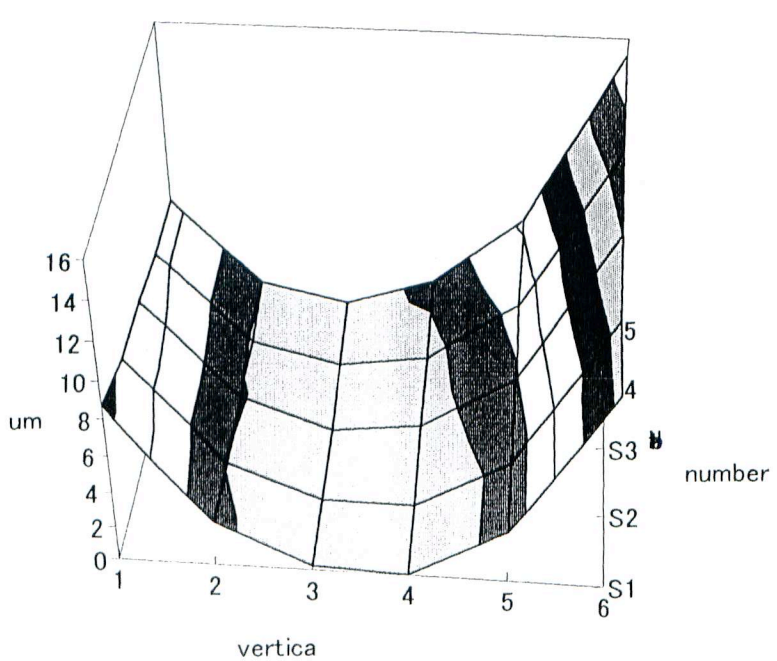


Measurement setup.

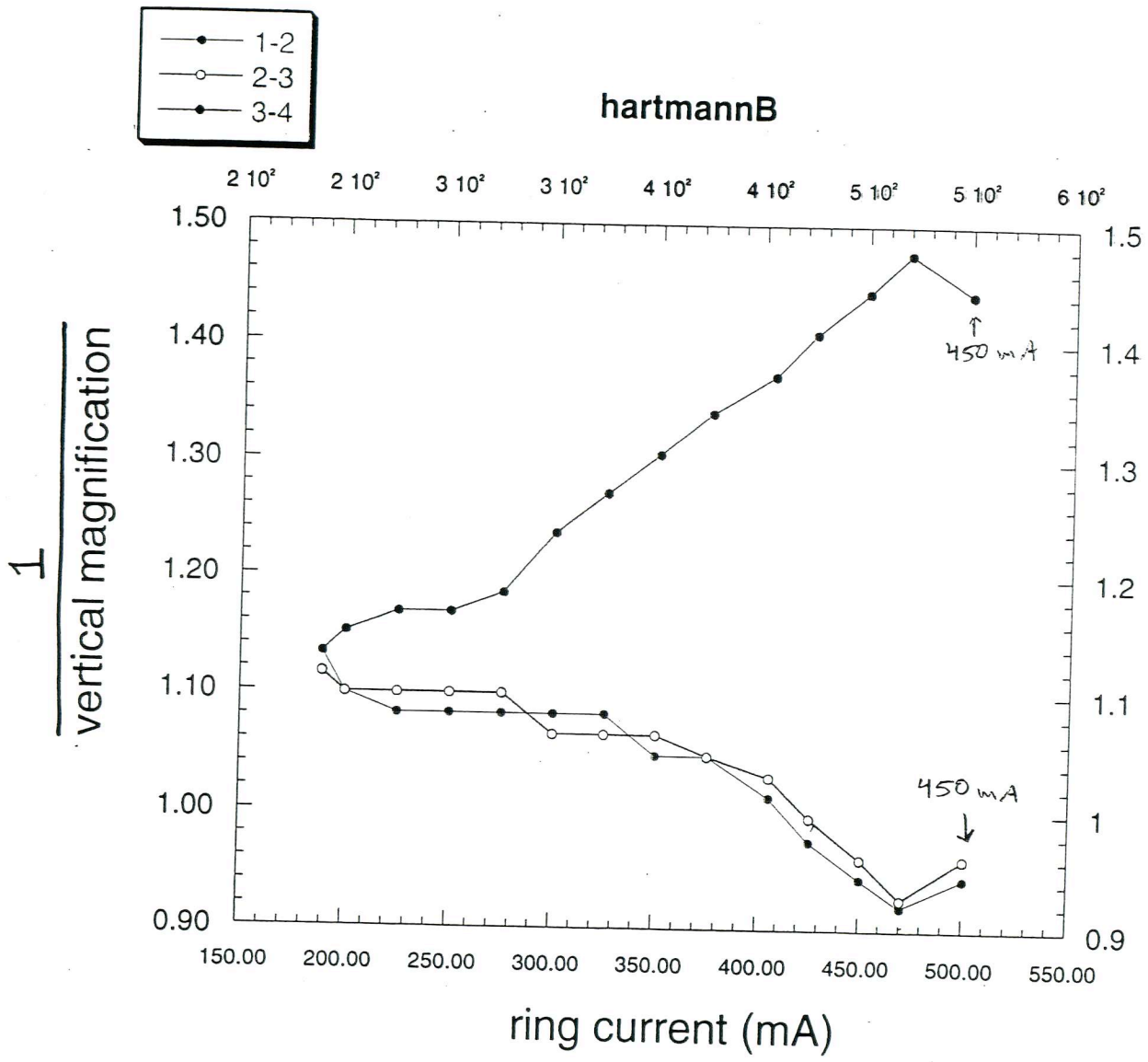
Hartmann pattern Observed in the Photon Factory. Ring current is 420mA.



Reconstructed wavefront from upper pattern.

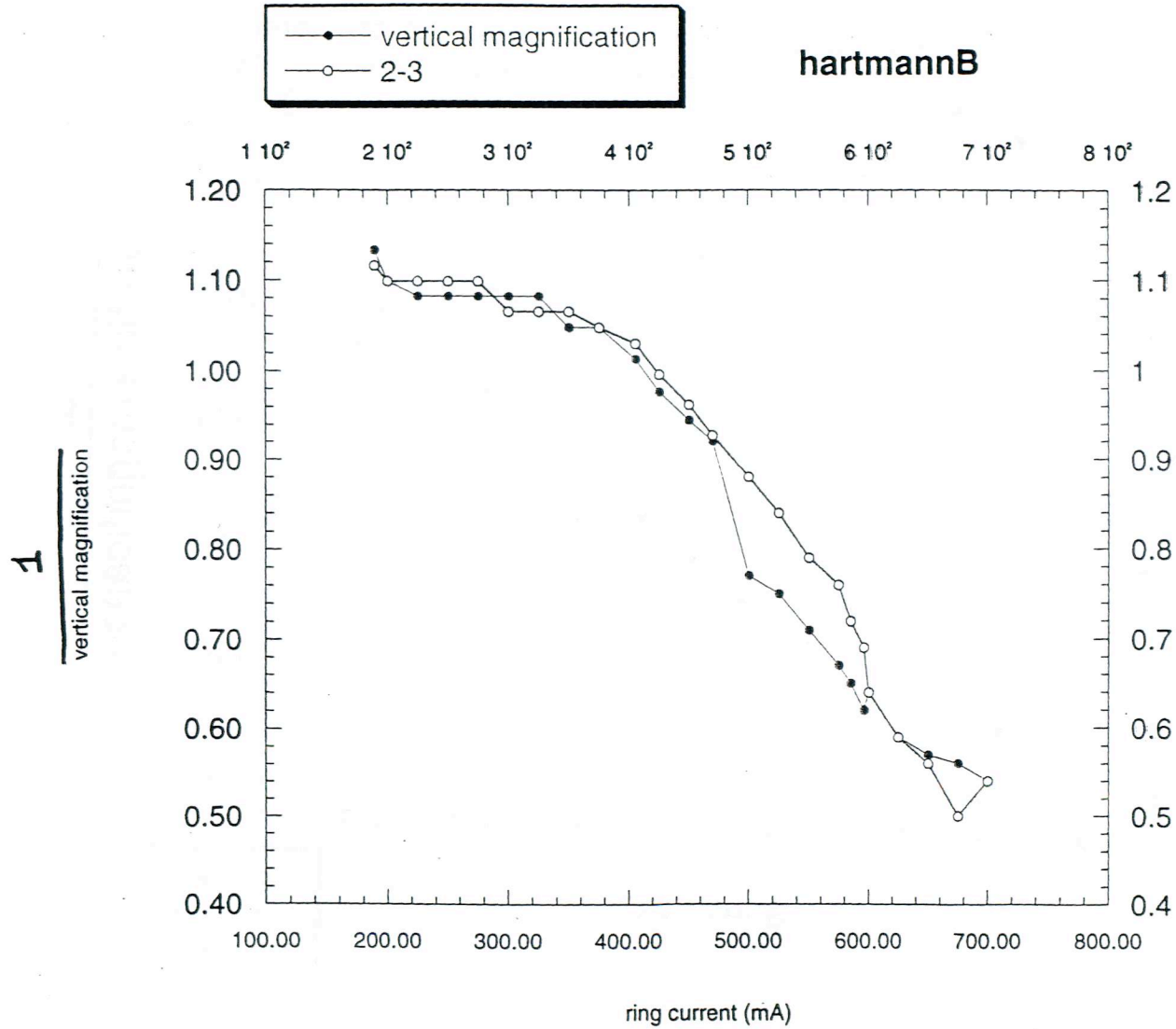


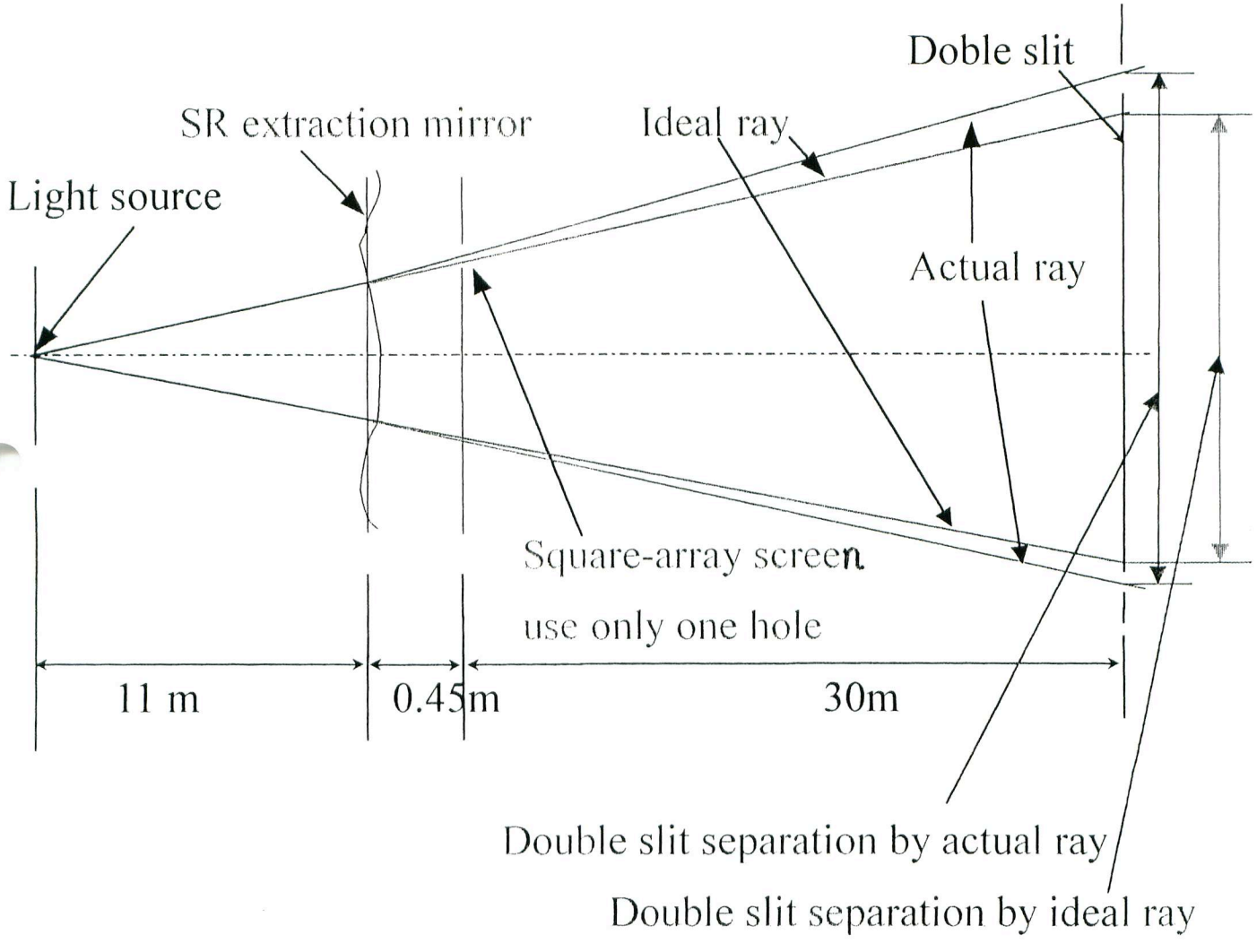
Nov. 2000



mask projection

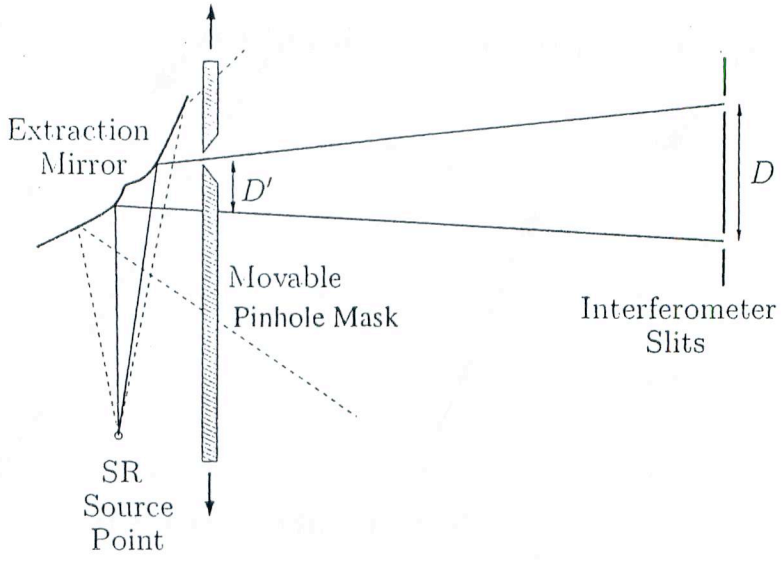
1
2
3
4


vertical magnification
2-3
hartmannB
1 10²
2 10²
3 10²
4 10²
5 10²
6 10²
7 10²
8 10²
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
100.00
200.00
300.00
400.00
500.00
600.00
700.00
800.00
1 / vertical magnification
ring current (mA)



Scanning the single-hole screen to determine the double slit separation by ideal ray.

Calibration of the double slit separation of SR interferometer by single-hole screen



2 Absolute Magnification Calibration via Pinhole Mask

A movable pinhole mask is placed just downstream of the extraction mirror. By finding the mask positions where the light from the pinhole hits the interferometer slits, the effective slit separation at the mask location can be measured. The beam size can be expressed as

$$\sigma = \frac{\lambda L}{\pi D M}\sqrt{\frac{1}{2}\ln\frac{1}{\gamma}}, \tag{2}$$

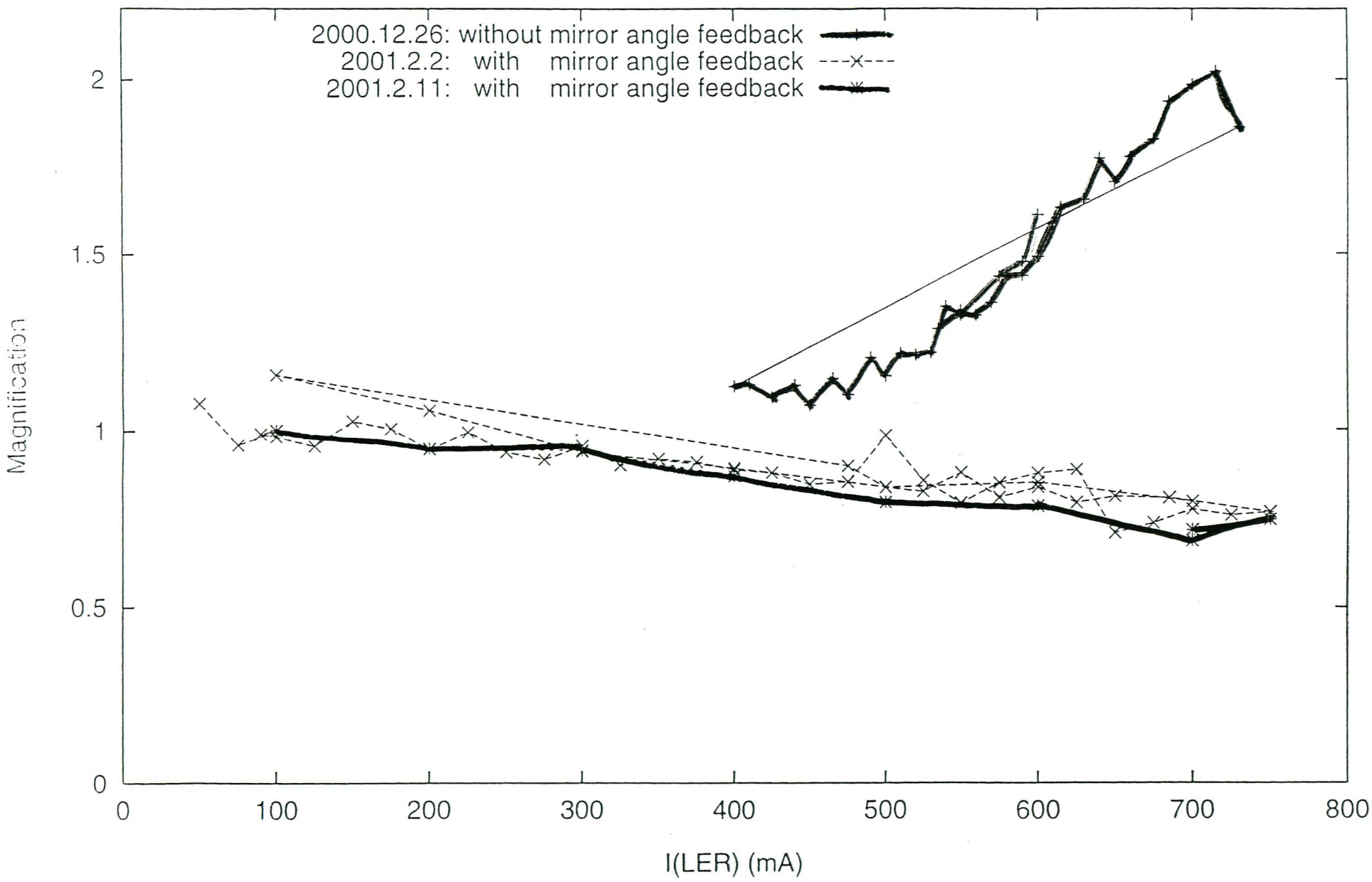
where γ is the visibility, D is the interferometer slit separation, L is the distance from the source point to the slits, and M is the magnification due to curvature in the extraction mirror. It can also be expressed as

$$\sigma = \frac{\lambda L'}{\pi D'}\sqrt{\frac{1}{2}\ln\frac{1}{\gamma}}, \tag{3}$$

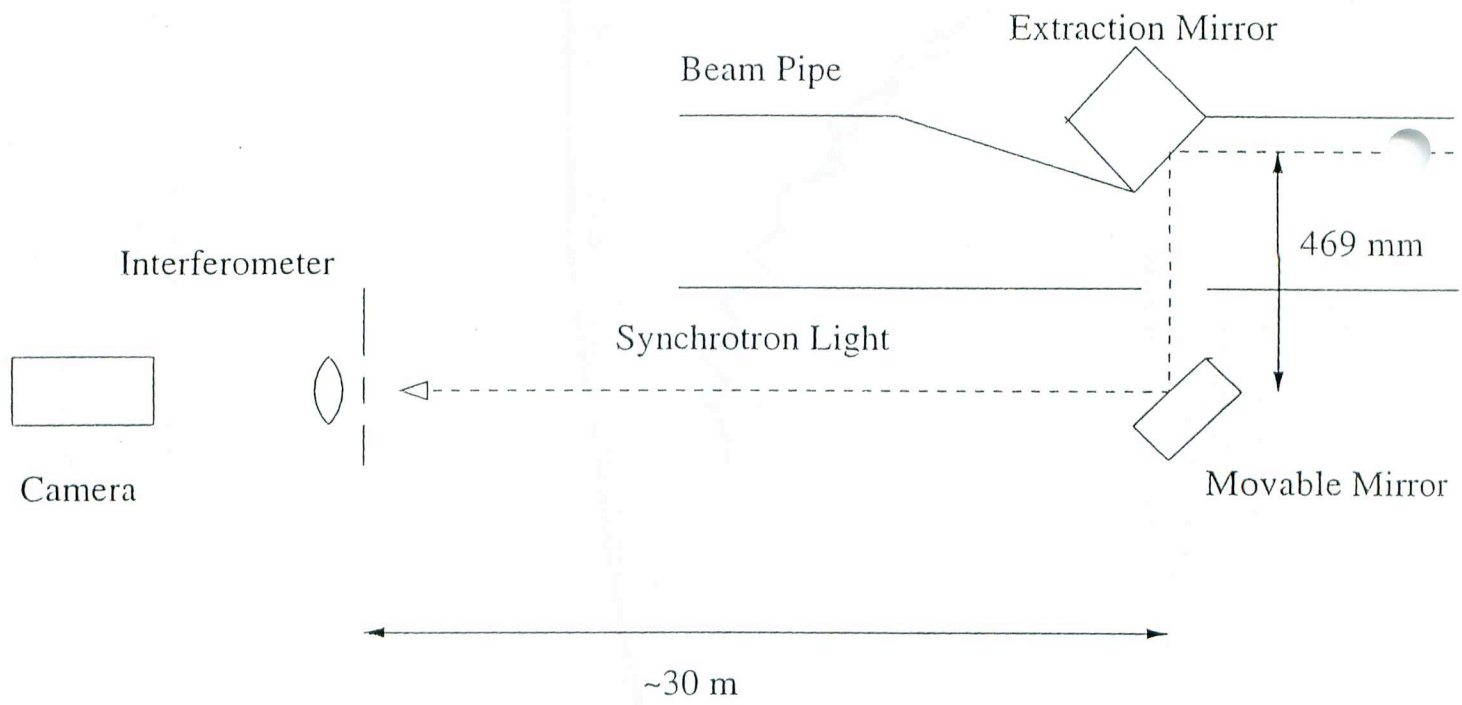
where D' is the effective slit separation at the location of the pinholemask and L' is the distance from the beam source point to the pinhole mask. The magnification is then

$$M = \frac{L/D}{L'/D'}. \tag{4}$$

Apparent LER beam size magnification due to mirror distortion



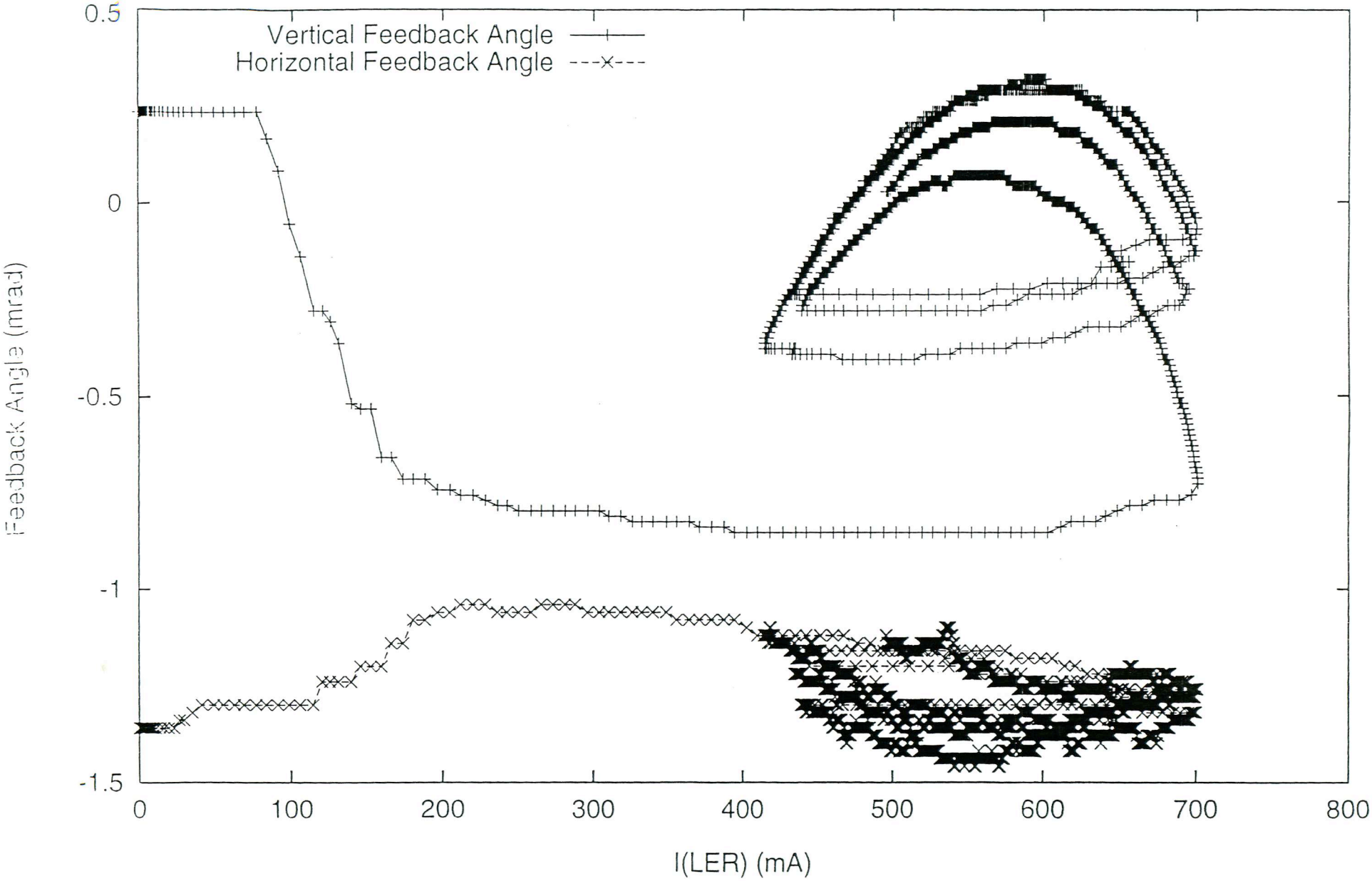
SR Monitor Mirror Angle Feedback



By monitoring image position on camera, adjust movable mirror angle to compensate for changes in extraction mirror angle (X & Y, LER & HER).

Use vertical interferogram for vertical angle feedback, and horizontal interferogram for horizontal angle feedback.

LER mirror angle feedback operation from cold start through several fills



Bunch by bunch feedback systems

1.Status

A)Transverse feedback systems

☆Working very well for both HER and LER.

☆Digital filter function has been changed from simple-delay mode to two-tap FIR mode.

☆Measured damping time ～0.25ms@500mA(LER-horizontal)

B)Longitudinal feedback systems

☆Not used / tested yet.

C)Betatron tune measurement systems

☆Working very well without troubles.

☆Data transfer function available for peak fits.

☆Selected-bunch tune measurement system has been added.

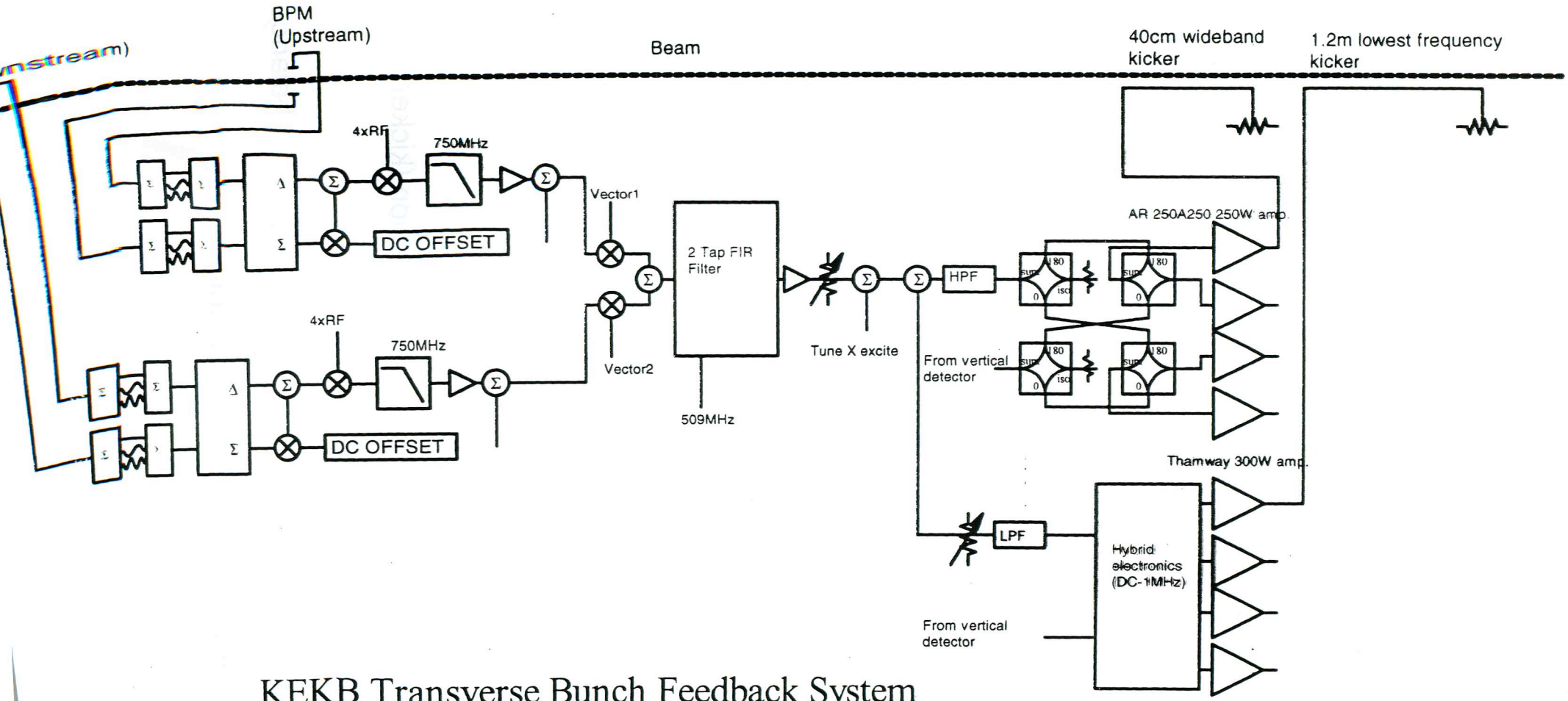
D)Bunch current monitors

☆Working very well without troubles.

E)Bunch oscillation recorders(BOR)

☆Used to measure the growth mode/rate of the instabilities.

☆Beam loss trigger modules are under development.



KEKB Transverse Bunch Feedback System

2.Progress from Feb/2000

1)Digital filter function

Changed from simple-delay mode to two-tap FIR mode.

Tap positions:

Ring	Direction	TAP1	TAP2	Nx	Ny
HER	Horizontal	137	297	.53	
	Vertical	137	617	.	.13
	Horizontal	137	297	.53	.
	Vertical	137	297		.65
LER	Horizontal	141	301	.51	.
	Vertical	141	941		.09
	Horizontal	141	301	.51	
	Vertical	141	301		.60

☆Two-tap mode operation (DC-cancel)

○Saturation at high-power amplifiers have been removed.

→Operation of the feedback systems have been much easier!

→Higher feedback gain than simple-delay mode is available.

2)Equalization of lower frequency (<1MHz) and wideband kicker.

☆Lower frequency kicker systems have been included in the feedback loop for both HER and LER.

☆Cross-over frequency

HER: 200kHz LER: 400kHz

○Huge horizontal oscillations during injection (kicker bump not closed) can be damped much faster.

×Feedback systems can easily be unstable. Gain balances between the two band systems are very touchy.

3)Remote control systems

A)Signal switch systems around betatron tune measurement systems have been added.

☆Switching between the selected-bunch betatron tune measurement system and global tune measurement system.

☆Transverse beam oscillation excitation (RF-KO).

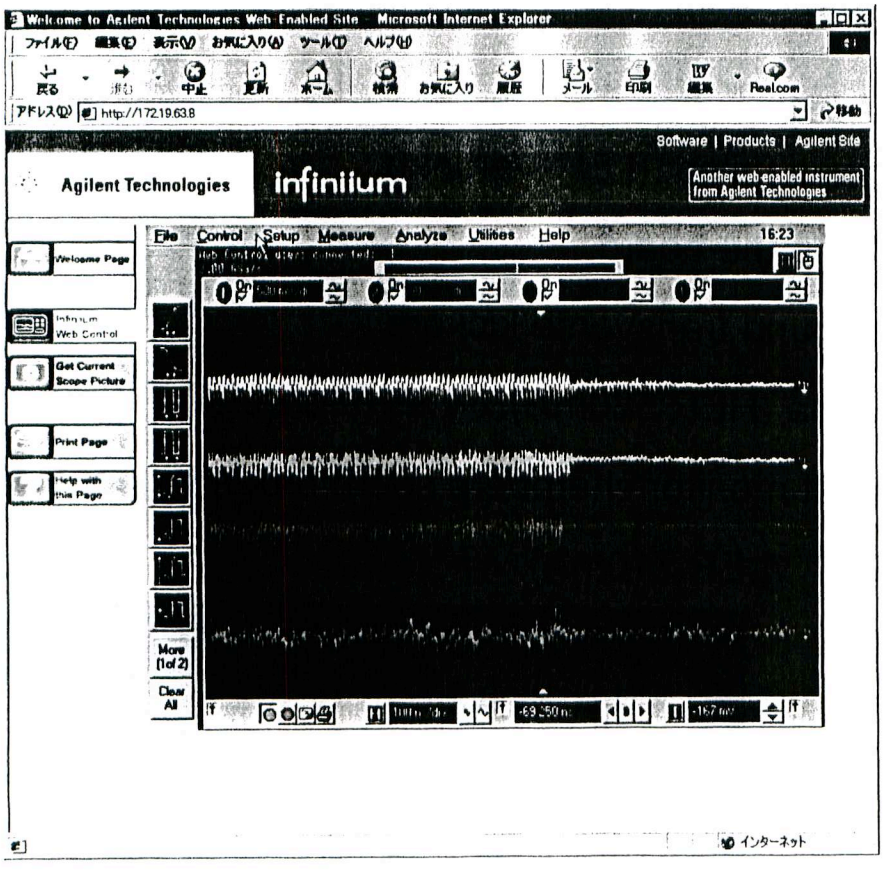
☆Calibration the tracking generator of the spectrum analyzer.

B)Signal switch systems for the real-time oscilloscope and the web-controlled infinium oscilloscopes.

☆Monitoring the real-time signal of the feedback systems.

○Time-domain signal (oscilloscope) vs. freq.-domain signal(SA)

○Kick error/ timing jitter of the injection kickers.



Troubles

1)Amplifiers breakdown

A)Wideband amplifiers

☆3 amplifiers (2 LER, 1 HER) have been broken by Aug/2000.

☆10 out of 11 amplifiers have been broken. (8: operation, 3: spare)

☆Monitoring gains of amplifiers from Oct/2000 and found no clear troubles until now!

B)LER Low frequency amplifier.

☆All the final power output cables in the amplifier have burned out. Combiners, FETs, power cables from amplifiers to kicker and transverse kicker were OK.

☆Too thin cable (RG-58) for high power.

→Thicker cables (5D)

2)Digital filter

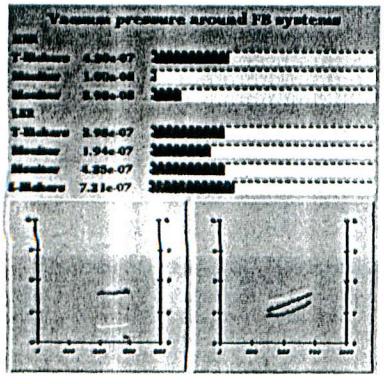
☆One digital filter was failed. (LER-Vertical)

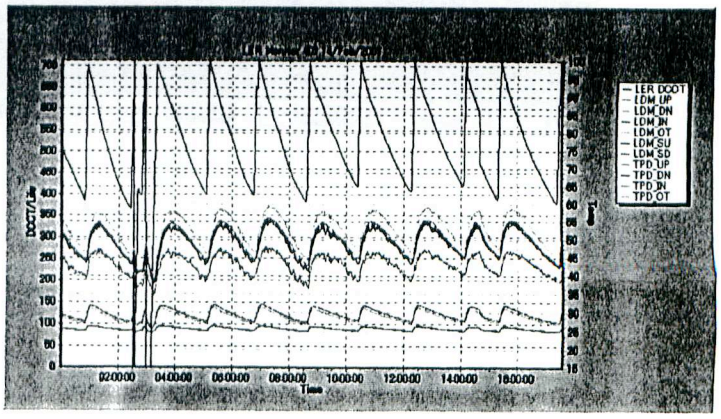
→Soldering trouble on the board.

3)Vacuum pressure around transverse kickers

☆Less than 5×10^{-7}pa (HER 580mA)、4×10^{-7}pa(LER 710mA)

☆Temperature rise at monitor chambers seem rather higher than expected ($\Delta T\sim35^{\circ}$ /LER 710mA).





Plan for FY2001

1)Automatic beam phase correction systems.

☆With increasing the beam current, differences of the beam phase relative to distributed RF signal become large.

☆Feedback gain, residual errors from detection circuits changes with the beam phase.

→Detect beam phase and feedback to the master phase shifter.

2)Longitudinal feedback system.

☆Not needed until now.

☆2 out of 8 wideband circulator is in trouble. No spares now.

☆Repair the bad-conditioned circulators and investigate the causes.

3)More remote control knobs.

☆Install more signal switches.

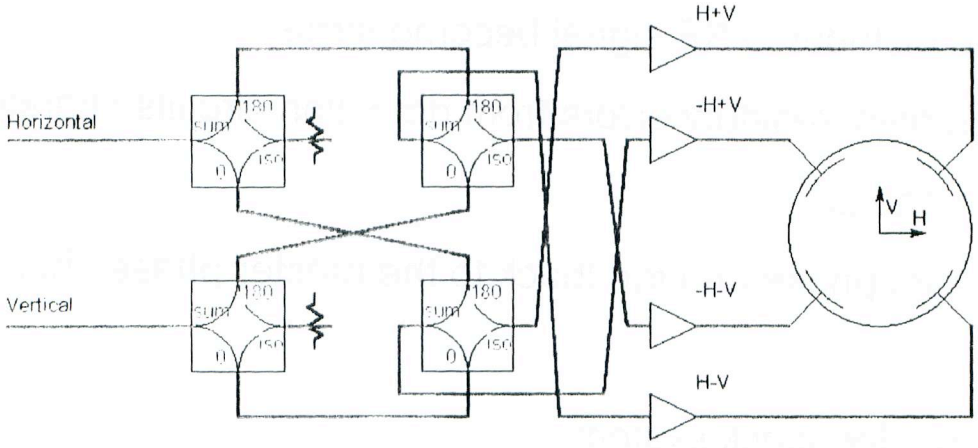
☆Vector phase controllers.

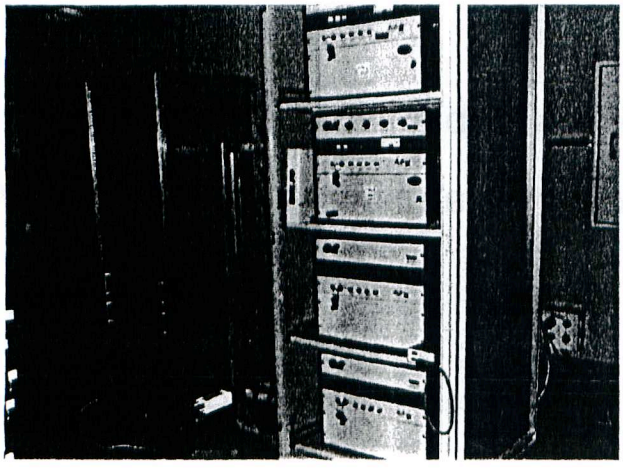
4)For higher beam / bunch current.

☆Forced air-cooling for hot chambers (LER monitors).

☆Prepare better chambers if the heating is too high.

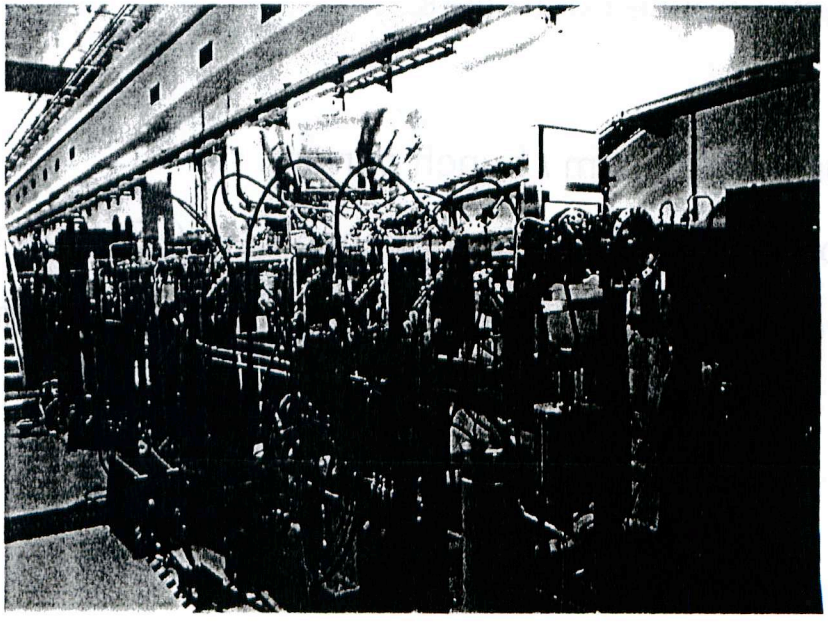
Transverse Amps/Kickers

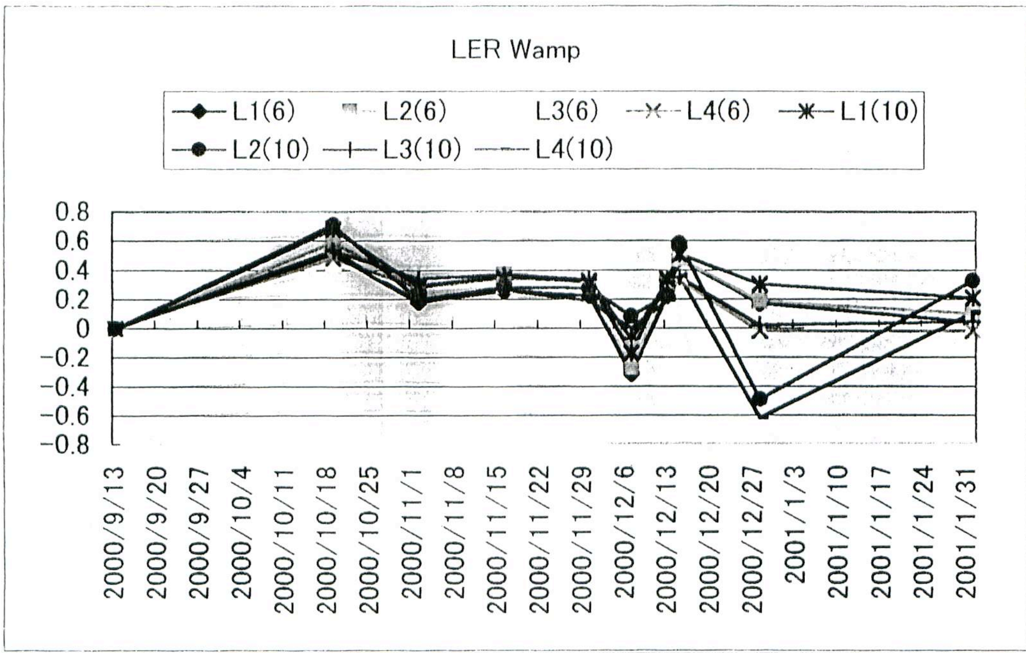


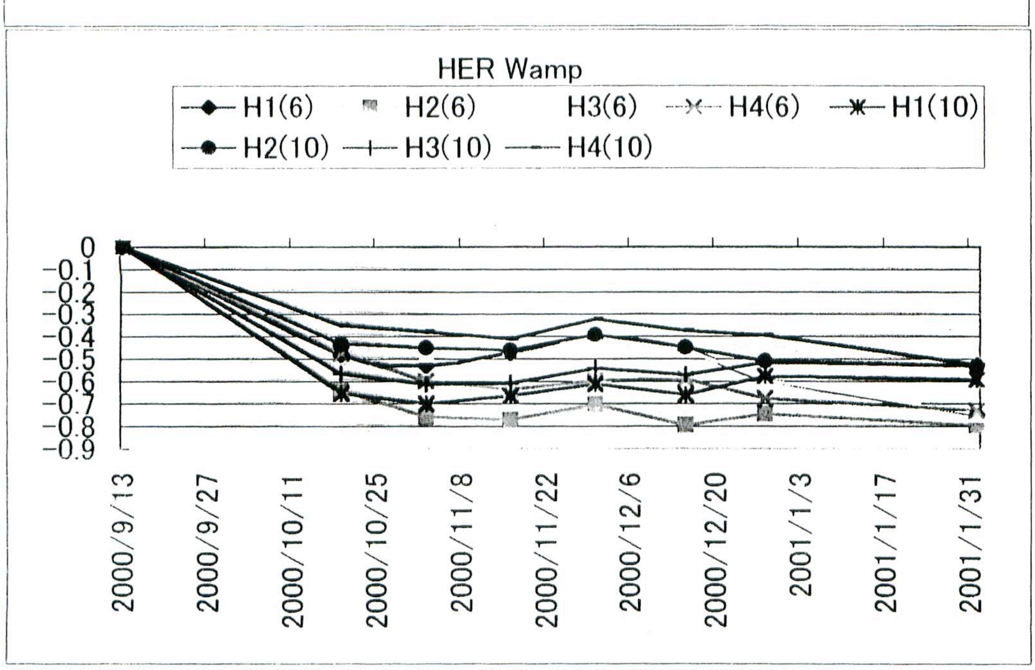


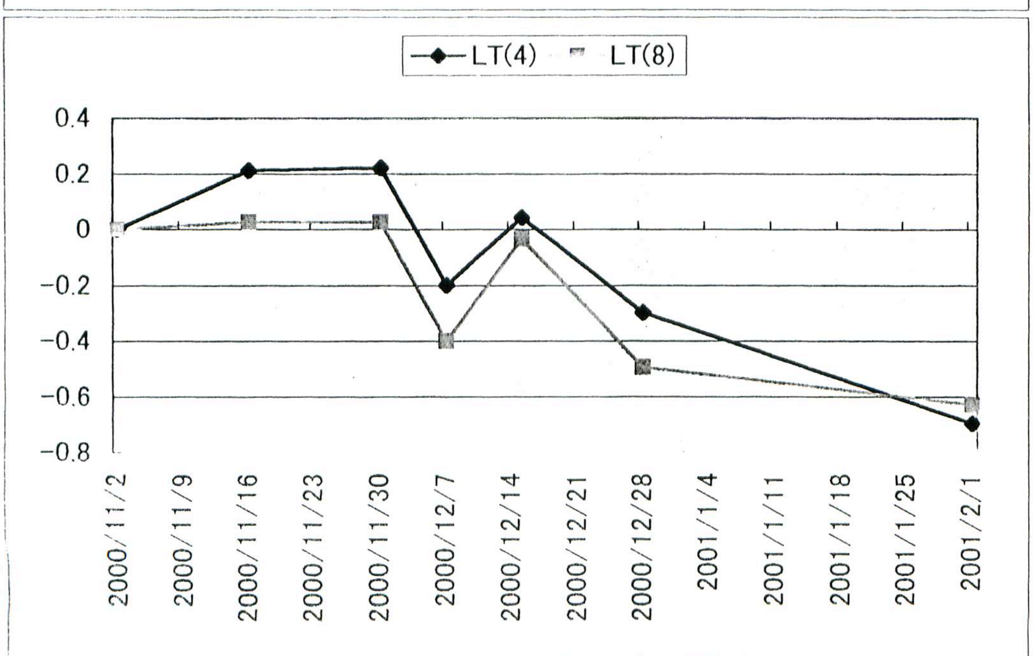
Transverse amplifiers

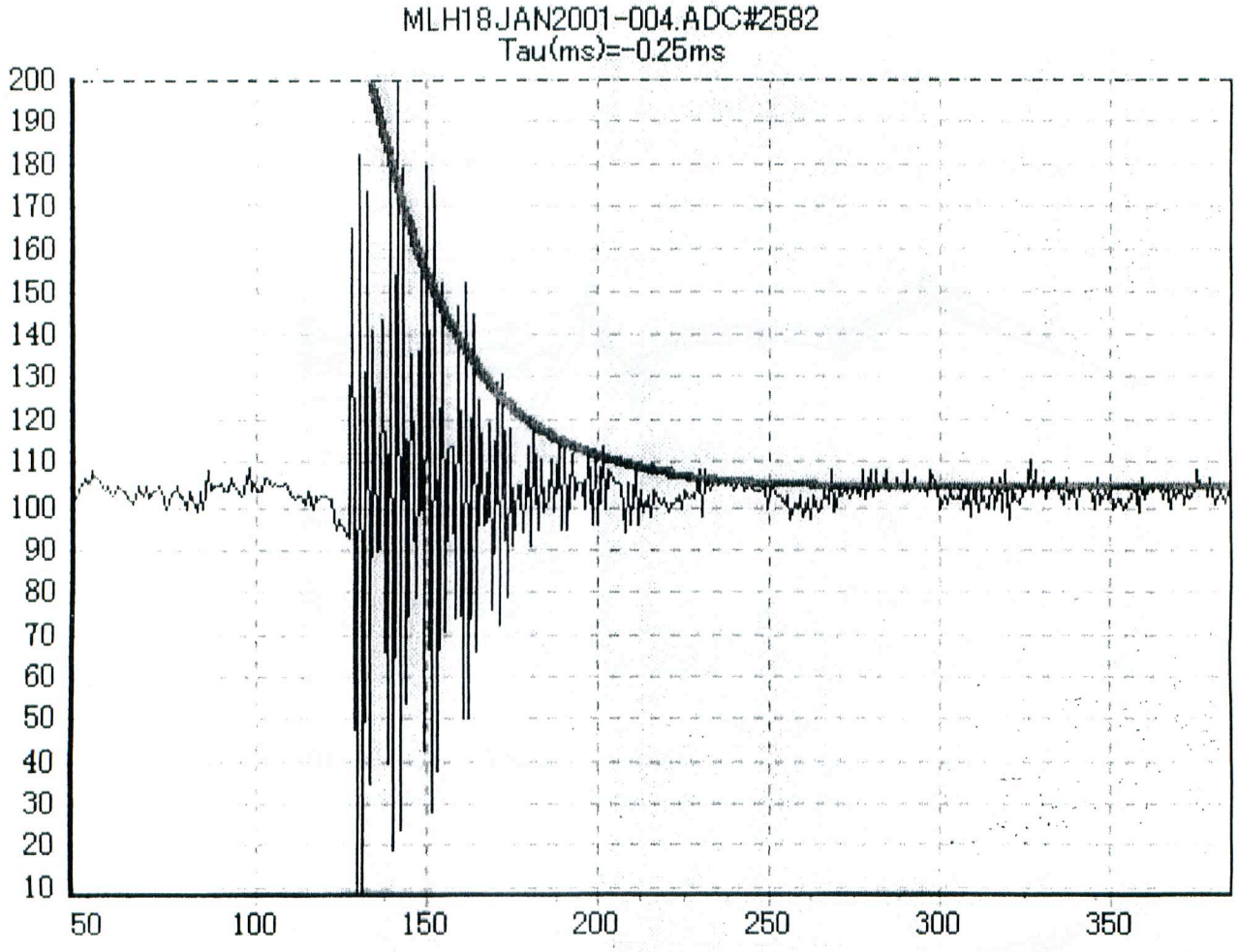
Transverse kickers (HER)

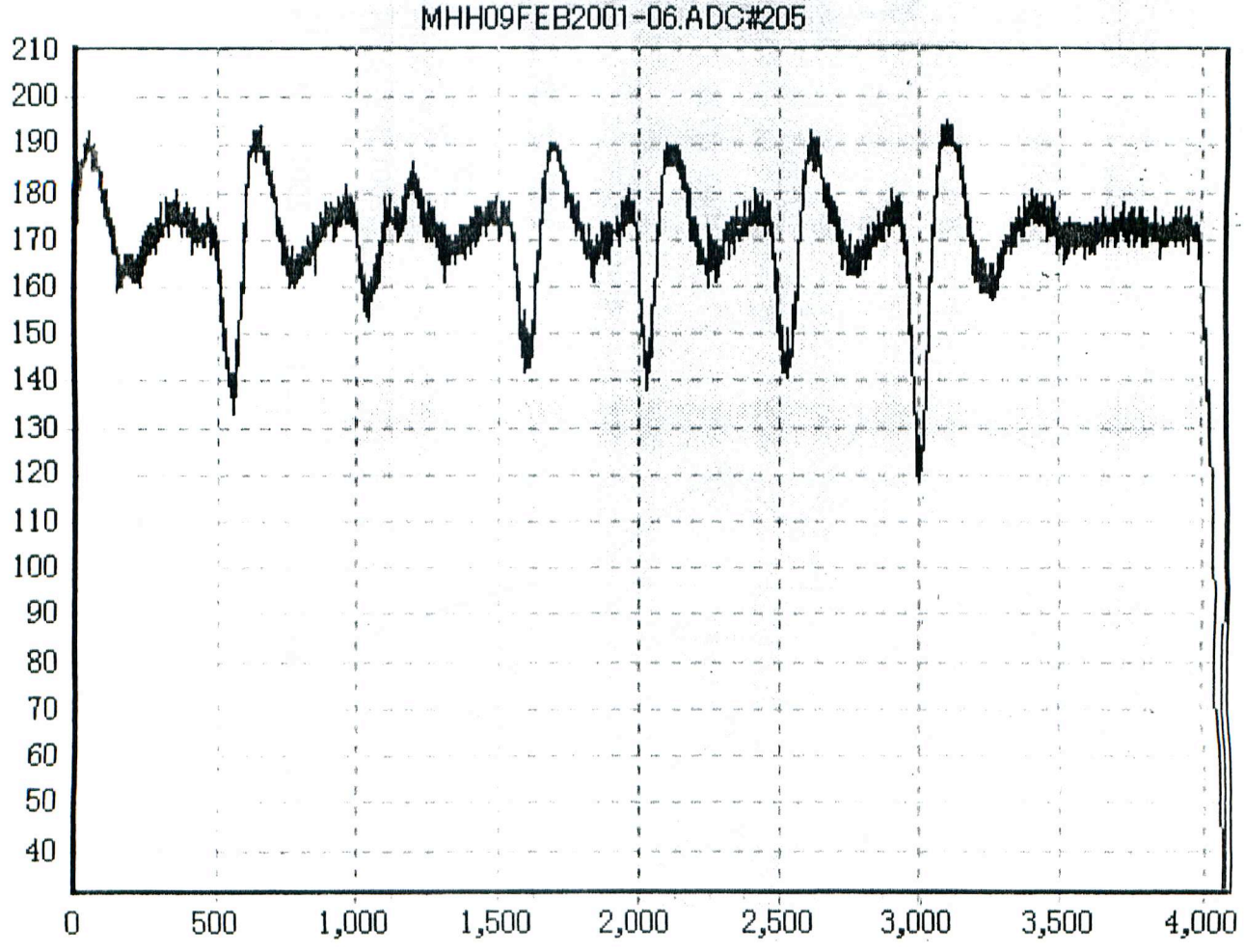



LER Wamp
L1(6)
L2(6)
L3(6)
L4(6)
L1(10)
L2(10)
L3(10)
L4(10)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
2000/9/13
2000/9/20
2000/9/27
2000/10/4
2000/10/11
2000/10/18
2000/10/25
2000/11/1
2000/11/8
2000/11/15
2000/11/22
2000/11/29
2000/12/6
2000/12/13
2000/12/20
2000/12/27
2001/1/3
2001/1/10
2001/1/17
2001/1/24
2001/1/31


HER Wamp
H1(6)
H2(6)
H3(6)
H4(6)
H1(10)
H2(10)
H3(10)
H4(10)
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
2000/9/13
2000/9/27
2000/10/11
2000/10/25
2000/11/8
2000/11/22
2000/12/6
2000/12/20
2001/1/3
2001/1/17
2001/1/31


LT(4)
LT(8)
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
2000/11/2
2000/11/9
2000/11/16
2000/11/23
2000/11/30
2000/12/7
2000/12/14
2000/12/21
2000/12/28
2001/1/4
2001/1/11
2001/1/18
2001/1/25
2001/2/1


MLH18JAN2001-004.ADC#2582
Tau(ms)=-0.25ms
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
50
100
150
200
250
300
350


MHH09FEB2001-06.ADC#205
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000