KEKB Accelerator Review Committee

23-25 Jan. 1997

BEAM INSTRUMENTATIONS

Beam Monitor Group
S.Hiramatsu

1. Beam Position Monitors (BPMs)
2. Synchrotron Radiation Monitors
   Beam size and profile
3. DCCTs
4. Others

1. Beam Position Monitor

- Electrostatic pickup with 4 buttons
- 452 BPMs/LER

Type	ϕ94	ϕ150	H150xV94	Others
Numbers	414	14	22	~2

- 452 BPMs/HER

Type	H104xV50	ϕ150	Others
Numbers	398	38	~16

- Pickup electrode; 12mmϕ button
- Position resolution ; <10μm
- Measurable range; 10μm<x,y<10mm
  10mA<i_b<2.6A
- Frontend electronics; superheterodyne
  signal: 1GHz IF: 20kHz
  ADC at 20kHz
  supectrum analysis by DSP
- Processing time; <250msec/button with 10μm resolution (S/N>92dB) @<10mA
- Closed orbit measuring time; <1sec/4-buttons(programable)
- Prototype frontend processor; S/N~90dB in 0.25sec/button (more 2dB?)
- One frontend processes 4 BPMs(2 for LER & 2 for HER) .
  1st step: 226 frontends
- Signal test at AR;
  direct signal: <0.1mA bunch current - measurable
  spectrum analysis: S/N~92dB is expected at i_b=2.6mA .

- Narrow band coupling impedance (σ_z=4mm);

  LER: 3.2kΩ/400 BPM (@7.6GHz)

  HER: 4.7kΩ/374 BPM (@7.5GHz) [1 cut]

  2.3kΩ/374 BPM (@7.0GHz) [2 cut]

  z_{max} for τ_E=23msec at α=1x10^{-4}, ν_s=0.01

  2.3kΩ for LER, 12.5kΩ for HER

2. Synchrotron Radiation Minitor

Optical lines

a. Beam image (beam size)

b. Streak camera (Bunch monitor)

c. Double-slit interferometer (beam profile)

- Beam size measurement with **diffraction corrected** beam image.

  diffraction limited optics

  σ_x(LER/HER) 472/650μm → 507/680μm (observed)

  σ_y(LER/HER) 69/120μm → 102/158μm (observed)

  diffraction spreading: 30-40μm → correction by point spread function

- SR extraction mirrors;

  Be-mirror mounted on Cu block

  effective area: LER 10mmHx44mmV

  HER 10mmHx50mmV

  location: LER FUJI straight section (QR4/QR5)

  HER OHO straight section (QR3/QR4)

- Wavefront-correction mirrors will be employed to correct the wavefront distortion by thermal deformation of the extraction mirror.
- Laser system for optics calibration will be installed.

  Point spread function (diffraction) & mirror distortion will be measured.

- Mirror distortion monitor;

  Shack-Hartmann sensor (laser+interferometer with micro-lens array)

  sensitivity: 0.02μm~λ/30 (surface distortion)

  → feedback to the wavefront correction mirror
- Beam profile measurement with **double-slit interferometer**.

  λ=300-700nm

  resolution; $\Delta\sigma<1\,\mu m$

  requirement; contrast of interference pattern>3%

  → intensity unbalance of 2 beams <1.5% (feedback by beam shifter and PMs)

3.DCCTs

- KEK original DCCTs will be installed.

measurable range;	10μA<i_b<3A
response;	DC-10kHz
drift;	1-3μA/deg

- The prototype DCCT was tested at the AR with 600mA beam current.

responce;	DC-500Hz
drift;	5-8μA/deg
accuracy;	~0.5%

*No problem in the DCCT itself but small problem of heating in the ceramic break of the beam chamber (~80deg @570mA).

4.Others

4-1 One-Turn BPM

20 one-turn BPMs are planed.

1-5 bunches will be sellected by a fast analog SW.

Expected resolution; 50-70μm @i_b=0.1mA (S/N~60dB)

Fundamental components were tested at AR.

Bunch selection by analog SW

Signal detection by I/Q demodulator

S/N~43dB @i_b=0.1mA, single bunch

(more improvement reqired?)

4-2 BPM at IP

Specially desinged BPMs will be installed in the QCS beam chamber (55mmφ inner diameter).

pickup;	4 buttons with 6mmφ diameter
feedthrough;	SMA

4-3 Event Timing

Bunch detectors will be installed in the IR.

pickup;	electrostatic pickup with wide and smooth response (same one as the bunch-by-bunch feedback signal detector)
locations;	2 in both sides of IR for each ring

4-4 Laser-Wire Monitor

Laser/beam timing was tested in the Tokyo Univ. linac at JAERI.

Collision experiment is under way.

electron beam;	17MeV,150pC/pulse
	beam size: 480μm
laser;	790nm, 100fsec, 210mJ
	spot size: 100μm
timing jitter;	σ_t~3.7psec

4-5 Bunch Current Monitor

Beam current of every bunch is measured in the signal processing systems of bunch-by-bunch feedback.

tested in AR;	synchronous det. at 1.5GHz
	error<5%(affected by synchrotron oscl.)
	reqired I/Q demod.

4-6 Tune Measurement

Transverse & vertical tune are measured in the signal processors of bunch-by-bunch feedback systems.

4-7 Wall Current Monitor

Each ring of LER and HER has a wall current monitor for bunch identification.

Design & fabrication will be in '97-'98.

4-8 Fast CT

Each ring of LER and HER has a fast CT for bunch current calibration.

Design & fabrication will be in '97-'98.

Heating problem of the ceramic break in the beam pipe should be solved.

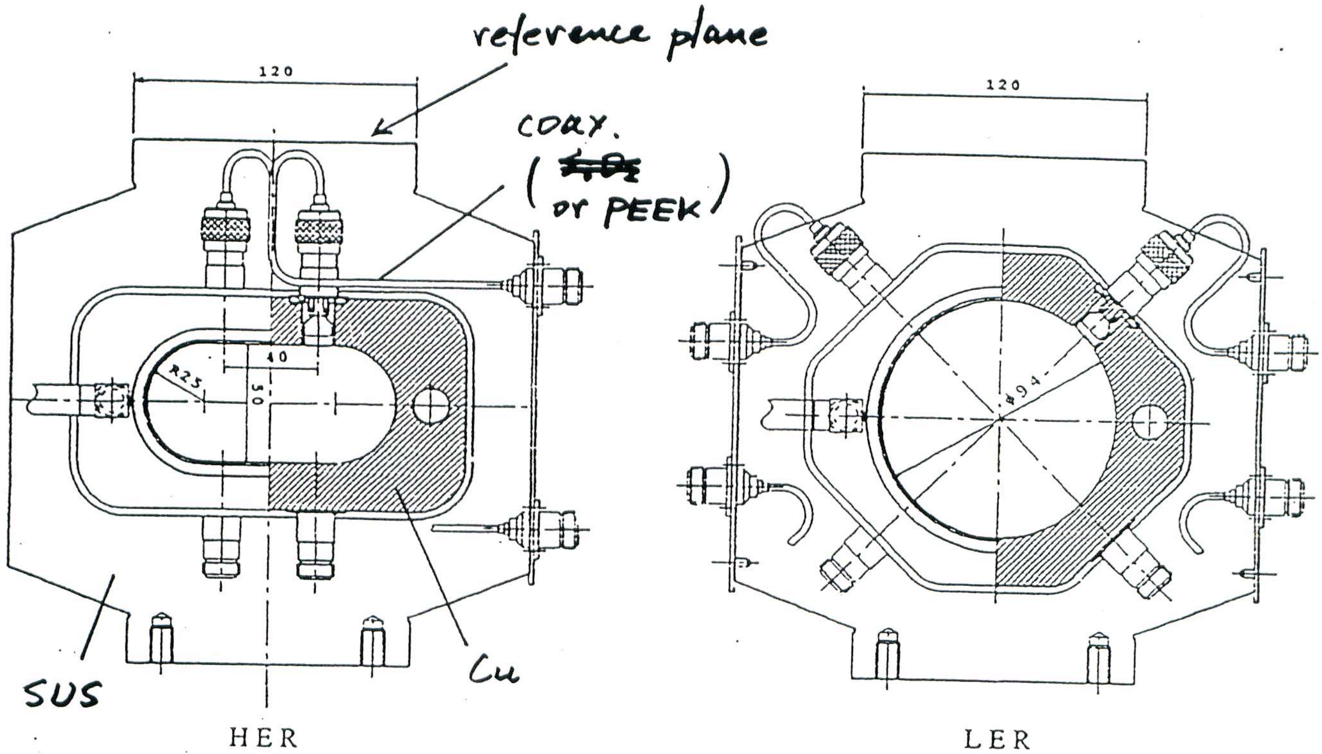
4-9 Screen Monitor

No plan for the screen monitors.

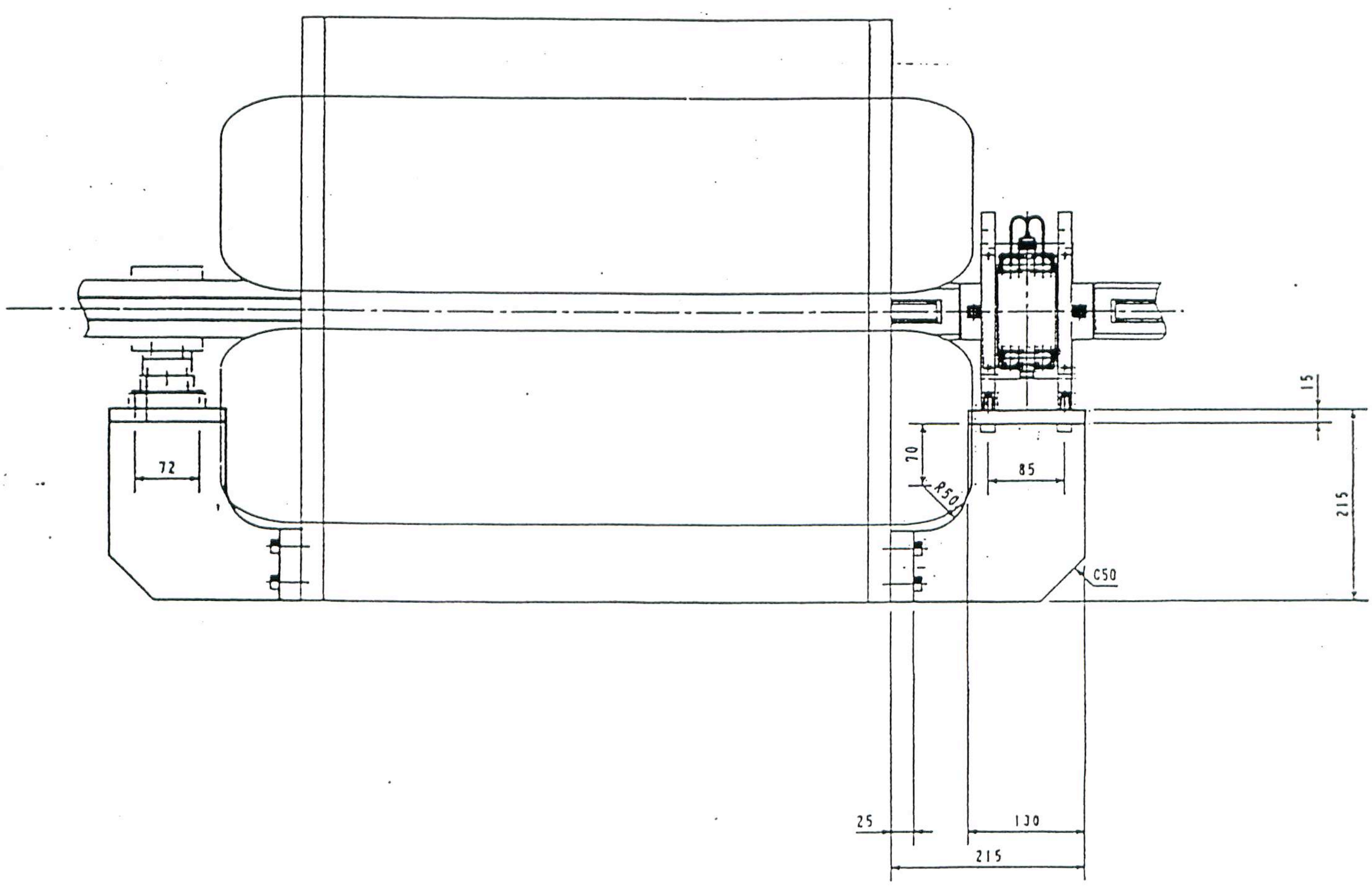
Direct signals from 452+452 BPM heads can be monitored instead of the screen monitors.

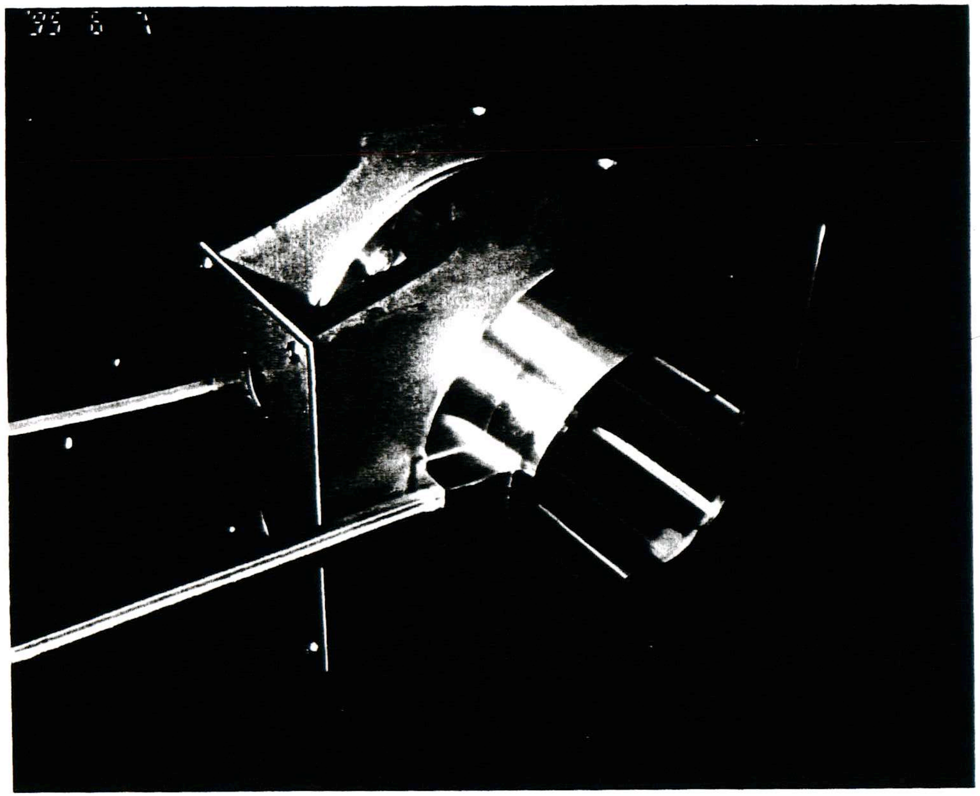
4-10 Beam Loss Monitor

No plan for the beam loss monitors.

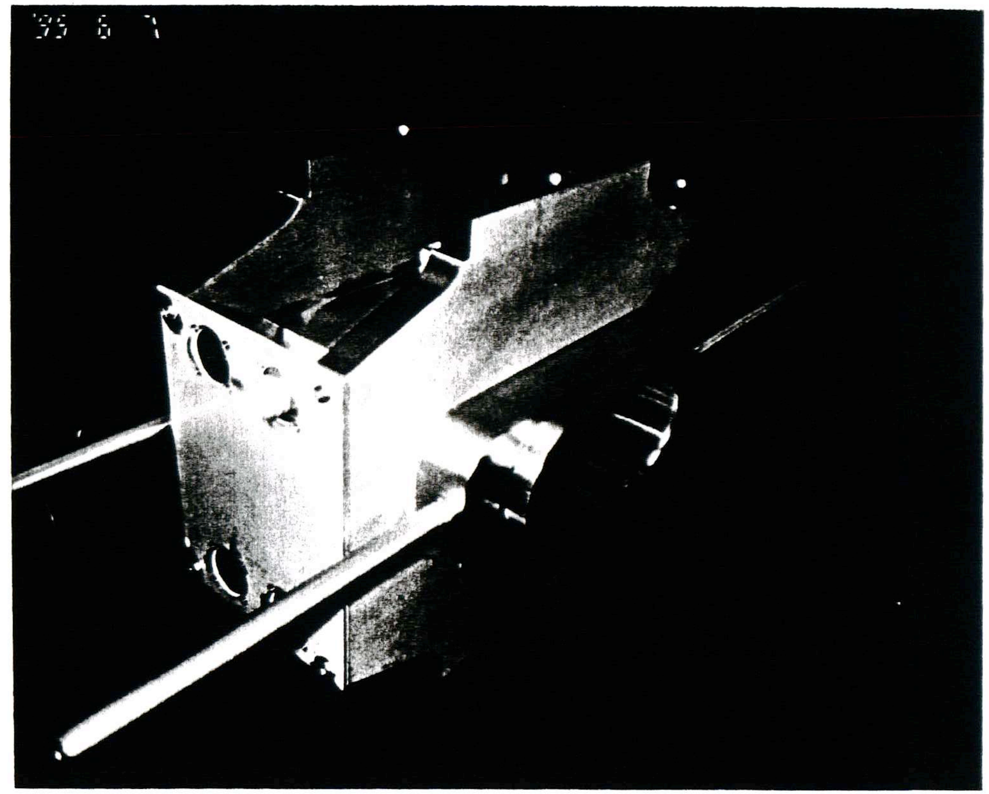


BPM block for the BF ring





BPM block for the LER

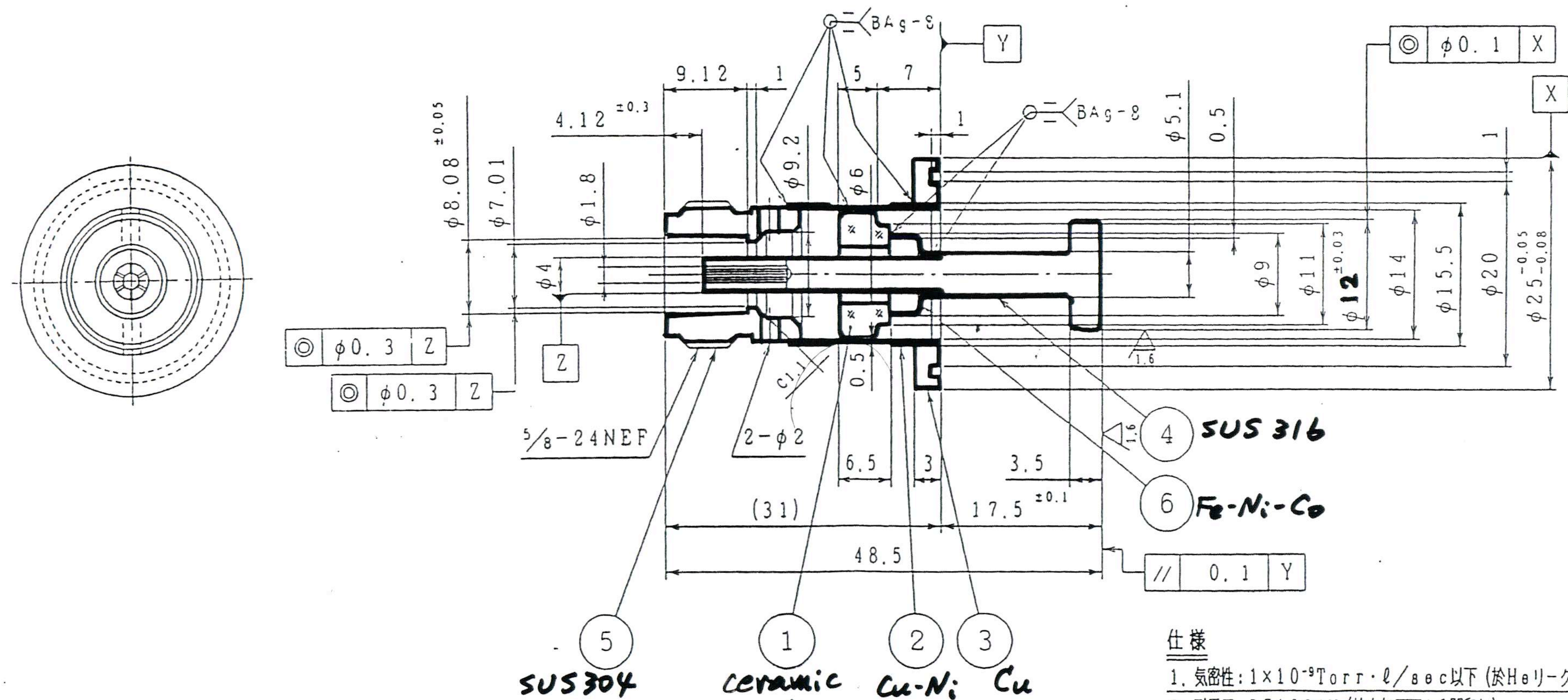


BPM block for the HER

NL-102-700

BPM feedthrough / LER

記号	来歴	年月日	訂正	審査	作番
					P43195



仕様

1. 気密性：1×10⁻⁹Torr·ℓ/sec以下（於Heリークディテクター）
2. 耐電圧：DC1000V（於大気圧下1分間印加）
3. 絶縁抵抗：1000MΩ以上（於常温・常湿500V印加）

番号	部品名	材質	員数	備考
①	碍子	アルミナセラミック	1	色調：白
②	パイプ	Cu-Ni	1	Niメッキ付
③	フランジ	C1020	1	
④	ピン	SUS316	1	Niメッキ付
⑤	スクリュー	SUS304	1	Niメッキ付
⑥	L型フランジ	Fe-Ni-Co	1	Niメッキ付

分番	納番	部番	品番	片番	作区	製区	部品名	GTコード	校コ	資材コード
1		1					N.TL			

材質	材料	寸法	素材	仕上
摘	要	納明備考	重量(Kg)	

MT MY15X 入庫

備付 校 印

製図 審査 承認 95.06.05

三角法 製図尺度 2:1 原図縮尺 —

コード

N.TL

N端子

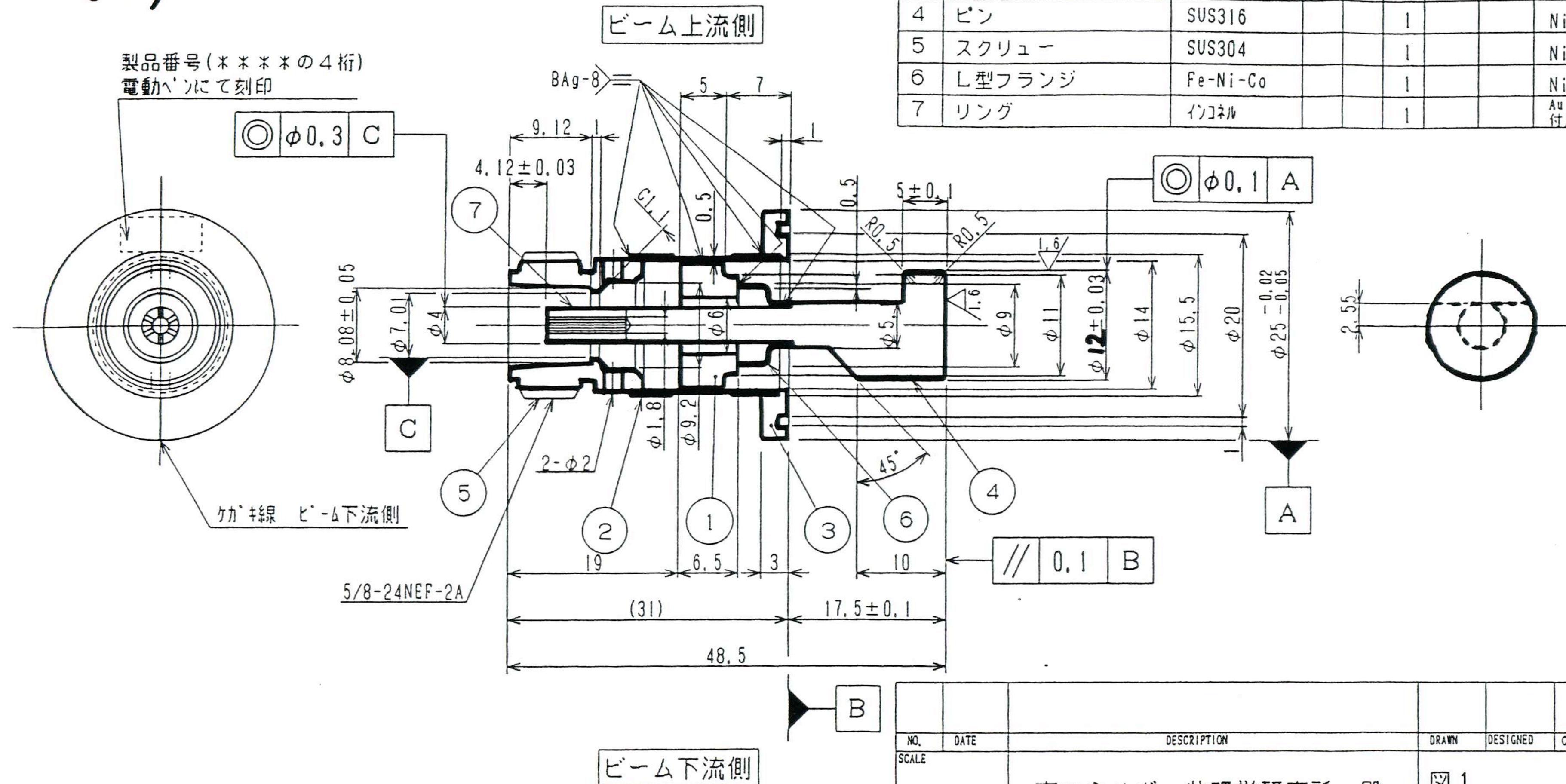
日立原町電子工業

NL-102-700

B A

BPM feedthrough / HER
(asymmetric structure)

MARK	PARTICULARS	MATERIAL	NO. REQUIRED WORKING	NO. REQUIRED SPARE	NO. REQUIRED TOTAL	MASS(Kg) PER ONE	MASS(Kg) TOTAL	REMARKS
1	碍子	アルミナ・セラミックス			1			色調：白
2	パイプ	Cu-Ni			1			Ni：メッキ付
3	フランジ	C1020			1			
4	ピン	SUS316			1			Ni：メッキ付
5	スクリュー	SUS304			1			Ni：メッキ付
6	L型フランジ	Fe-Ni-Co			1			Ni：メッキ付
7	リング	インコネル			1			Au：メッキ付 付属品



備考

1，ケガキ線は，③フランジの中心を通り，かつ中心電極(④ピン)上の面Dに対して垂直にひくものとします。

NO.	DATE	DESCRIPTION	DRAWN	DESIGNED	CHECKED	APPROVED

SCALE 2/1

高エネルギー物理学研究所　殿

1ST ANGLE PROJECTION / 3RD ANGLE PROJECTION

HER用ビーム位置モニター追加

図1

ビーム位置モニター用電極

構造図

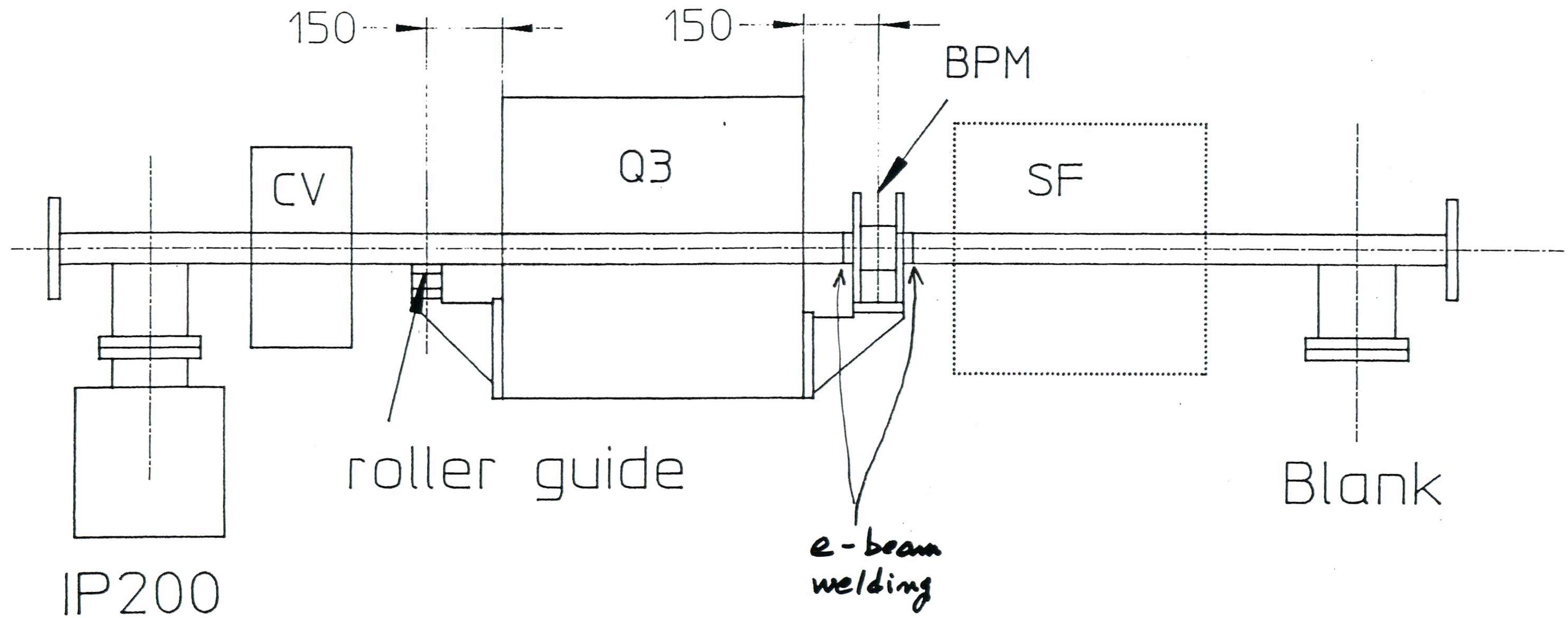
JOB NO. 5535-450

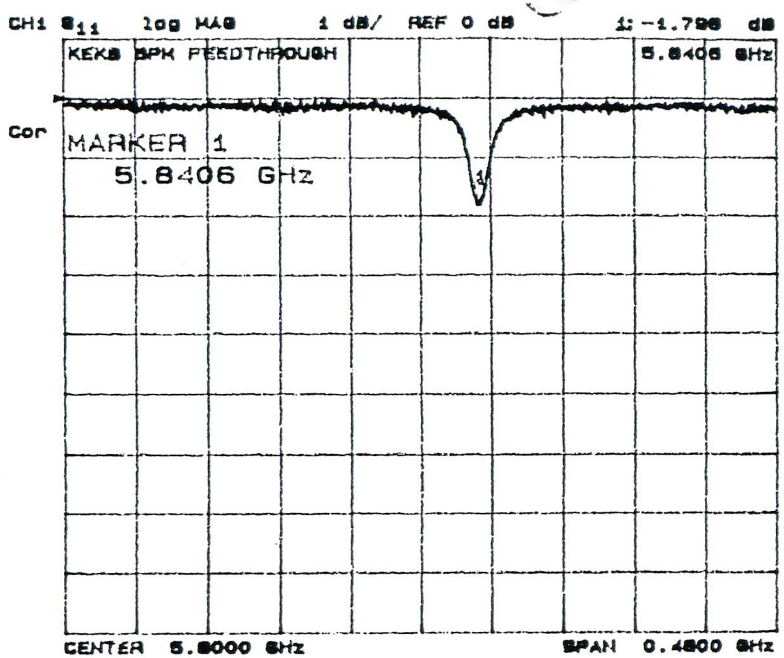
IHI開発プラント設計部

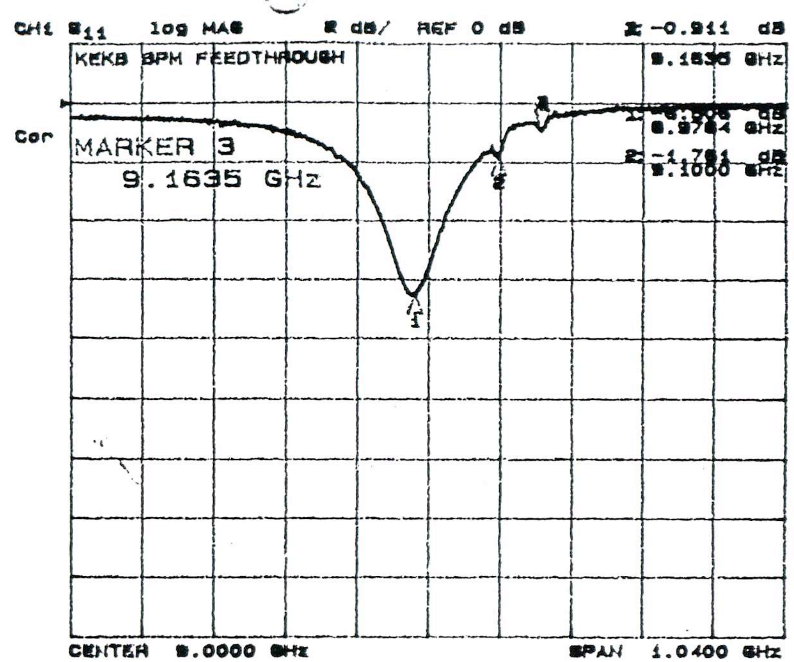
DRAWING NO.

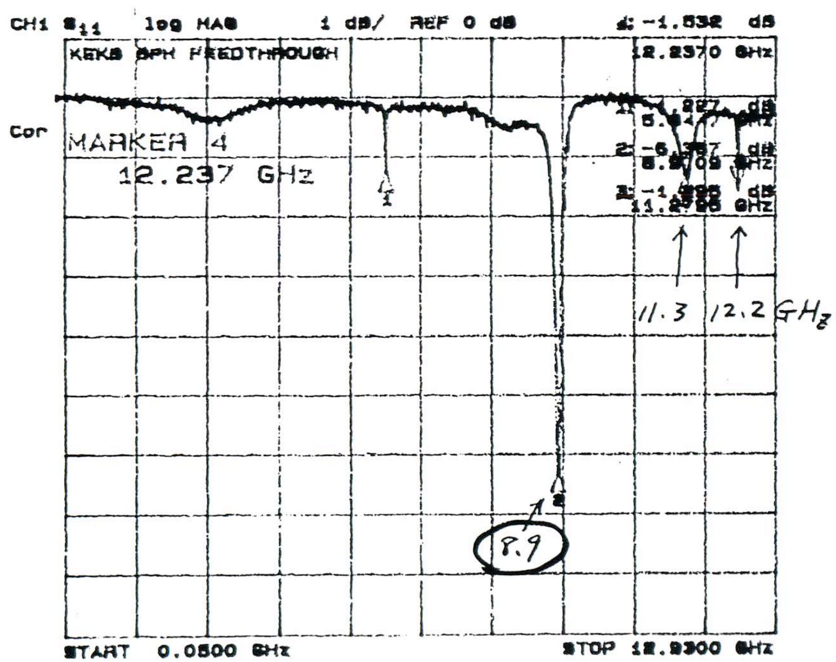
REV. 0　1/1

Ishikawajima-Harima Heavy Industries Co., Ltd.


150
150
BPM
Q3
SF
CV
roller guide
Blank
e-beam
welding
IP200







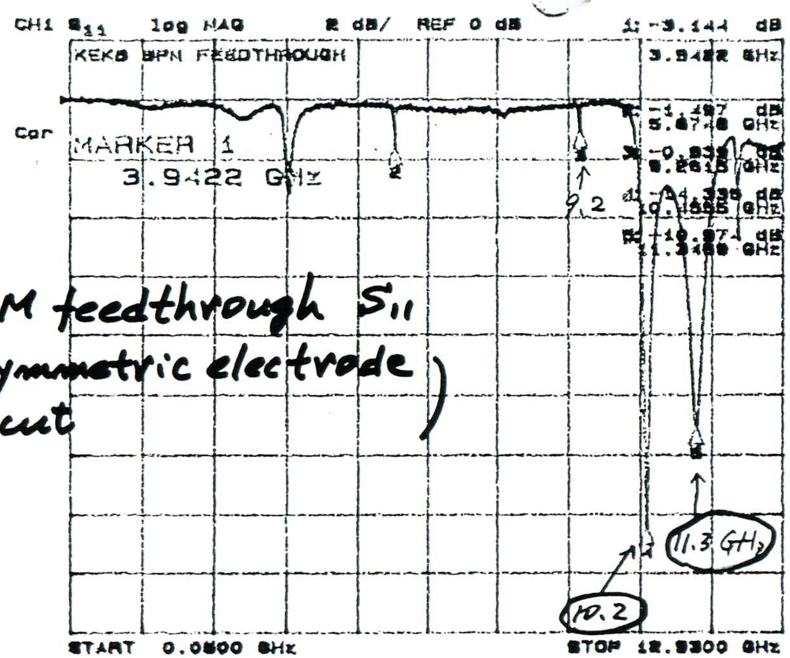
BPM feedthrough S_{11}
(symmetric electrode)

H8. 11/25
ダミー測定
(備)

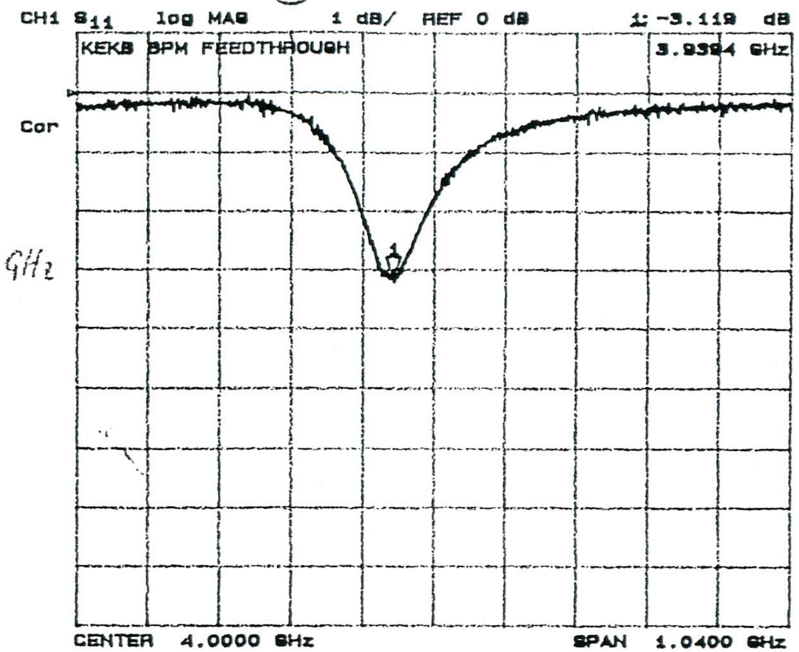
1996.12.12

×7 3.56
×8 4.068

3.962

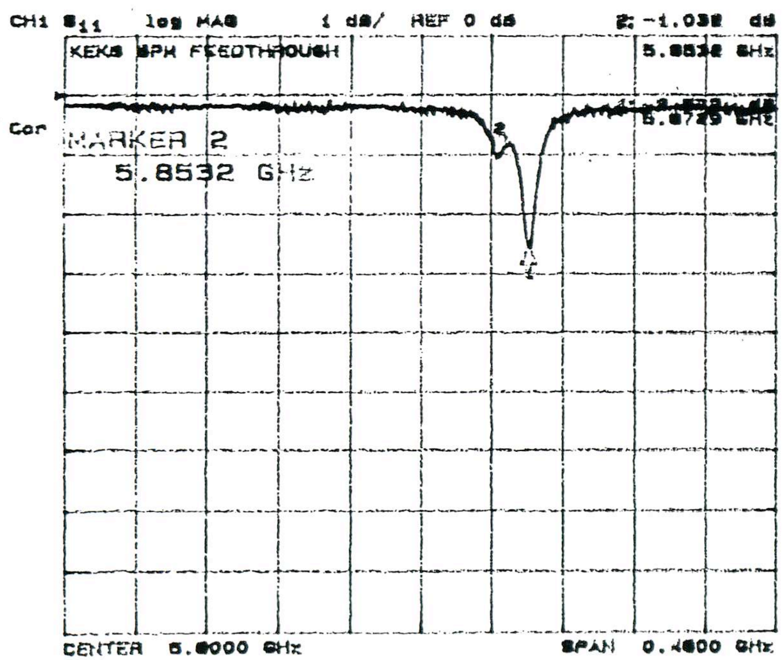


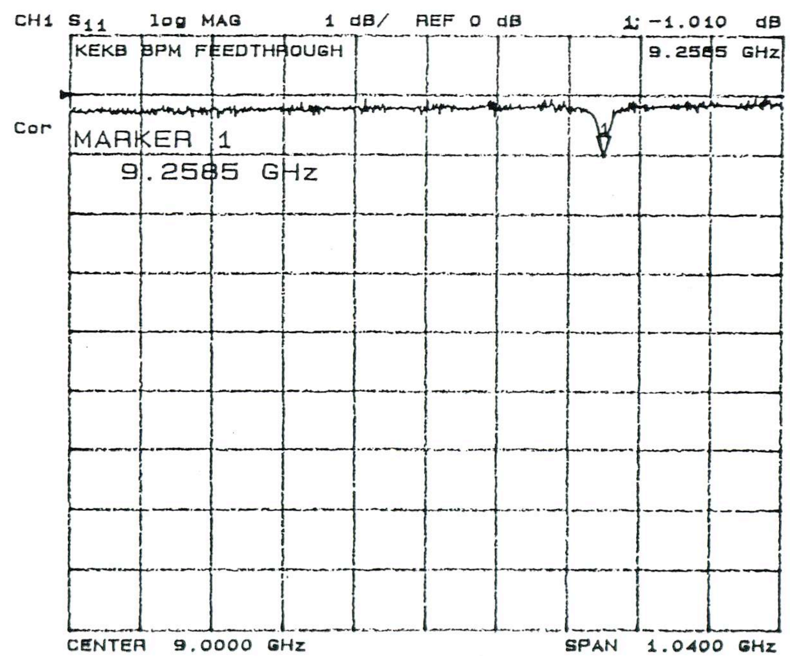
12.11 GHz



xh
20 10.172 ← 10.460
21 10.680
22 11.190 ← 11.364
23 11.698

HER
6001

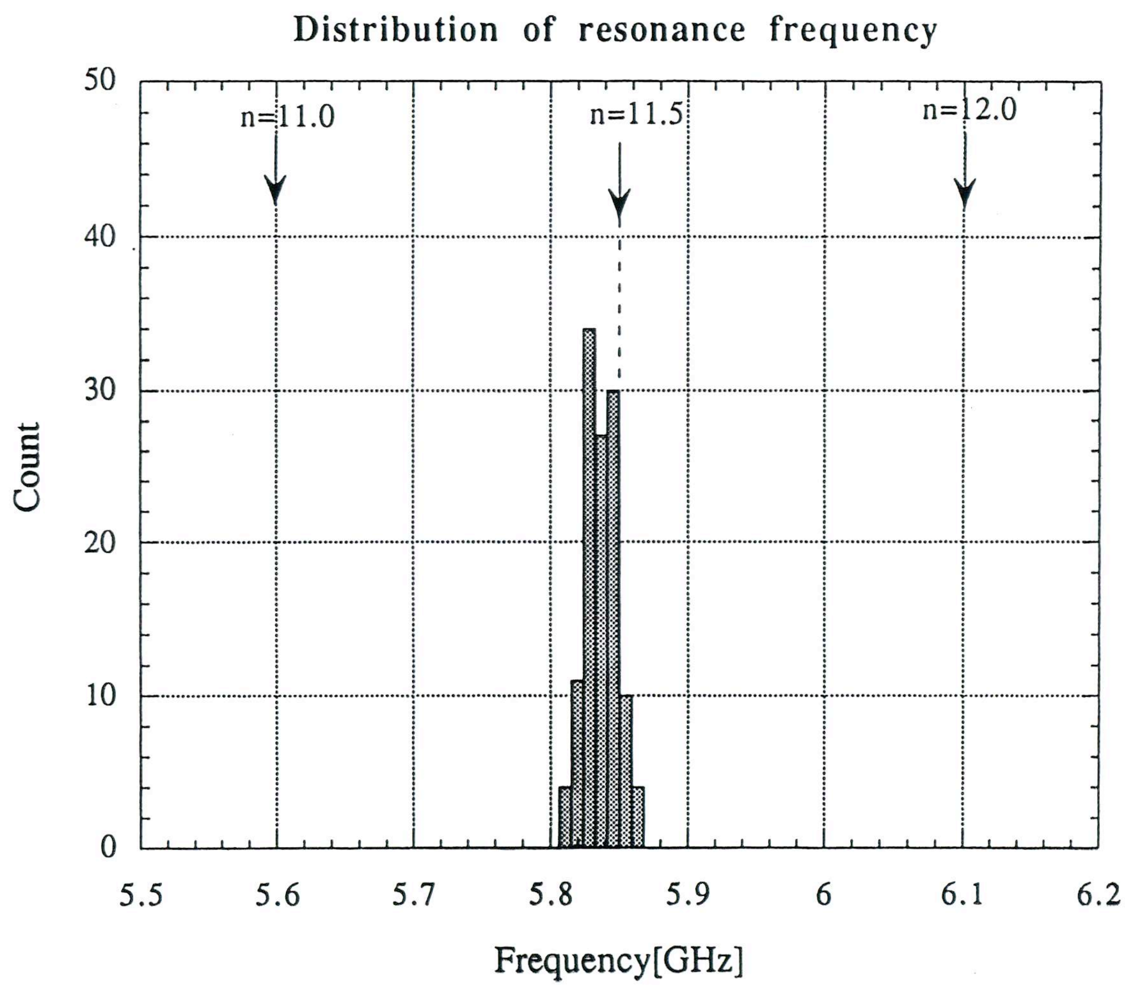




1996.12.12

BPM feedthrough : Resonance freq. in S_{11}

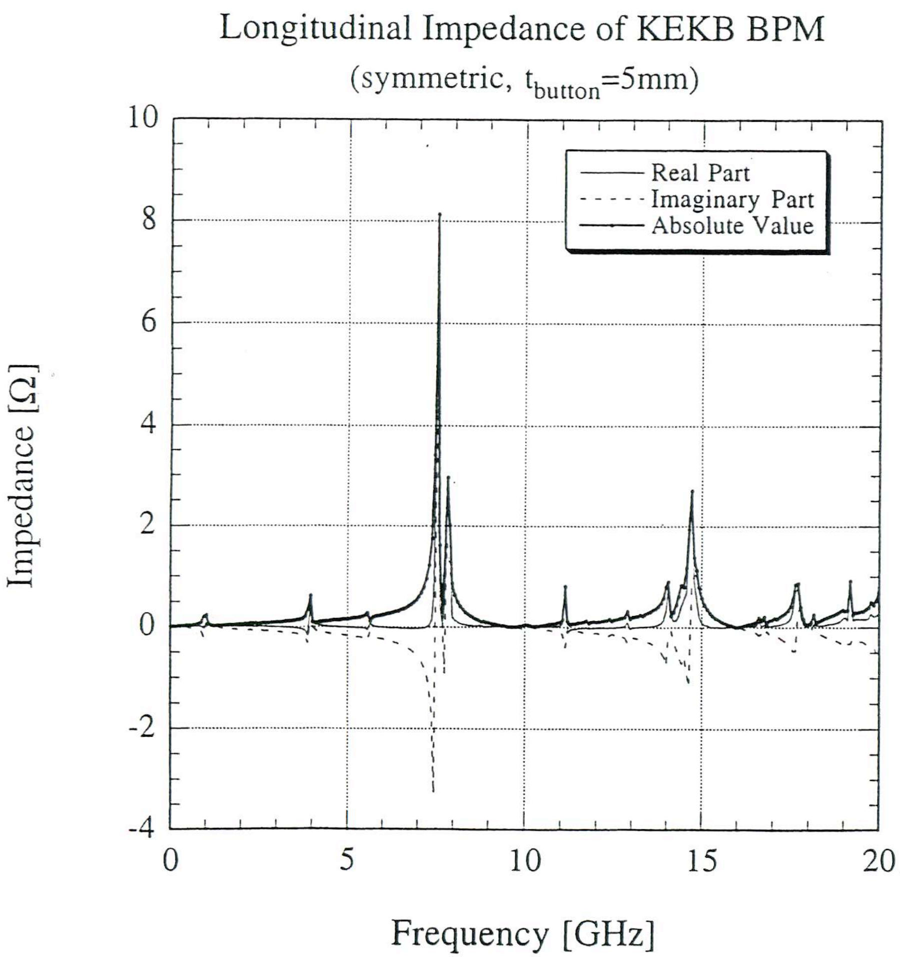
(symmetric electrode)



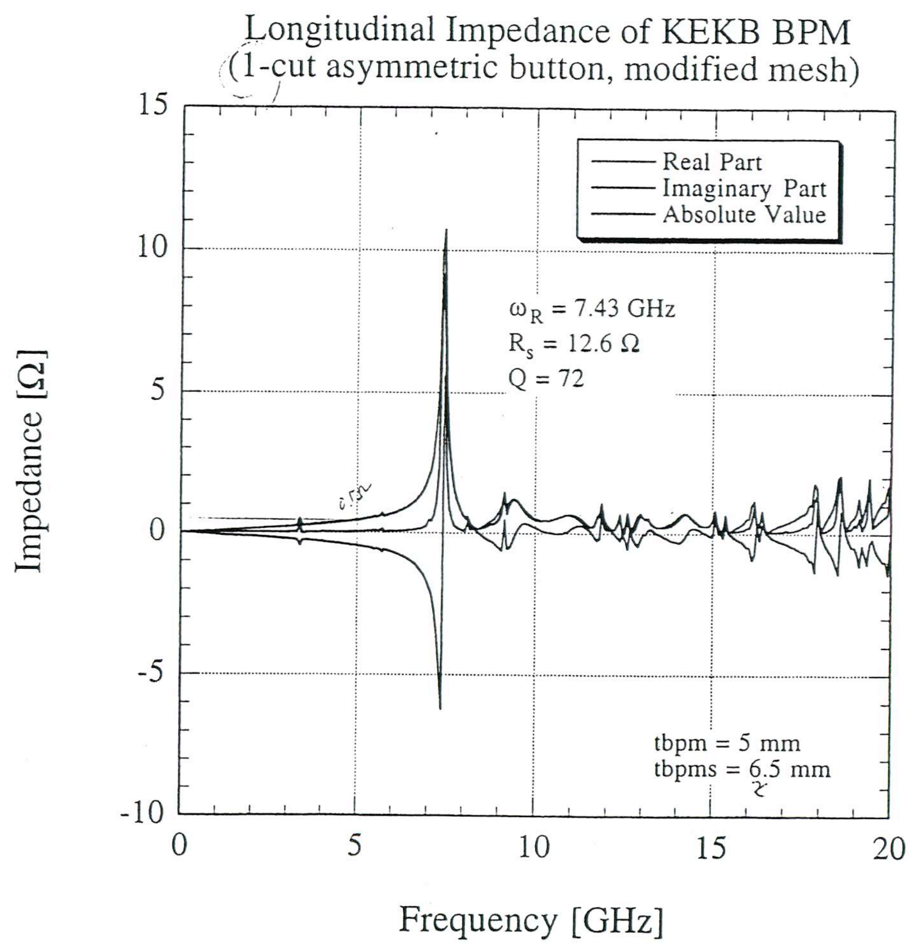
MAFIA

96. 6. 3

図-2



LER



HER

BPM Mapping Data LER (94mmφ)

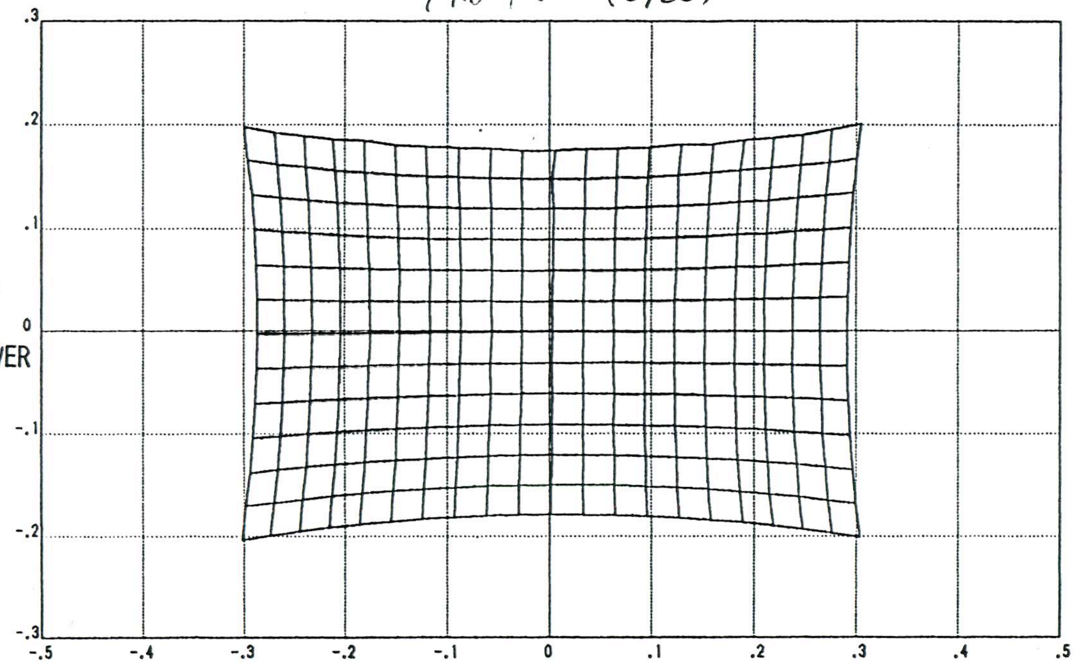
$$\left(\begin{array}{l} -10\,mm \le x \le 10\,mm \\ -6\,mm \le y \le 6\,mm \end{array} \right)$$

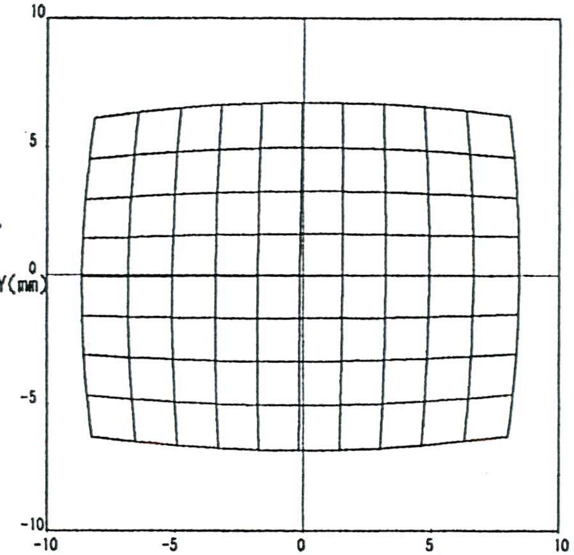
H_0 109.75 H_1 = 219.82

$$X = \frac{(A+D)-(B+C)}{A+B+C+D}$$

$$Y = \frac{(A+B)-(C+D)}{A+B+C+D}$$

A:LER008.dat No 162 (8/20) 24/Sep/1996 16:54



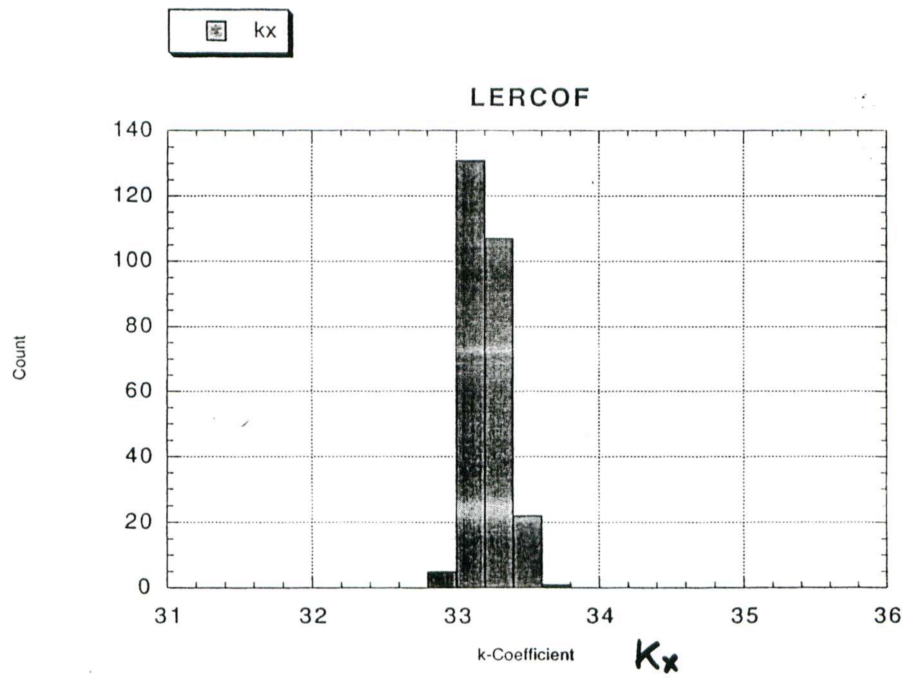


Origin (x0,y0) = (-0.111, 0.036)mm kx= 33.05 , ky= 33.02

f(h,v) =	1	h	v	hh	hv	vv	hhh	hhv	hvv	vvv
fx =	(-0.111)	(33.047)	(-0.251)	(0.131)	(0.300)	(0.217)	(18.906)	(1.100)	(-43.077)	(-0.620)
fy =	(0.036)	(-0.176)	(33.023)	(0.112)	(0.286)	(0.385)	(0.374)	(-44.777)	(0.396)	(23.557)

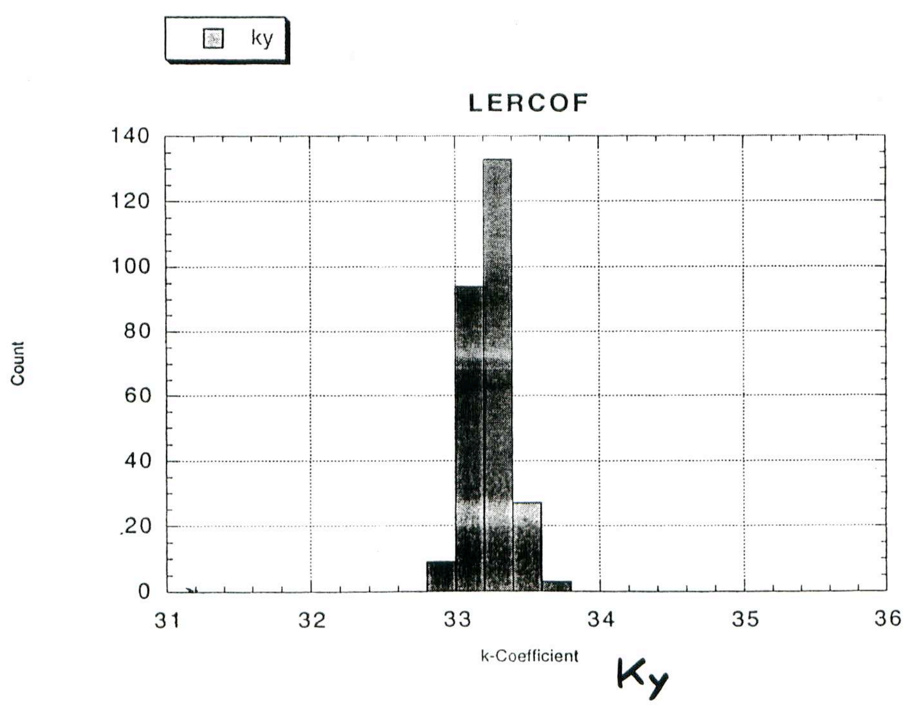
Standard error.....XE=(0.012)mm, YE=(0.009)mm

Distribution of K_x and K_y

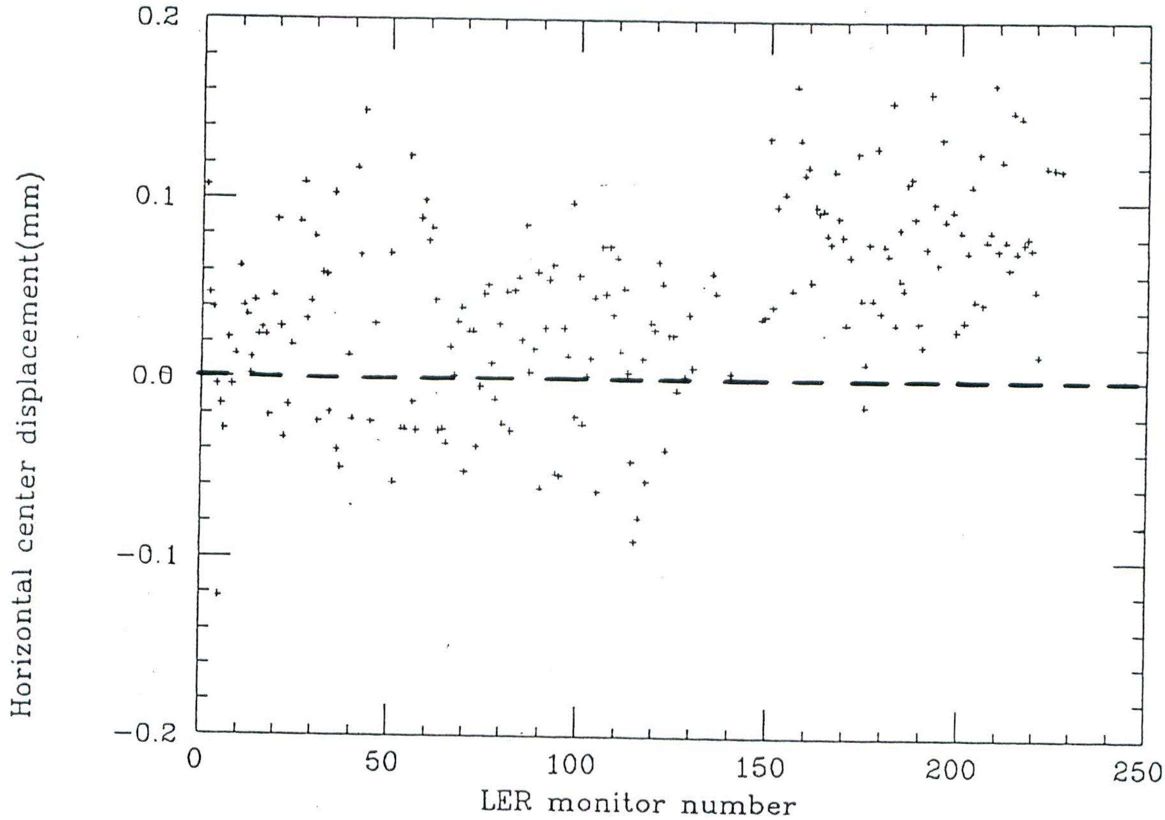


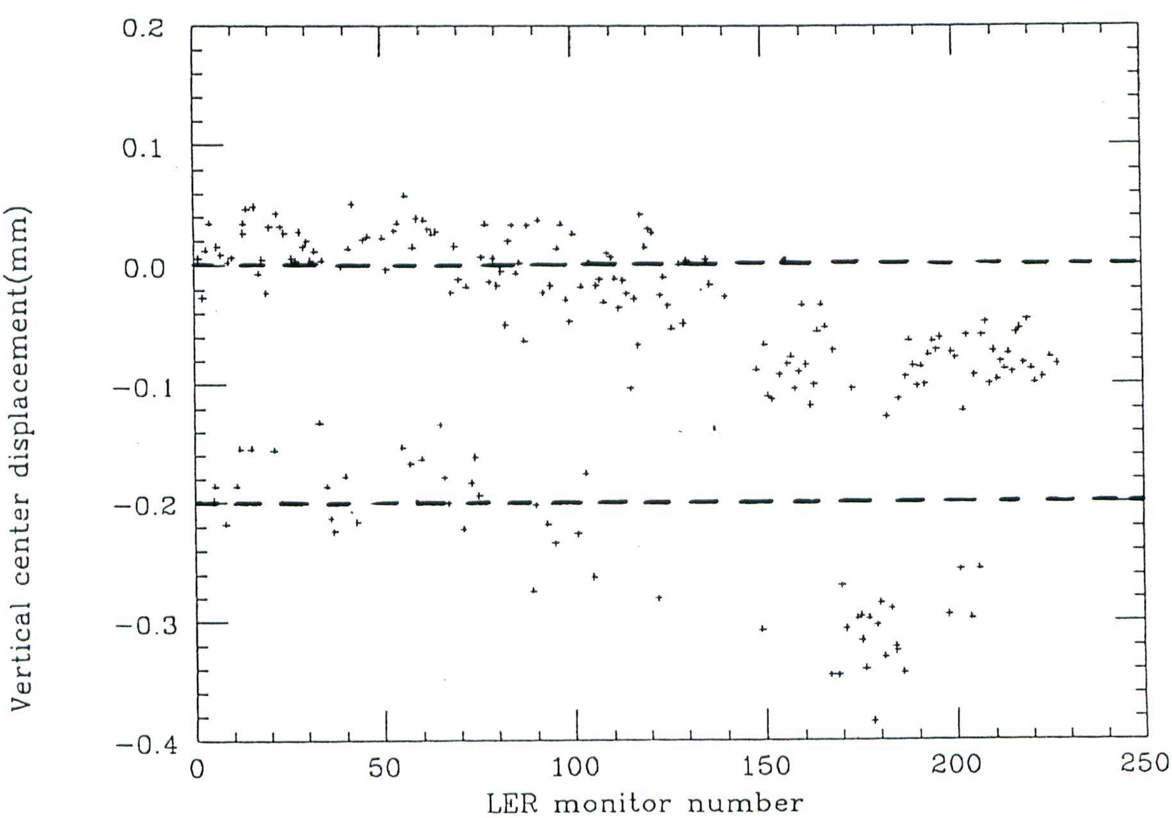
$$\begin{cases} x = K_x X \\ y = K_y Y \end{cases}$$

$(x, y \approx 0)$

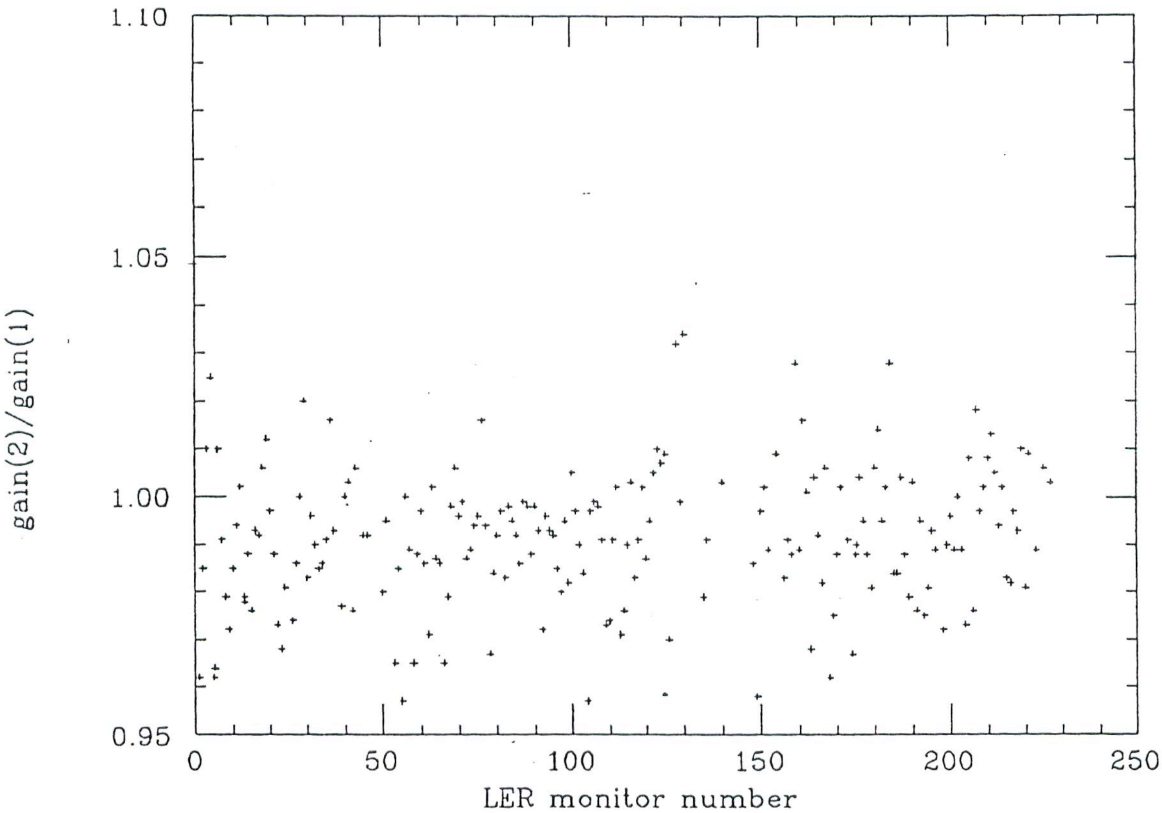


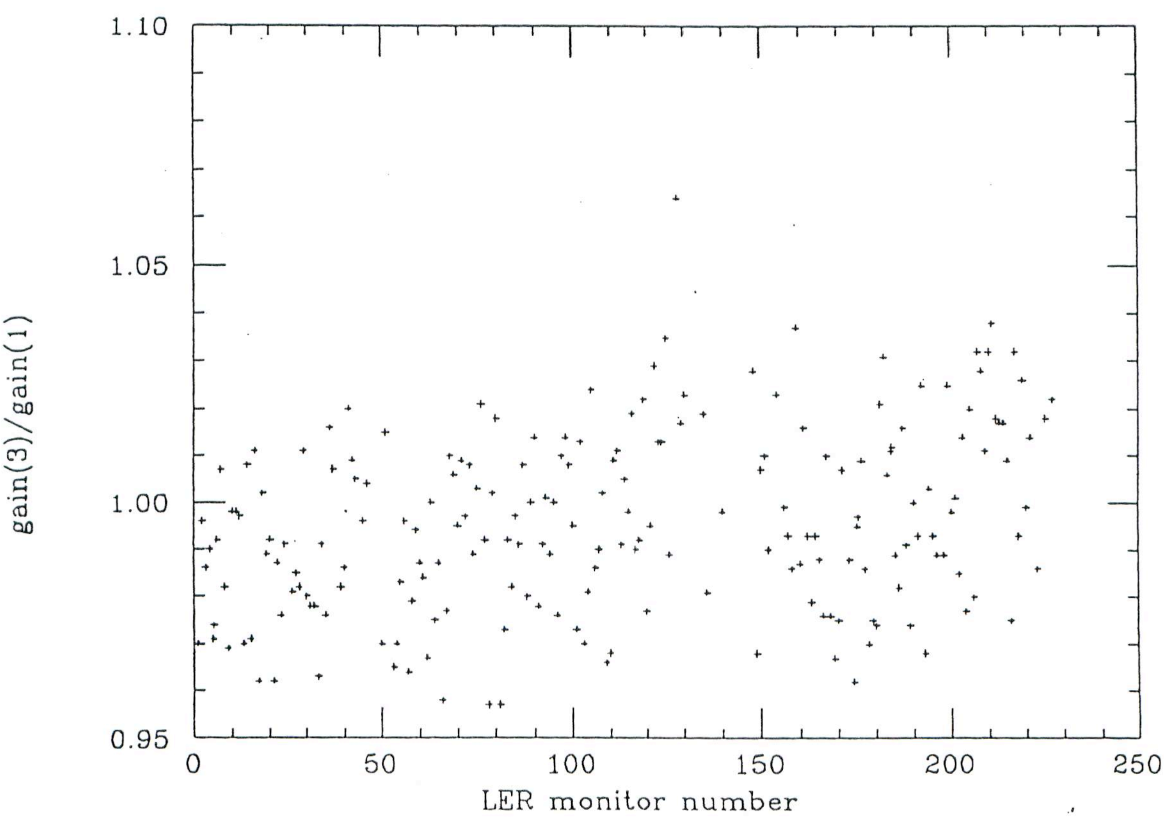
Analysis of Mapping Data by Least Squares Method

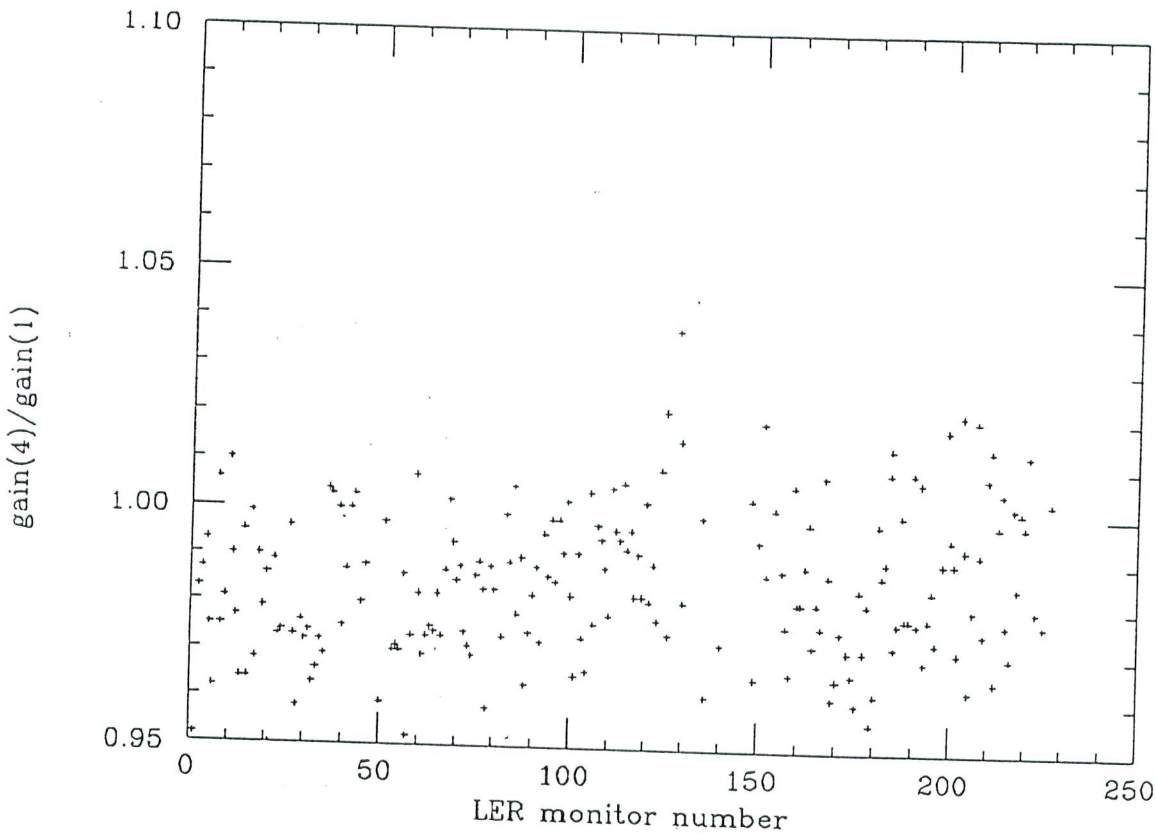




Pickup Gain Balance



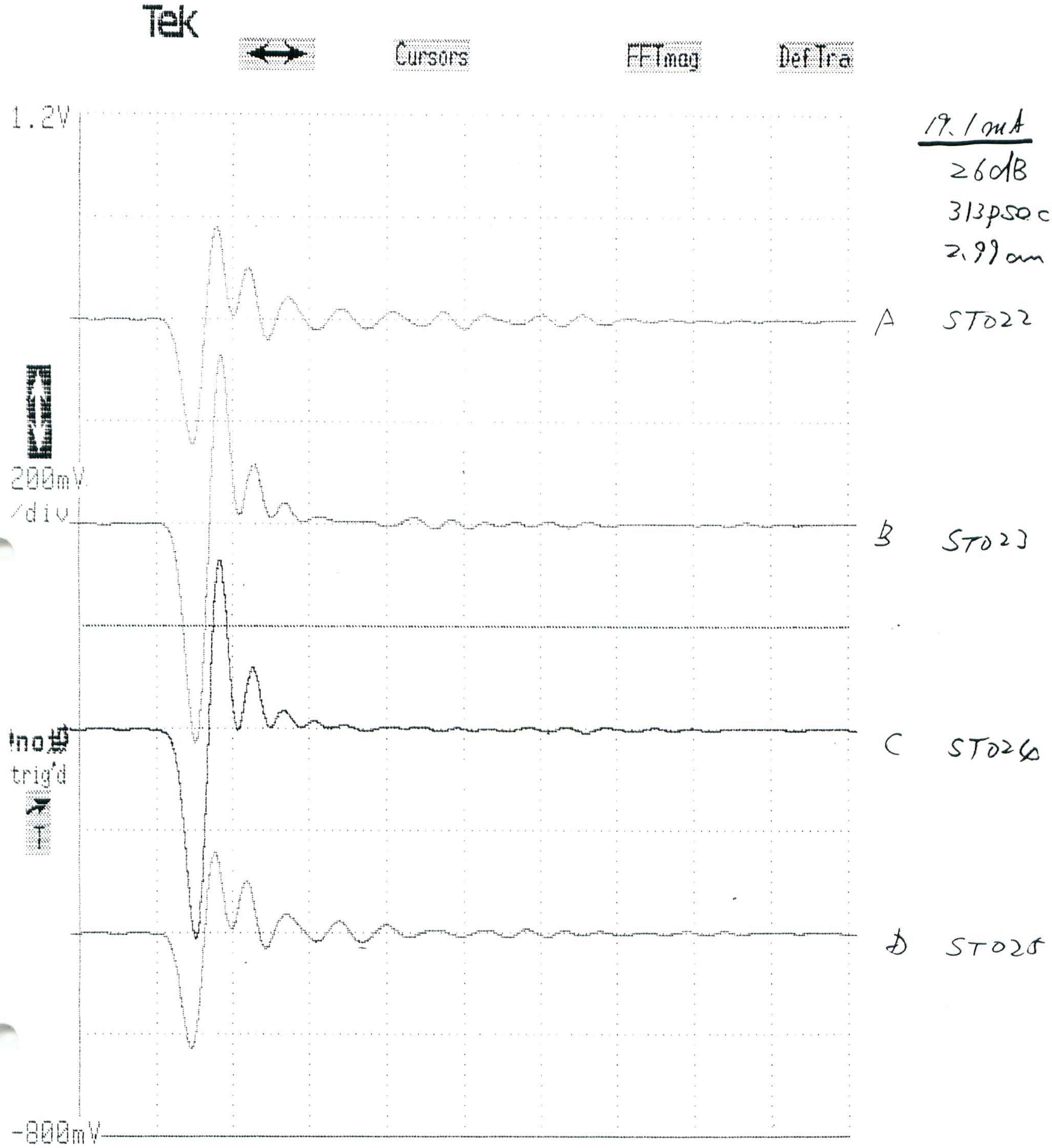




1.10
1.05
1.00
0.95
gain(4)/gain(1)
0
50
100
150
200
250
LER monitor number

11801A DIGITAL SAMPLING OSCILLOSCOPE
date: 6-NOV-96 time: 14:33:53

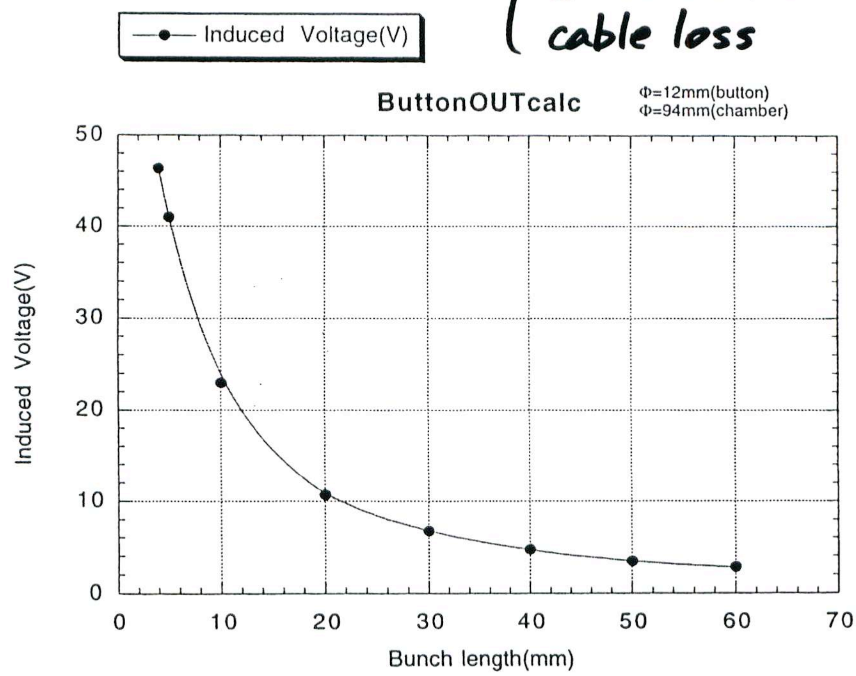
BPM Signal at AR



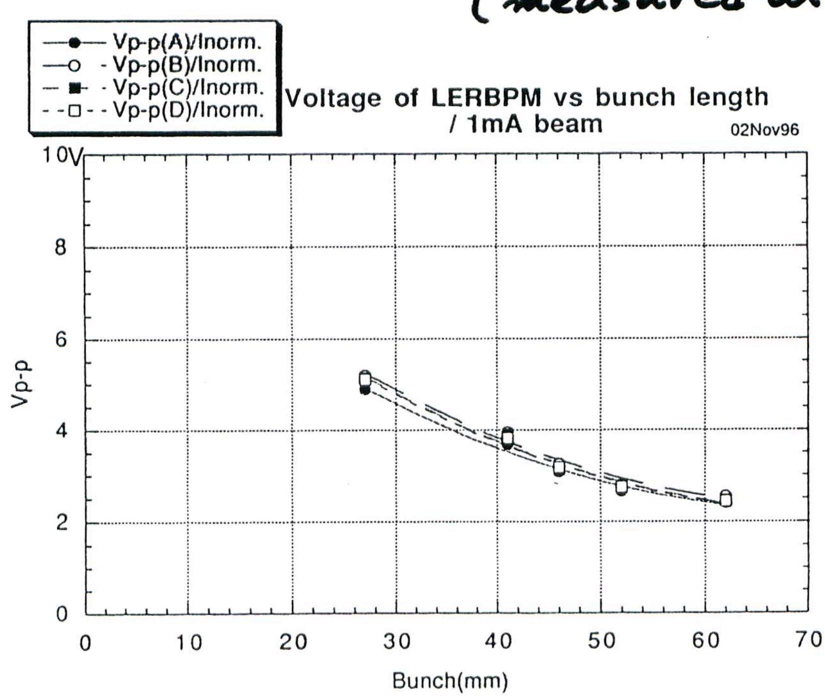
Store Trace	Recall Trace	Clear Trace	Delete Trace	Vert Mag: Tra 200mV/div Vert Pos: Tra 200mV	
Store Setting	Recall Setting	Sequence Settings Off	Delete Setting	Remove/Clr Trace 3 ST024	Chan Sel Calcd Tra

Peak voltage of bunch signal (V_{pp})

(calculation without cable loss)

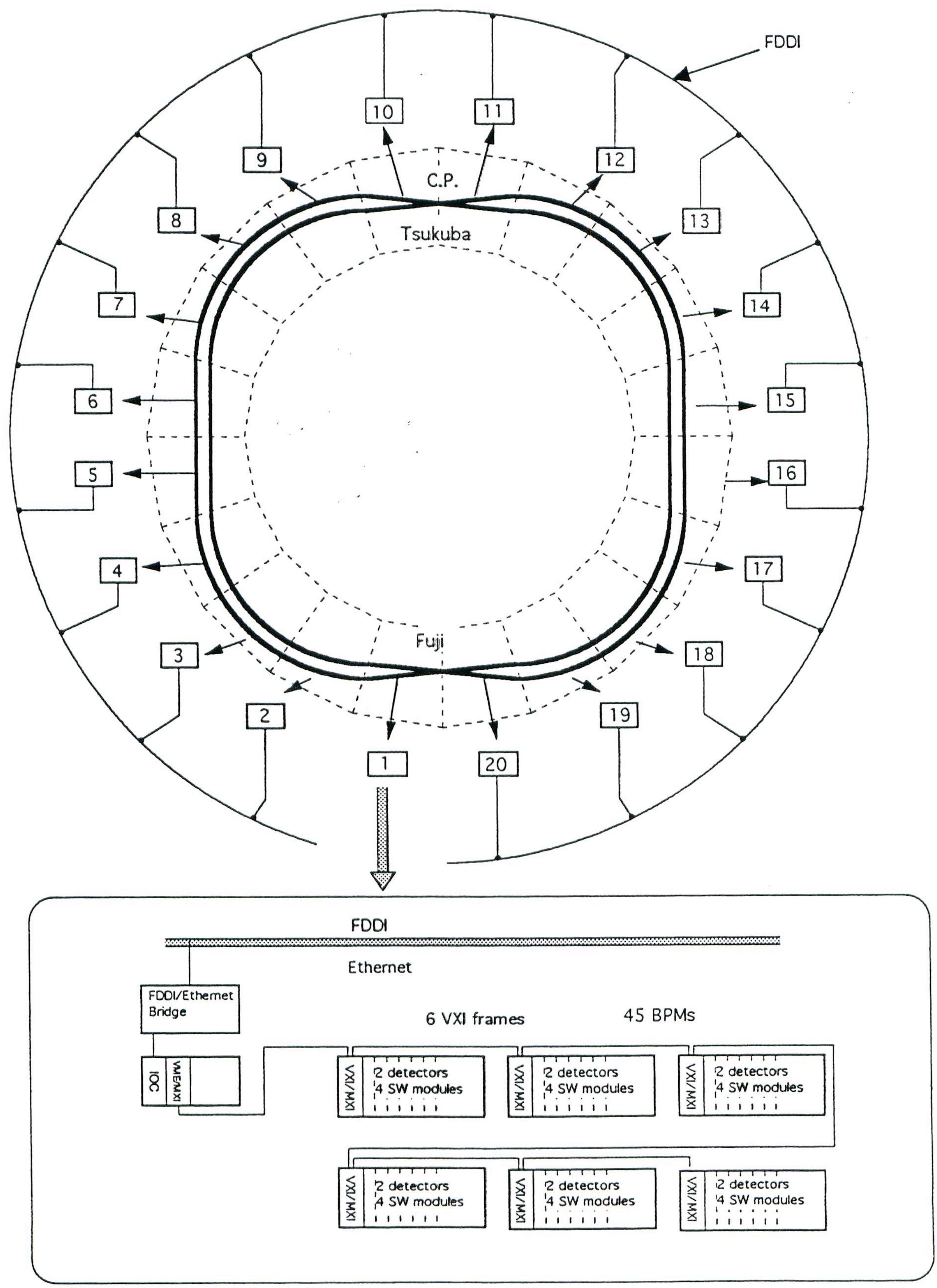


(measured at AR)



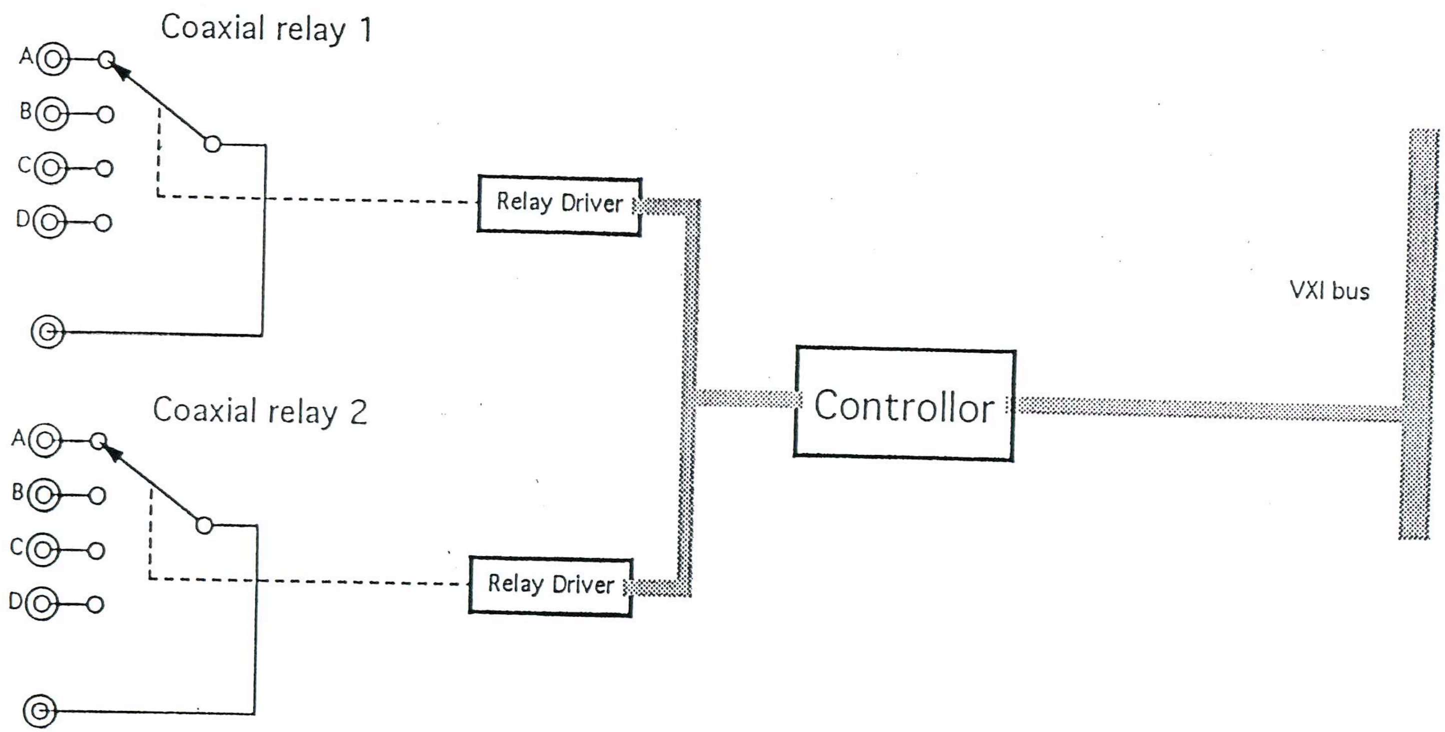
−12dBm @ 1.17GHz for i_b = 570mA

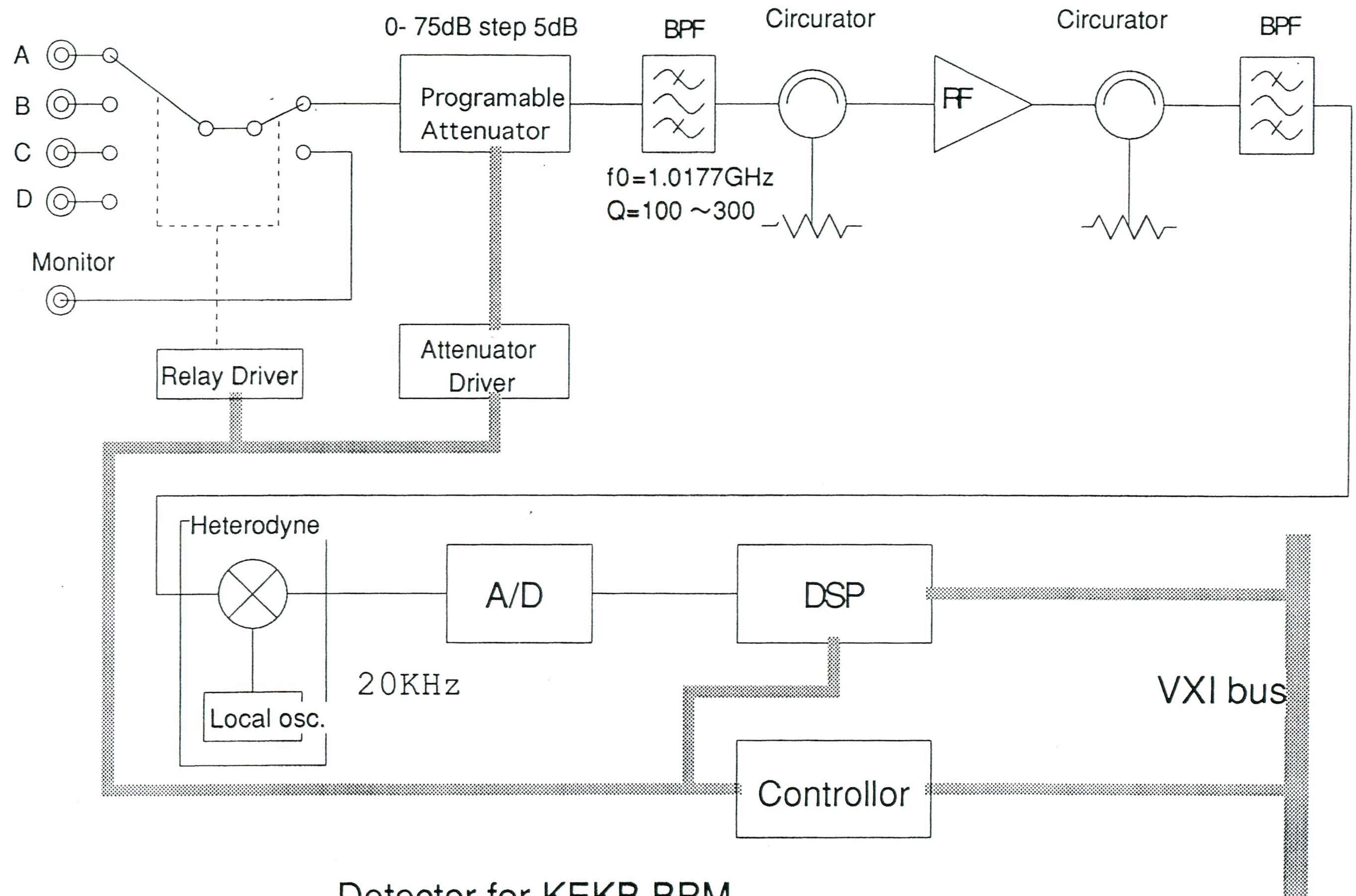
→ KEKB : <u>−44dBm</u> @ 1GHz for i_b = 10mA, Cable = 200m
expected



Beam Position Monitor System for B-Factory

240 Detector circuits

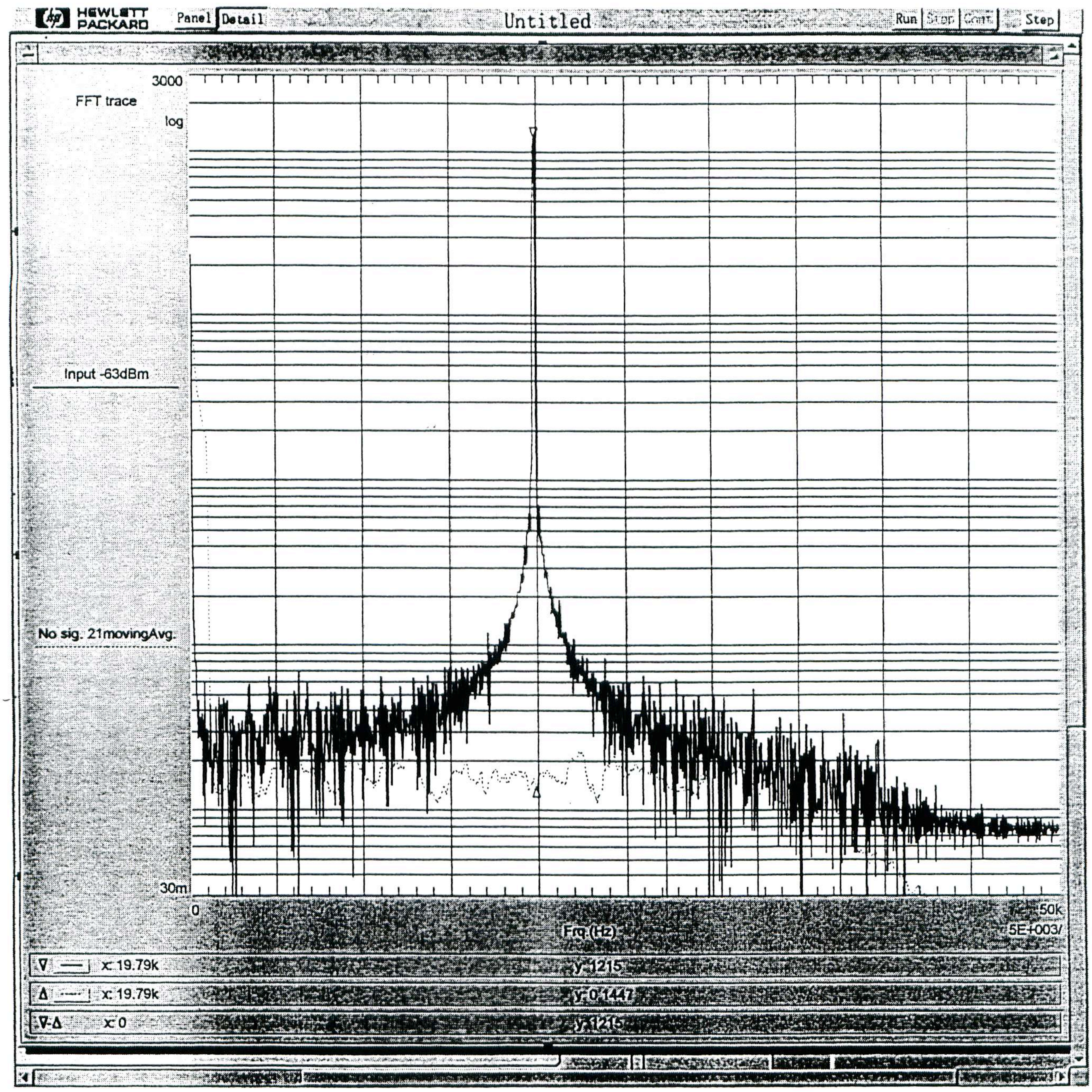

Coaxial relay 1
A
B
C
D
Coaxial relay 2
A
B
C
D
Relay Driver
Relay Driver
Controllor
VXI bus



Detector for KEKB BPM

S/N Check of BPM Frontend

Tue 10/Dec/1996 17:08:46 PST

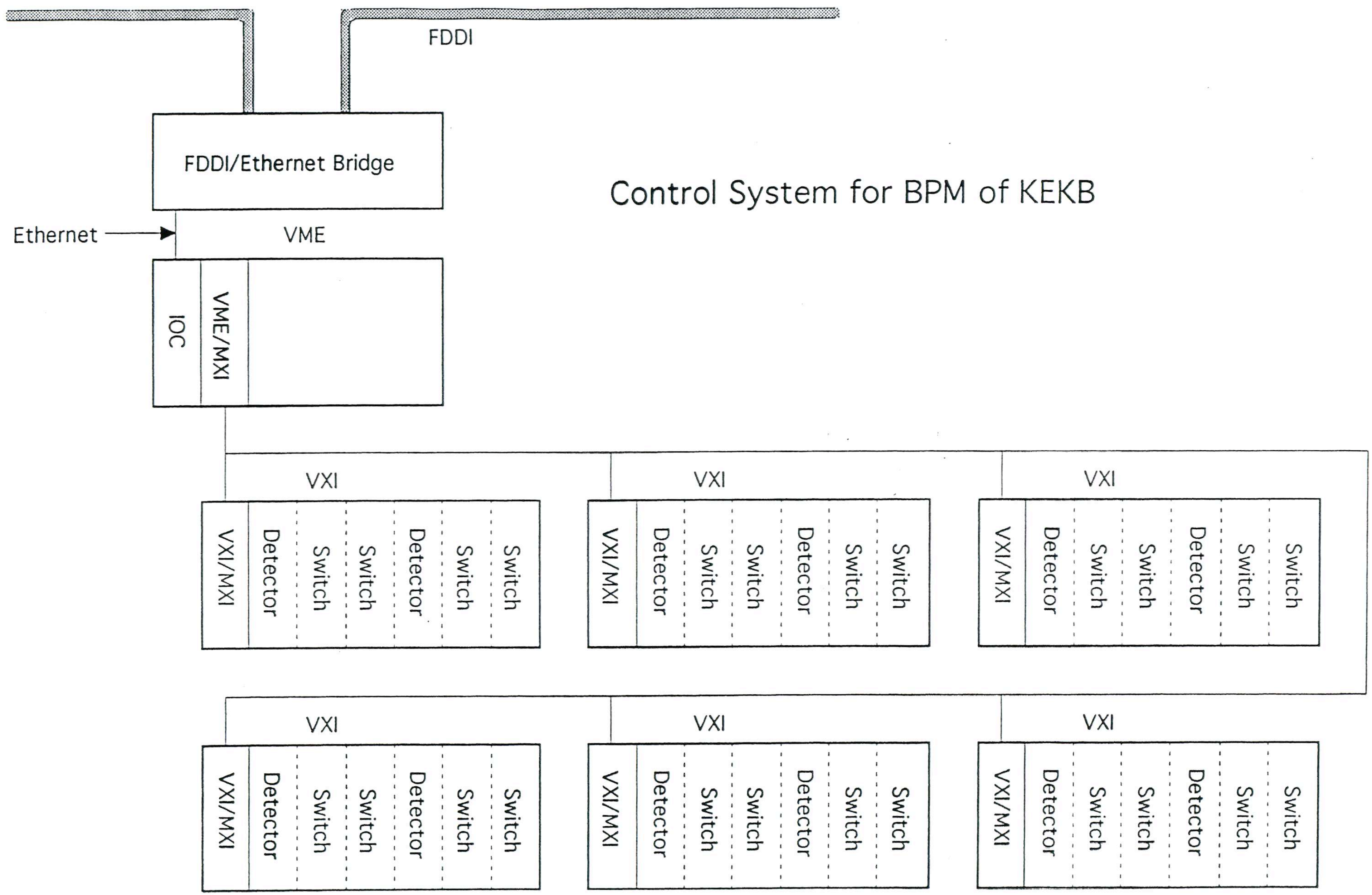


FFT 2048 points
av. 1
processing time ~ 40ms

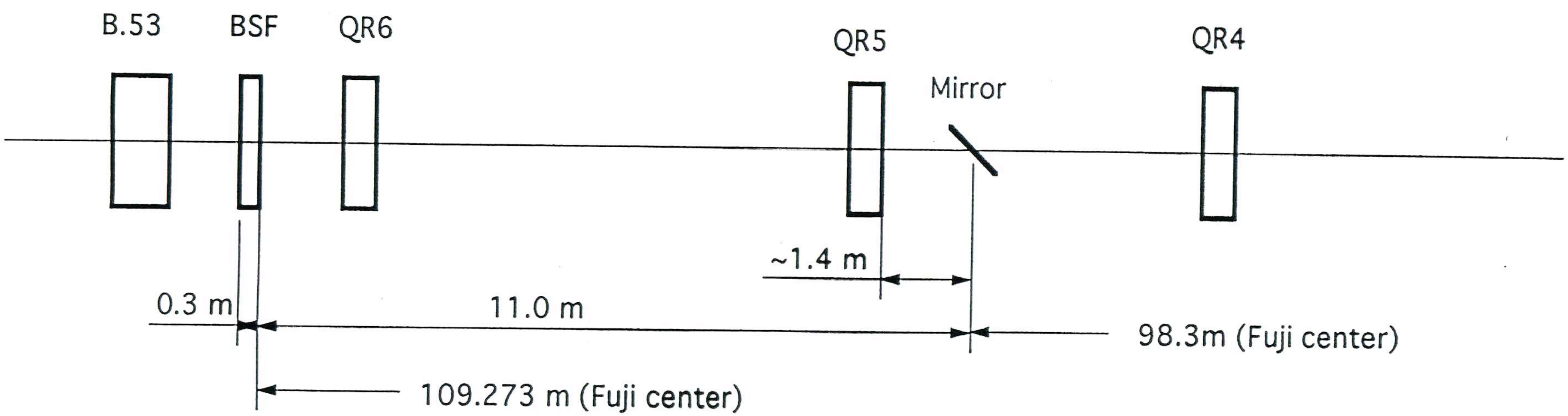
⇩

S/N ~ 92dB
for 400ms processing time (av. = 10).
(→ need factor 2 reduction !)

Control System for BPM of KEKB



LER SOR Monitor (Fuji Straight Section)



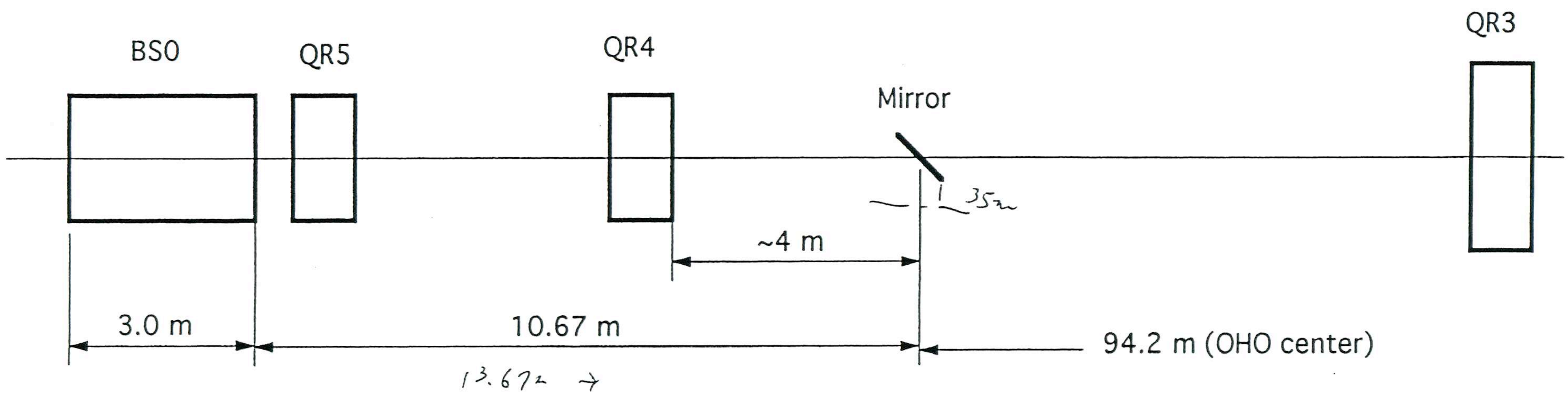
BSF:
$\rho = 60$ m
$\theta = 5$ mrad
P = 91.6 W/mrad
@3.5 GeV, 2.6 A

Dec. 05, 1995 K. Satoh

LERSOR95Dec05.cad

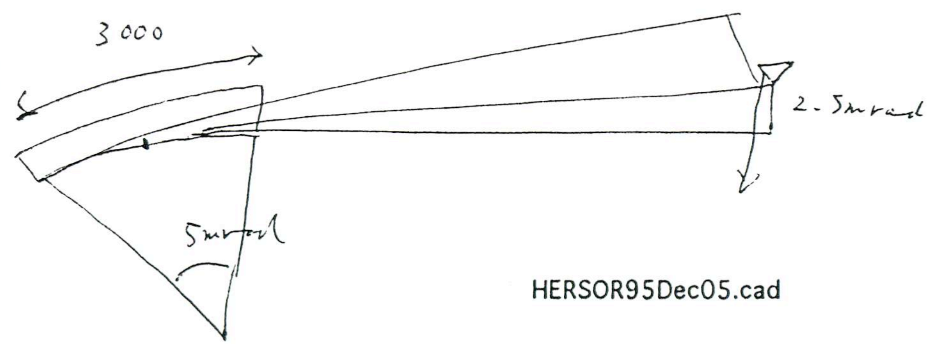
HER SOR Monitor

Oho Straight section



Dec05, 1995 K. Satoh

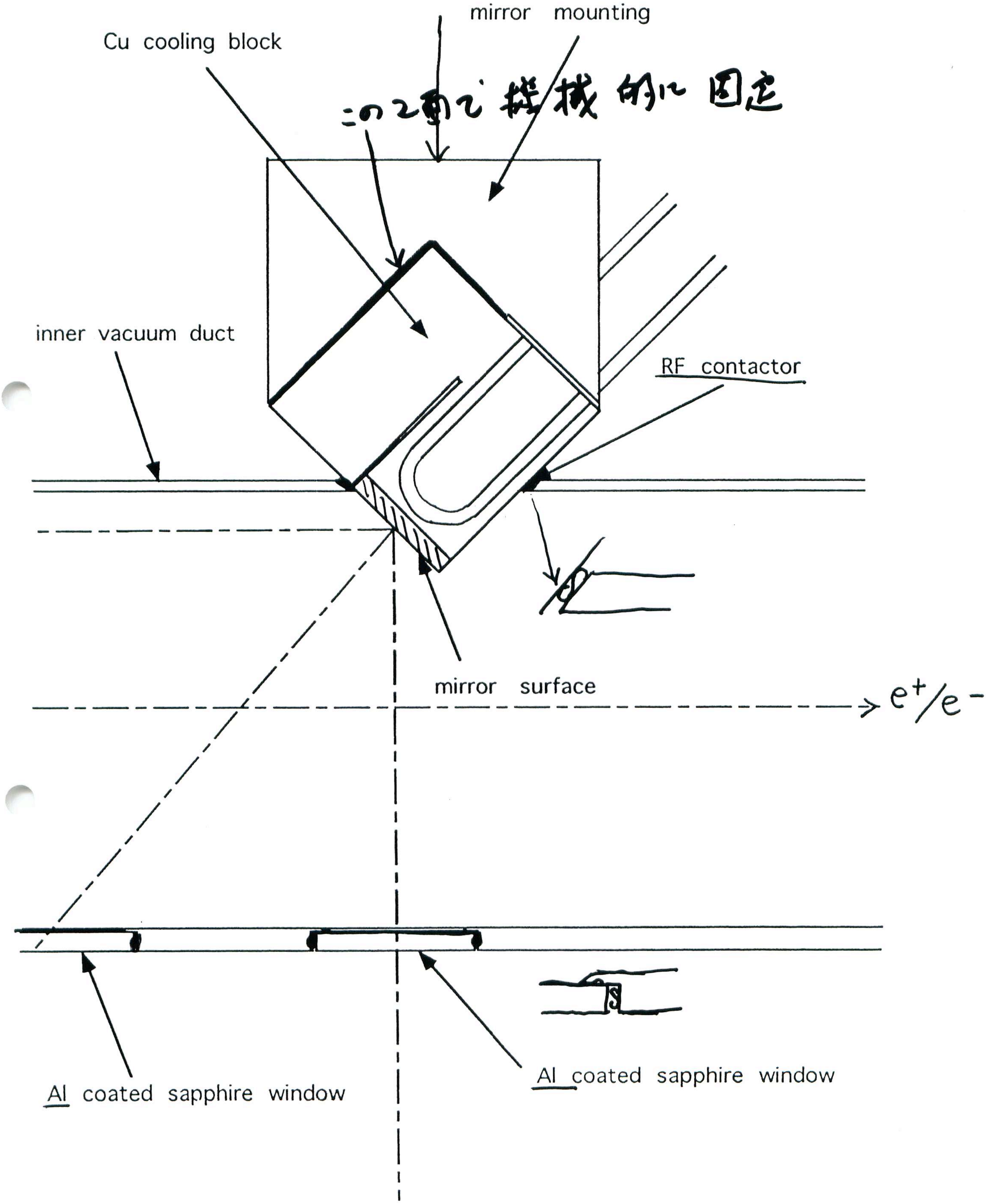
BSO:
ρ = 600 m
θ = 5 mrad
P = 105.8 W/mrad
@ 8 Gev, 1.1 A

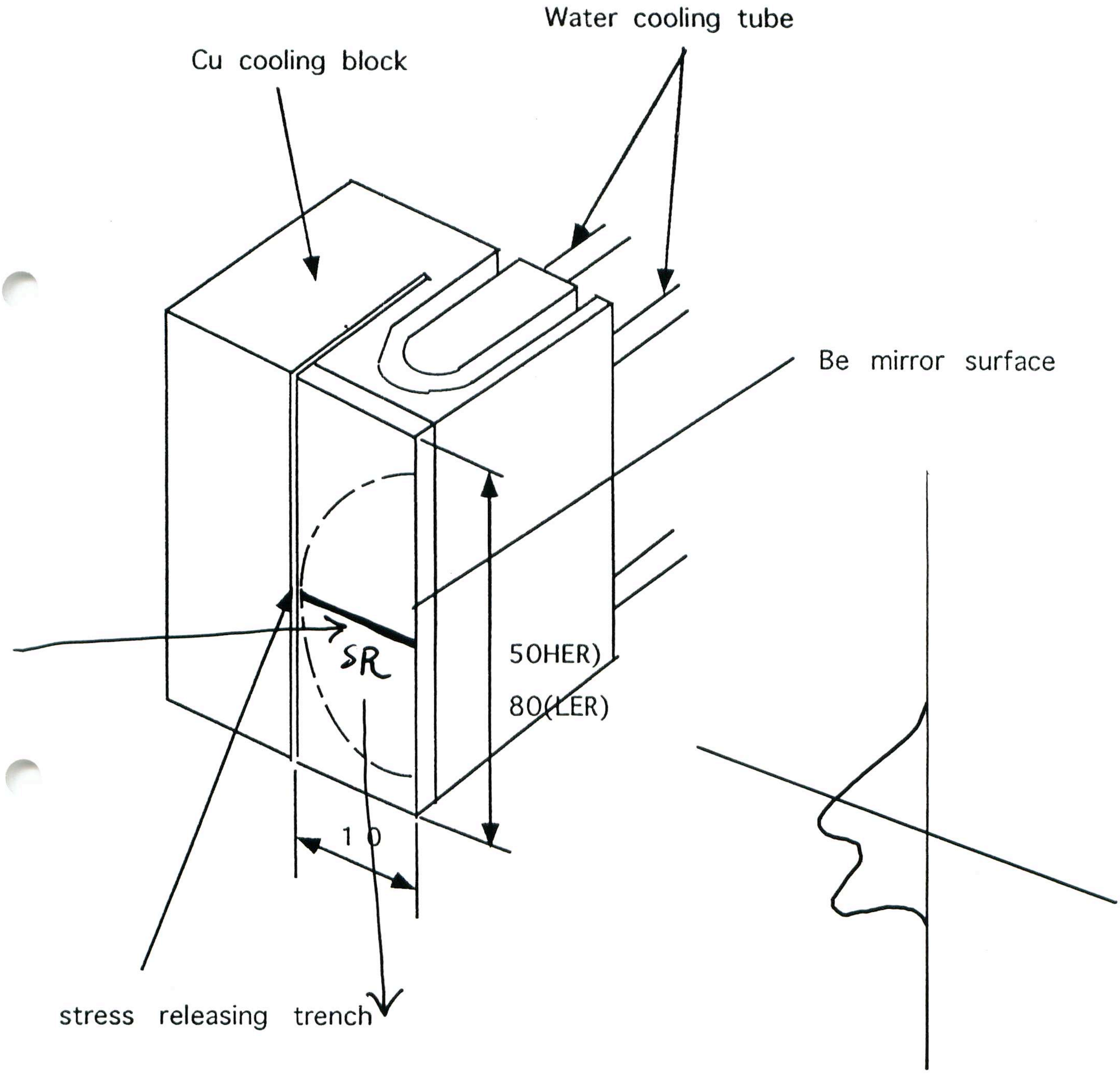


HERSOR95Dec05.cad

SR Extraction Mirror

mirrorをダクトにソフトタッチするため
一定のトルクで押しつける





Water cooling tube
Cu cooling block
Be mirror surface
SR
50HER)
80(LER)
1 0
stress releasing trench

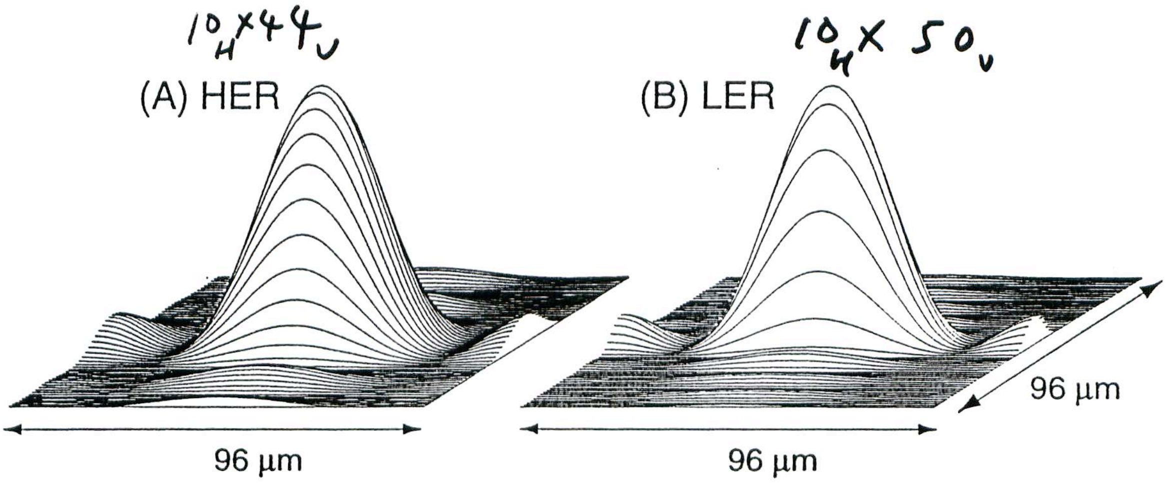


Figure 11.15: The Point Spread Function (PSF) of the focusing system. The side

	LER		HER	
	σ_x	σ_y	σ_x	σ_y
Original	472 μm	69 μm	650 μm	120 μm
With Aberration	472 μm	69 μm	650 μm	120 μm
With transverse diffraction	506 μm	102 μm	675 μm	158 μm
With longitudinal diffraction	~~427~~ 472 μm	69 μm	655 μm	120 μm
Total	507 μm	102 μm	680 μm	158 μm

Table 11.2: Expected values of observed beam sizes which include contributions from effects of aberrations and diffraction.

11.3 Laser Wire Monitors

In addition to the beam profile monitor based on imaged synchrotron light, the use of so-called laser wires is under consideration for better resolution with an ability to measure individual bunches.

The principle of the measurement is illustrated in Figure 11.17. A narrow laser beam ("laserwire") meets a beam bunch perpendicularly, creating a number of Compton-scattered photons. The population of scattered photons is proportional to the overlap area of the laserwire and the particle beam. Therefore, by scanning the laser light horizontally or vertically, and by measuring the flux of Compton-scattered photons, one-dimensional particle distribution of the bunch is obtained.

Discussions in this section assumes that the laserwire is placed at the end of a straight section. However, since the laserwire technique can offer a very high resolution, it may be also used at the collision point. The practical application depends on the availability of an adequate room for measurement ports.

PF

deconvolution with PSF

beam, the beam profile was measured at the stored current of 1mA. The focus of the system was carefully adjusted at the balanced astigmatism point. A CCD TM7/4915 and image processor LBA100A of Spiricon company was used to observe the beam image.

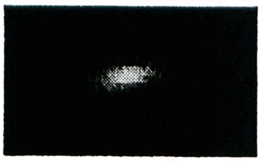


Fig.4 A beam image of the Photon Factory. The ring energy is 1GeV and the beam current is 1mA.

The rms beam sizes from the beam image are 96.5 µm in the vertical and 280µm in the horizontal. The raw image of the beam as shown in Fig.4 is given by a convolution of the PSF (Fig.3) and the geometrical image. Considering the conjugation ratio of 0.148, the rms width of the PSF is almost same size as in the beam size. Therefore, to observe the original beam size, it is necessary to deconvolute the raw image by the PSF. Recently, deconvolution technique (restoration of the image) is currently used in the astronomical observation[3]. In the present time, a Wiener inverse filter [4] was applied. In the spatial frequency domain, the convolution integral is represented by

$$G(u,v)=H(u,v)F(u,v) + N(u,v) \qquad (1)$$

where G denotes a two dimensional Fourier transform of blurred image, H is thought of as a inverse filter (two dimensional Fourier transform of PSF) , F is a two dimensional Fourier transform of original image, and N is as a two dimensional Fourier transform of noise term in the image. The Wiener inverse filter Hw in equation (1) is given by

$$H_w(u,v) = \frac{H^*(u,v)}{|H(u,v)|^2 + \dfrac{\phi_n(u,v)}{\phi_f(u,v)}} \qquad (2)$$

where the asterix indicates the complex conjugate of H. ϕ_n is the power spectra of the noise and ϕ_f is the power spectra of the signal. In the present time, the raw image was taken at the balances astigmatism point, we neglect asymmetric components of the obtained PSF as shown in Fig.3, and use a Gaussian approximation as the PSF. To perform the deconvolution process, we use the computer code Hidden Image which has the maximum entropy deconvolution method. A result of the deconvolution is shown in Fig.5. The rms beam sizes from this beam profile are 49.2 µm in the vertical and 206µm in the horizontal. By the use of measured values of β function, The emittance at 1GeV operation of the ring are 0.13 nmrad in the vertical and 22 nmrad in the horizontal.

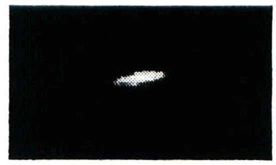


Fig. 5 Beam profile after deconvolution process, scale is same as in Fig.4.

6 CONCLUSIONS

A beam profile monitor for the high brilliant configuration of the Photon Factory was designed and constructed. A Be-mirror was applied as a extraction mirror of The visible SR beam. We have analyzed aberration of the focusing system including the deformation of the Be-mirror in the Fourier optical manner, and obtained a PSF at balanced astigmatism point. We measured a beam profile of the Photon Factory with a ring energy of 1GeV at the balanced astigmatism point of the focusing system. By the use of obtained PSF and beam profile image, we applied the image restoration method. After the image restoration process, we obtained a beam emittances 0.13 nmrad in the vertical and 22 nmrad in the the horizontal. We conclude; 1. the present system has a enough performance to measure the small enittamce in the high brilliant configuration of the Photon Factory; 2. the image restoration technique with measured PSF as used in the astronomical observation is very useful tool not only to eliminate the aberration of the focusing system but also obtaining the geometrical image.

7 ACKNOWLEDGMENTS

Authors wish to thank to Professors Dr.H. Kobayakawa and Dr. H. Maezawa (Photon Factory, KEK)to their encourage to make the system at the beamline 27. They are also grateful to Mr.Asaoka (Photon Factory,KEK) for his help in the design and installation of the Be-mirror in the beamline. Authors also thanks to Mr. Nogami(Photon Factory ,KEK) and Mr. Takeuchi (Tsukuba University) for their help in image processing.

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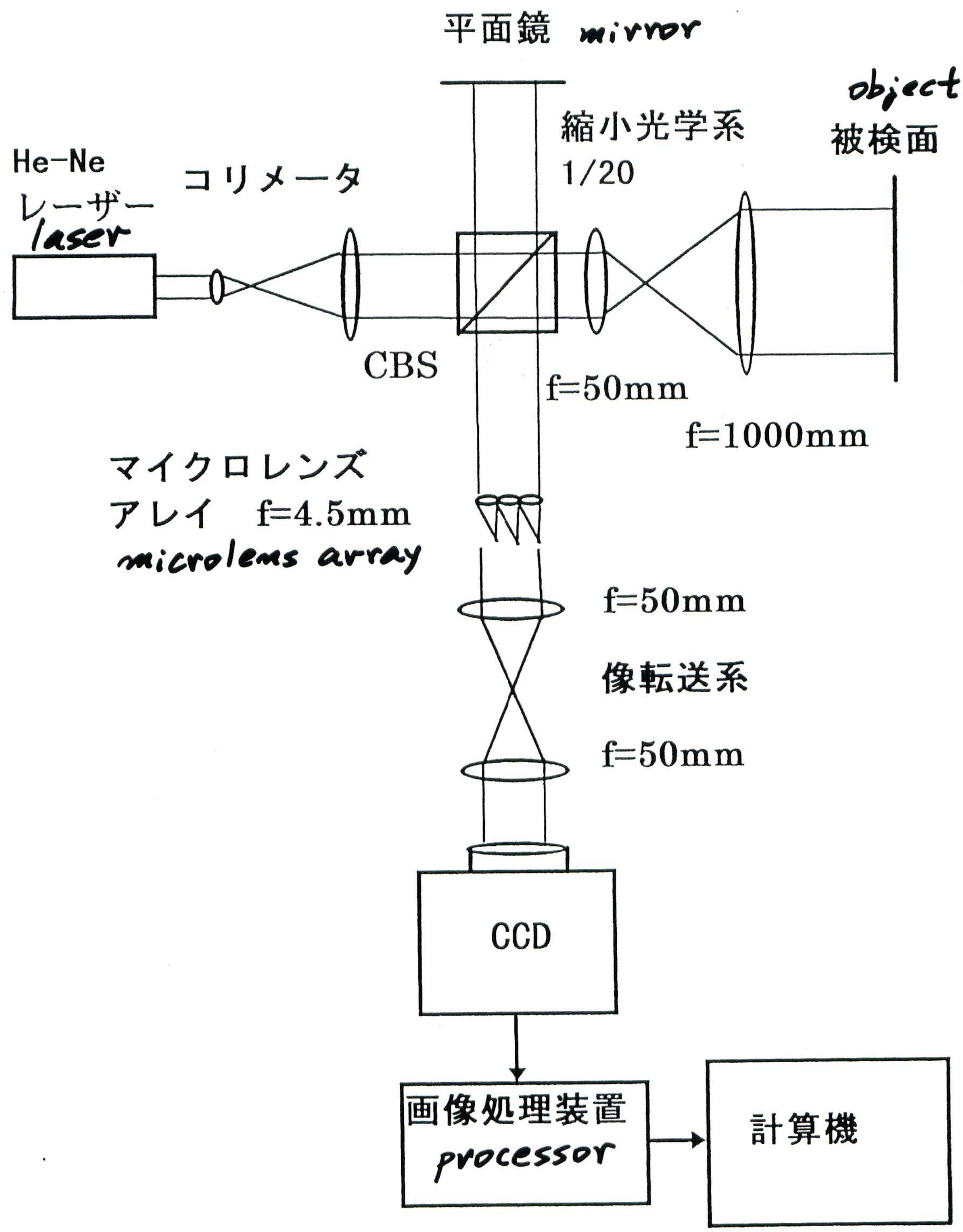
[2] M.Born and E. Wolf,"Principles of Optics, P459 Pergamon press. (1980).

[3] N.Weir,"Applications of Maximum Entropy Techniques to HST Data", Proc. the ESO/STECF Data analysis work shop, (1991).

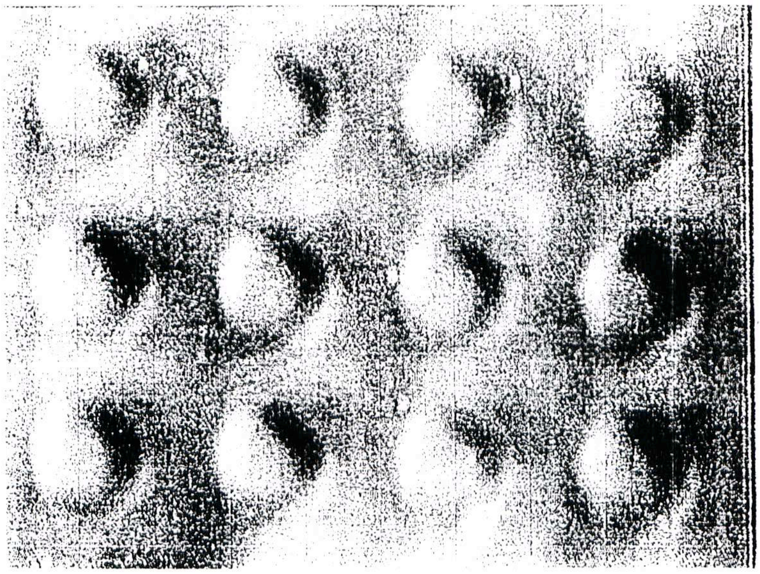
[4] A.Rosenfeld and A.C.Kak,"Digital Picture Processing", Academic Press, Inc. (1976).

Shack Hartmann センサー
sensor



microlens array

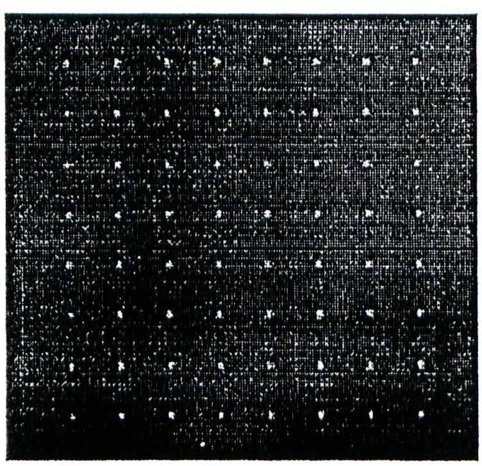
マルチレンズアレイ



焦点距離	4.5mm	*f*
レンズ径	150μm	*lens diam.*
ピッチ	250μm	*lens pitch*
素子数	8×8	*# of lens*

spot-pattern

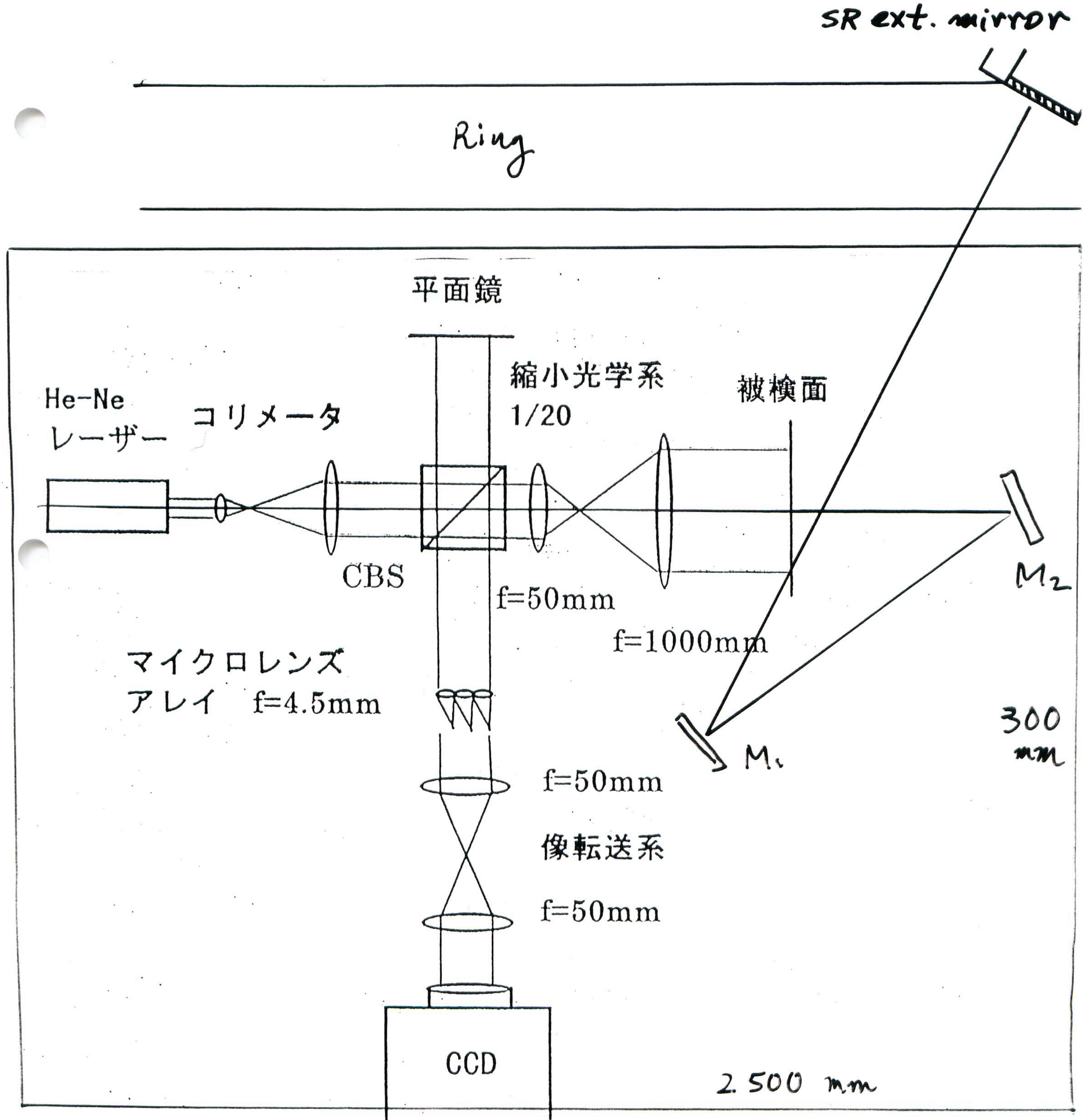
マルチレンズアレイの集光パターン



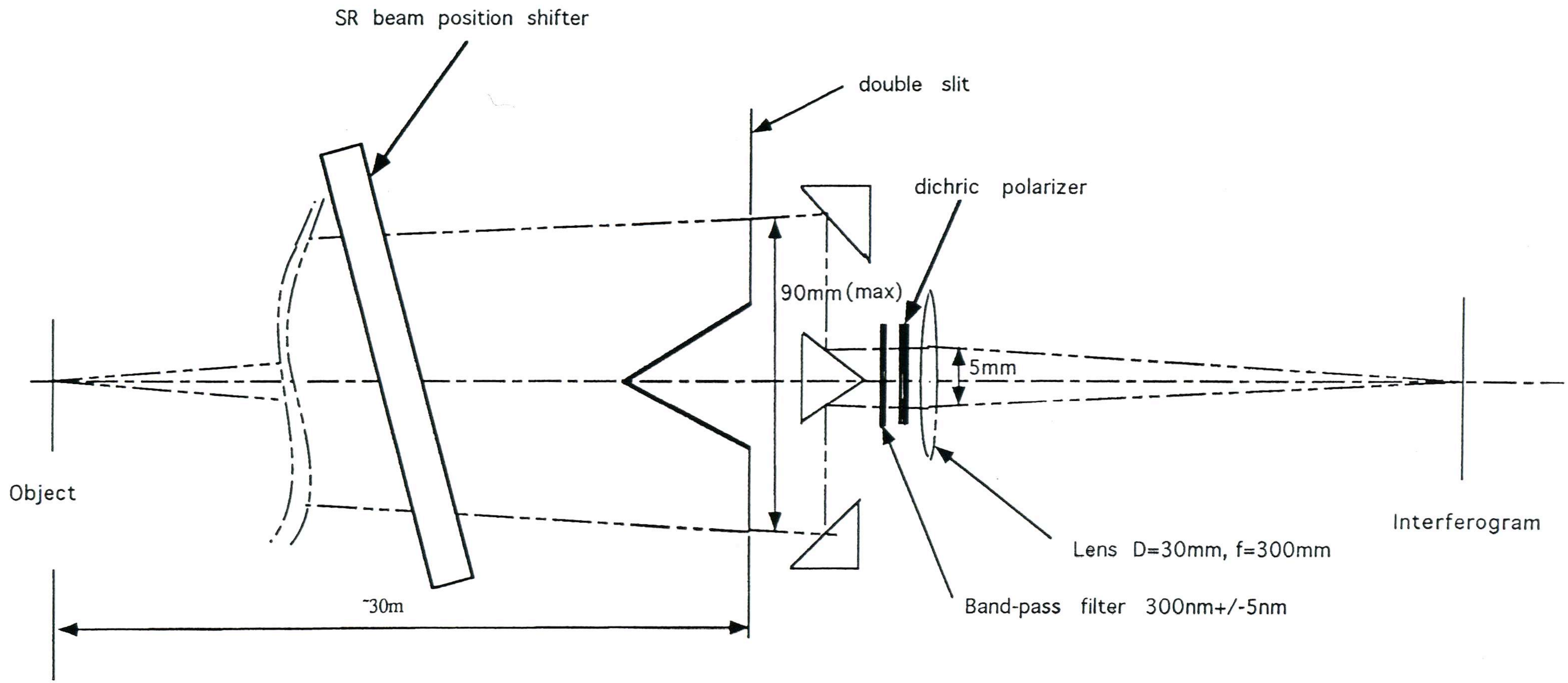
スポット径　30μm　*spot*

Shack - Hartmann センサーの 実際の 配置

Configuration of the Shack-Hartmann Sensor in the Ring



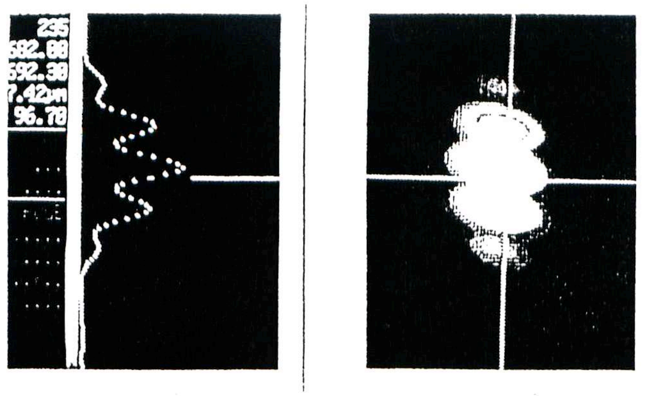
Beam size 測定用 偏光干渉計



Two beam interferometer for B factory

PFでの実験

Double-slit interferometer at PF

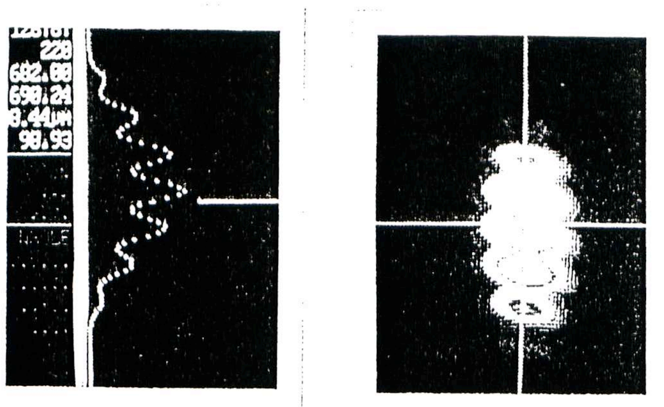


6mm 700nm No.11

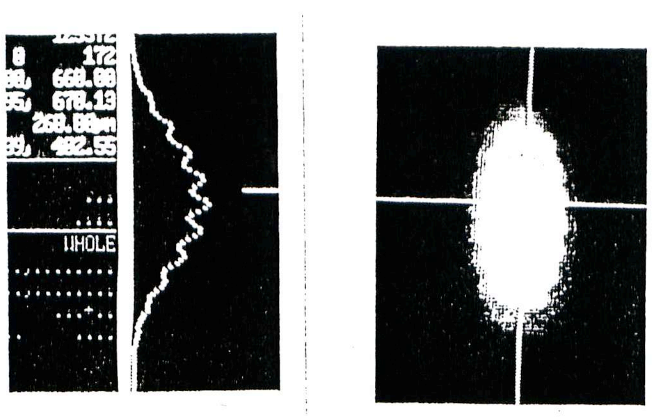
$D = 6\,mm$

$\lambda = 700\,nm$

$\Delta\lambda = 10\,nm$

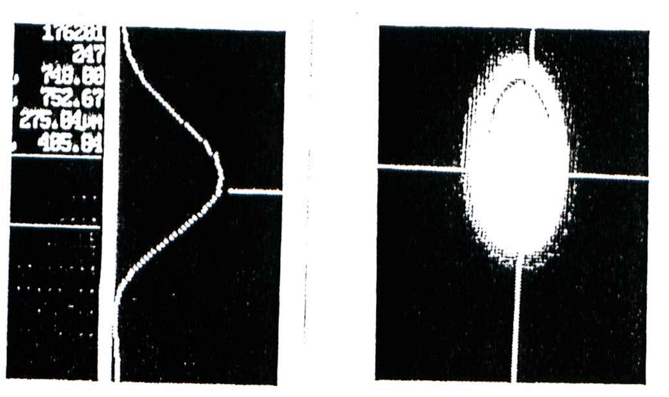


$D = 7\,mm$



10mm No.5 700nm

$D = 10\,mm$



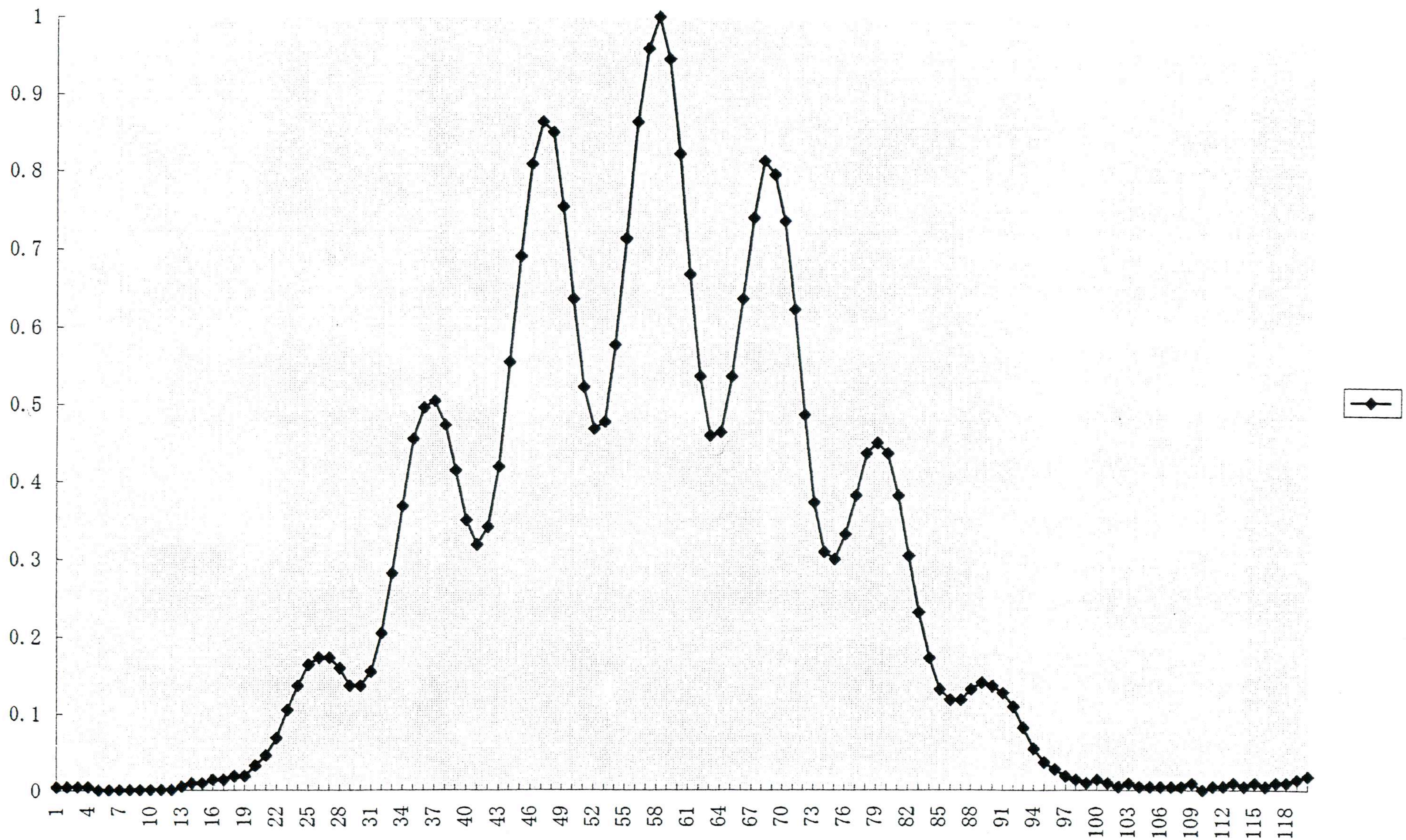
15mm 700nm No.7

$D = 15\,mm$

$\rightarrow \sigma = 170\,\mu m$

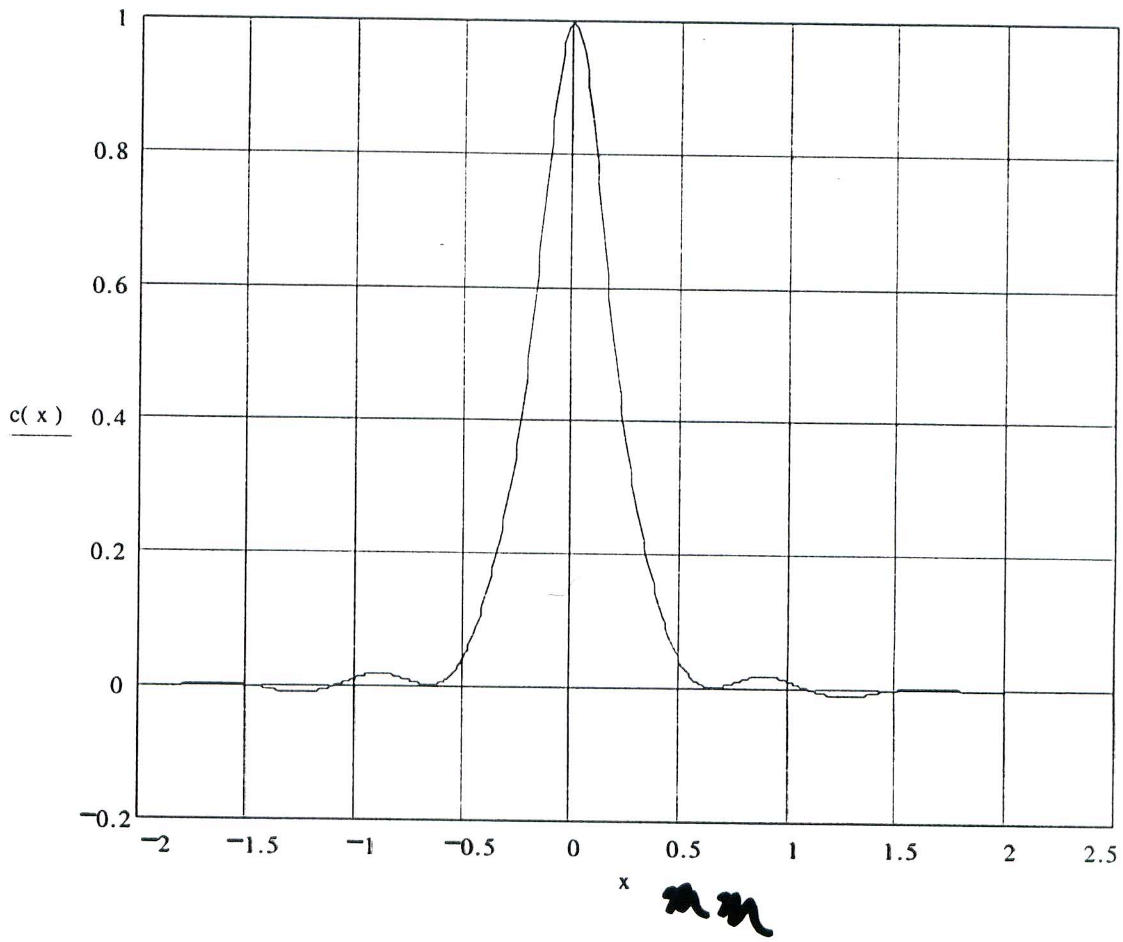
Interferogram

INTER12 グラフ 3



7mm 700nm

Reconstructed Beam Profile

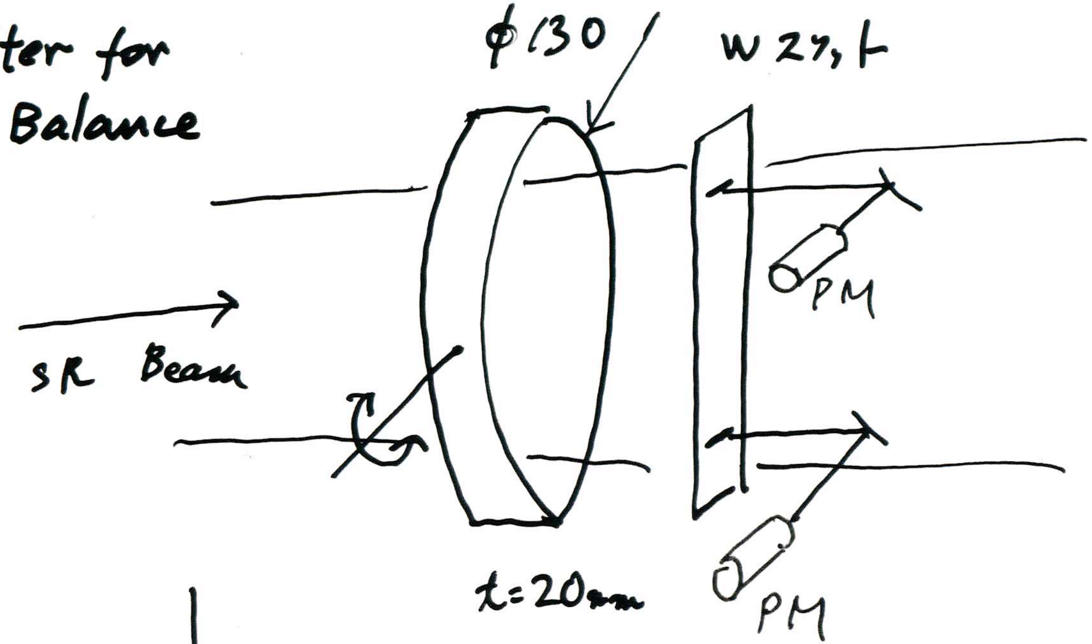


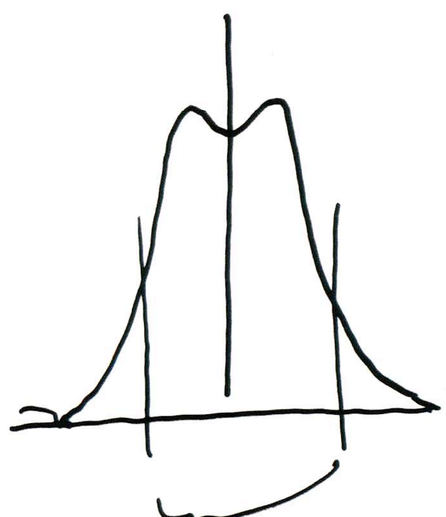
フーリエ変換によって 求めた ビームプロファイル

$\sigma = 170\mu m$ (60%)

ビーム シフター

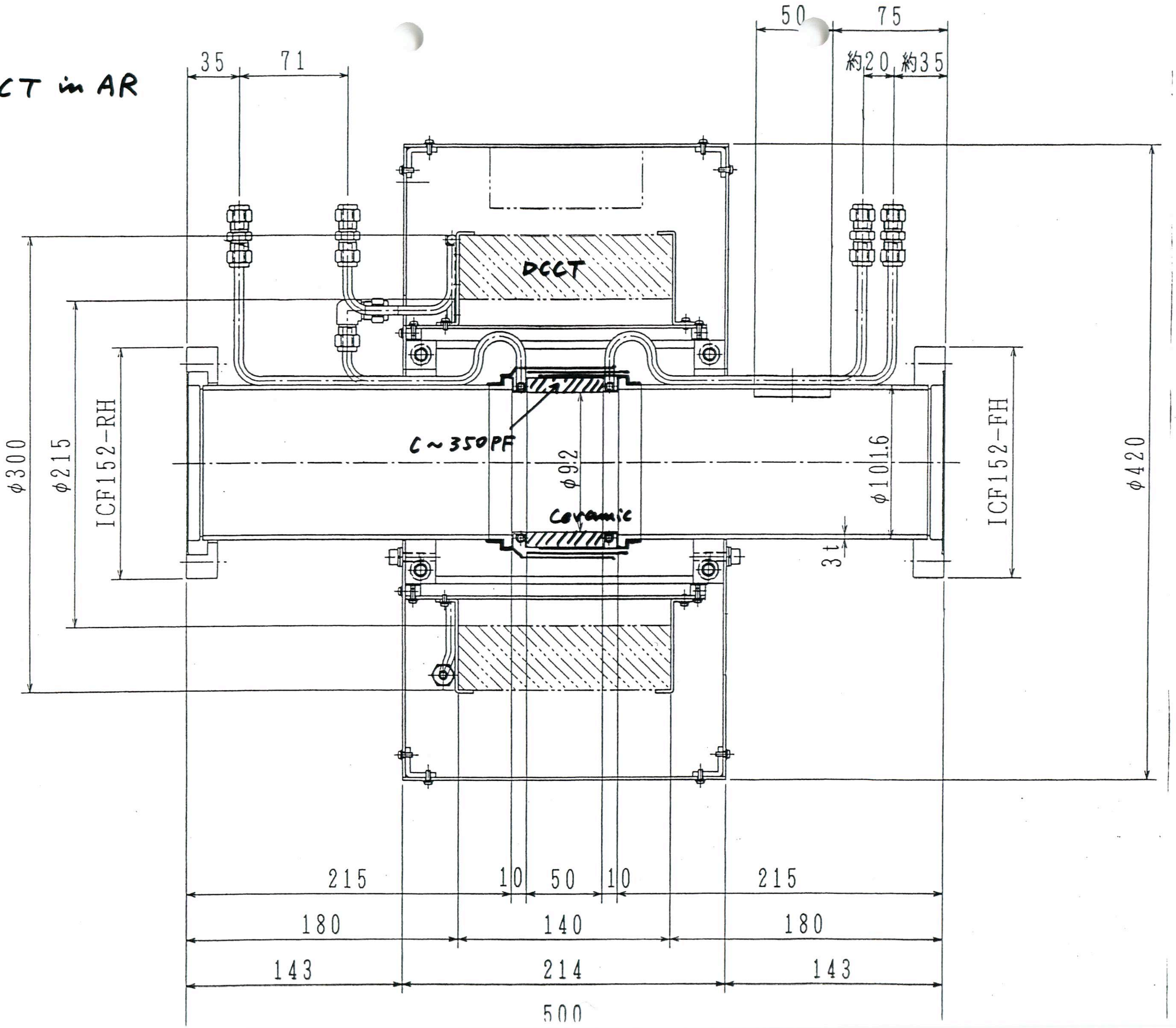
Beam Shifter for Intensity Balance



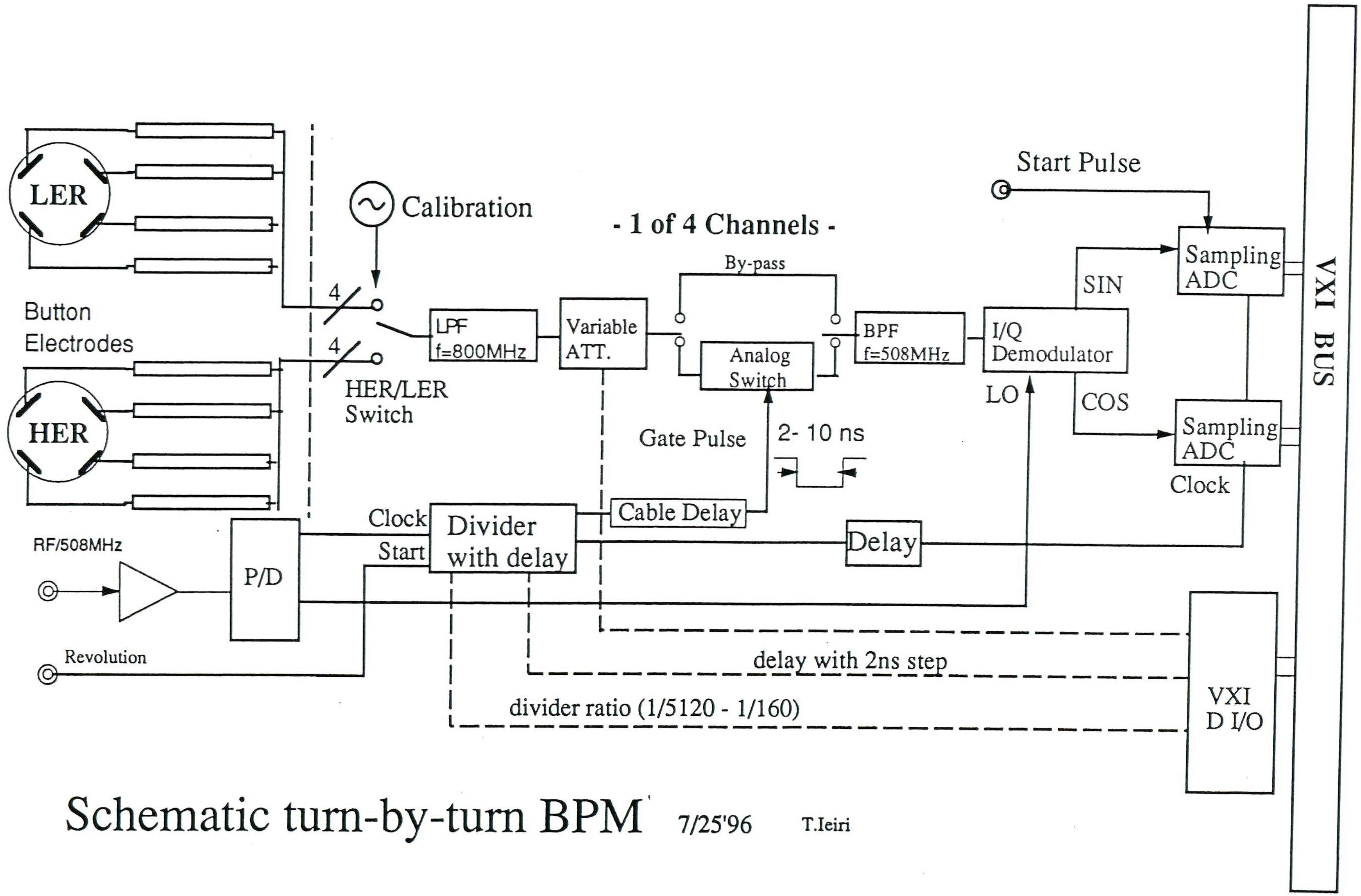


ビームのすその を PMで測り 屈折型の ビームシフターに
フィードバックを かける

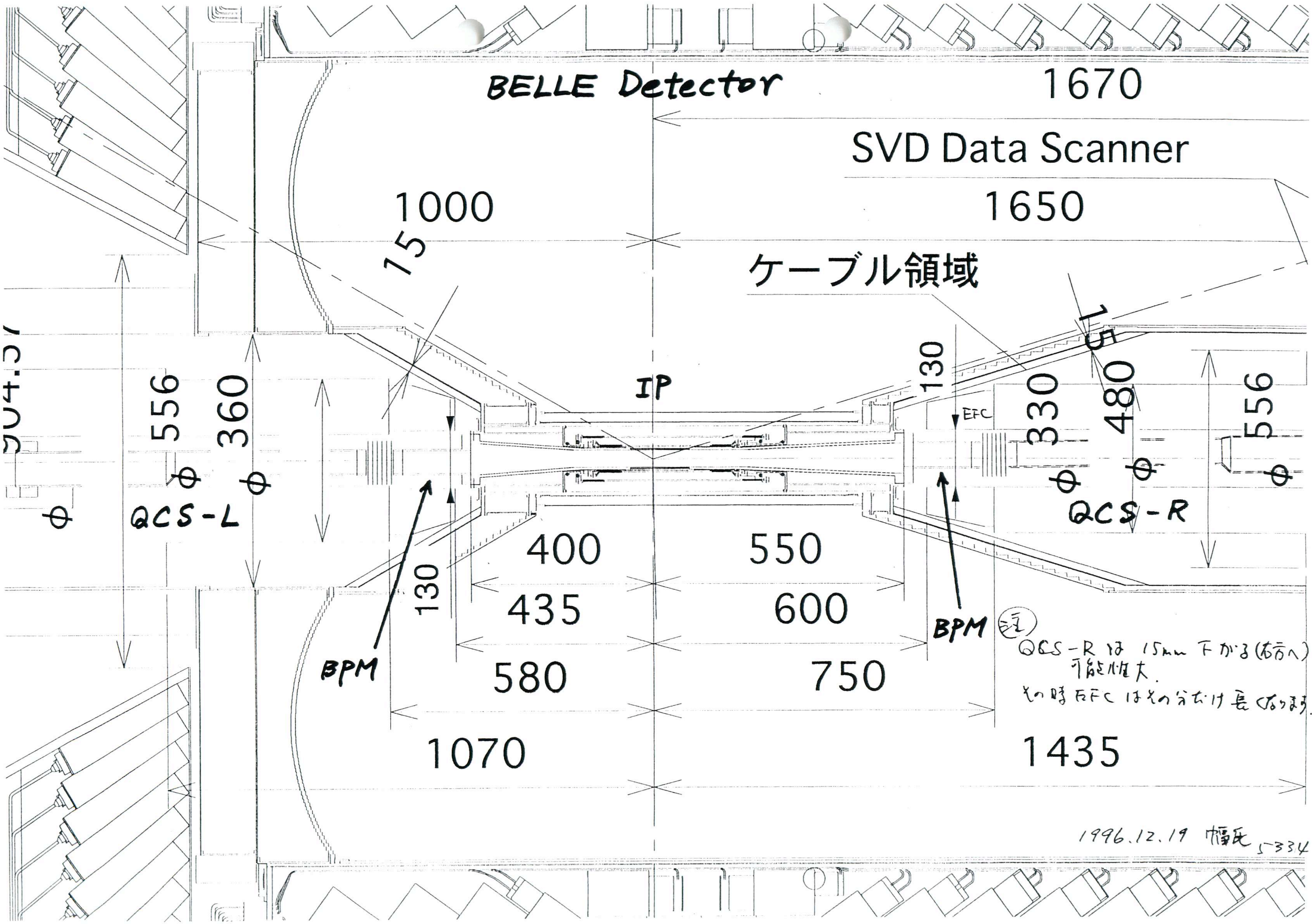
DCCT in AR

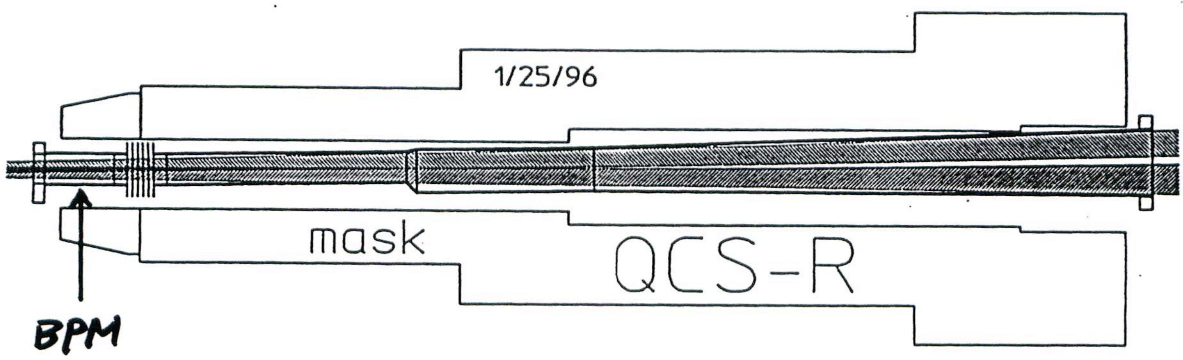


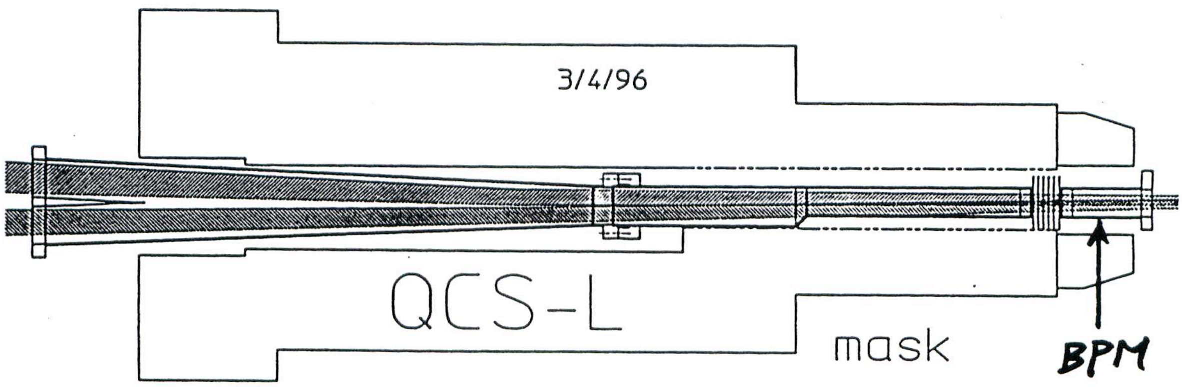
35
71
50
75
約20
約35
DCCT
C ~ 350PF
Ceramic
φ300
φ215
ICF152-RH
φ92
φ101.6
ICF152-FH
φ420
3t
215
10
50
10
215
180
140
180
143
214
143
500



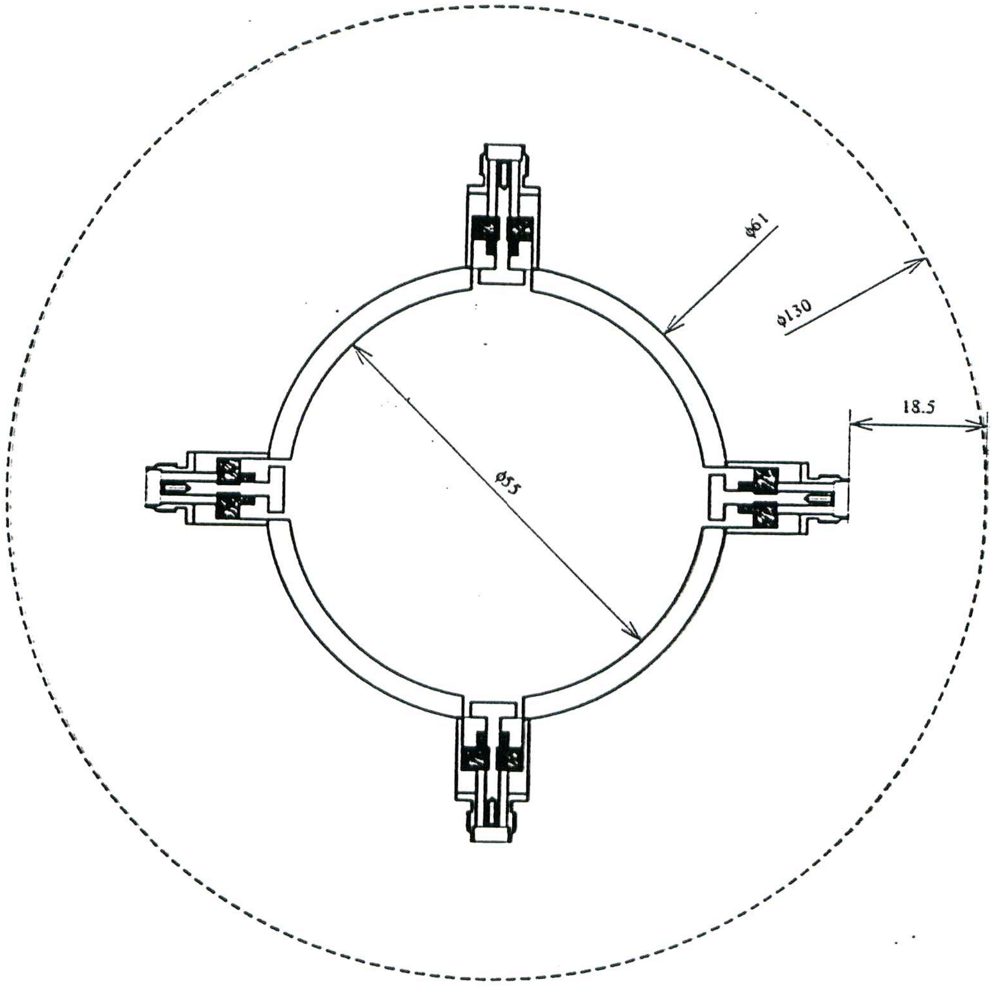
Schematic turn-by-turn BPM 7/25'96 T.Ieiri


BELLE Detector
1670
SVD Data Scanner
1650
1000
15
ケーブル領域
IP
15
130
EFC
330
480
556
Φ
QCS-R
556
360
Φ
QCS-L
130
BPM
BPM
400
550
435
600
580
750
1070
1435
注 QCS-R は 15mm 下がる(右方へ)可能性大.
その時 EFC はその分だけ長くなります.
1996.12.19 幅氏 5-3334

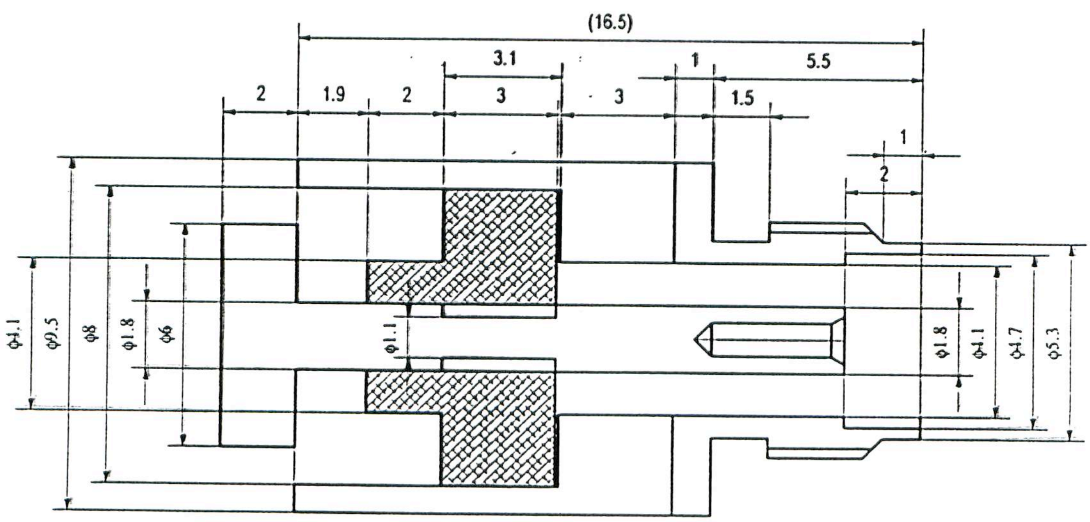

1/25/96
mask
QCS-R
BPM


3/4/96
QCS-L
mask
BPM

BPM at IR

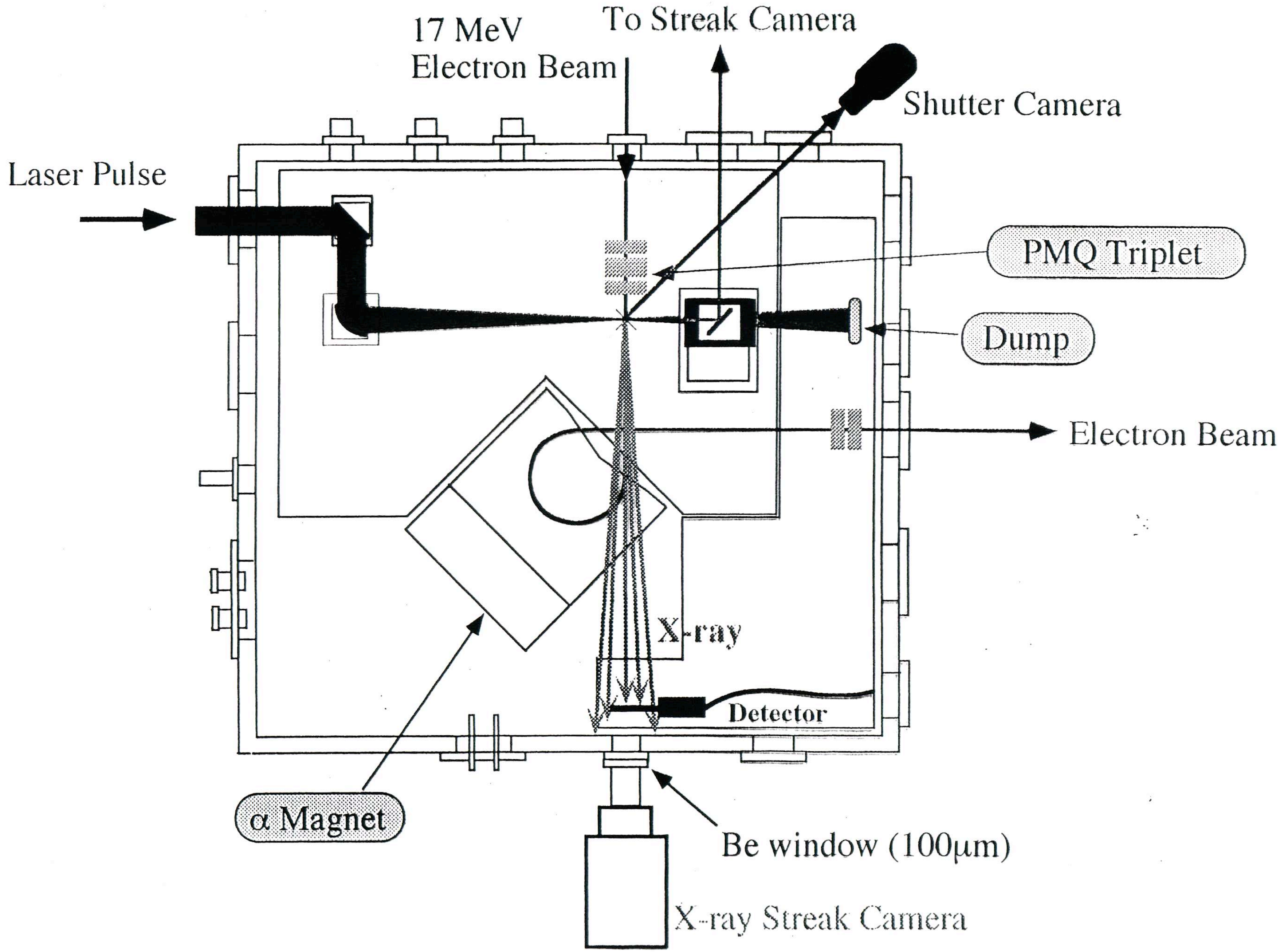


Feedthrough



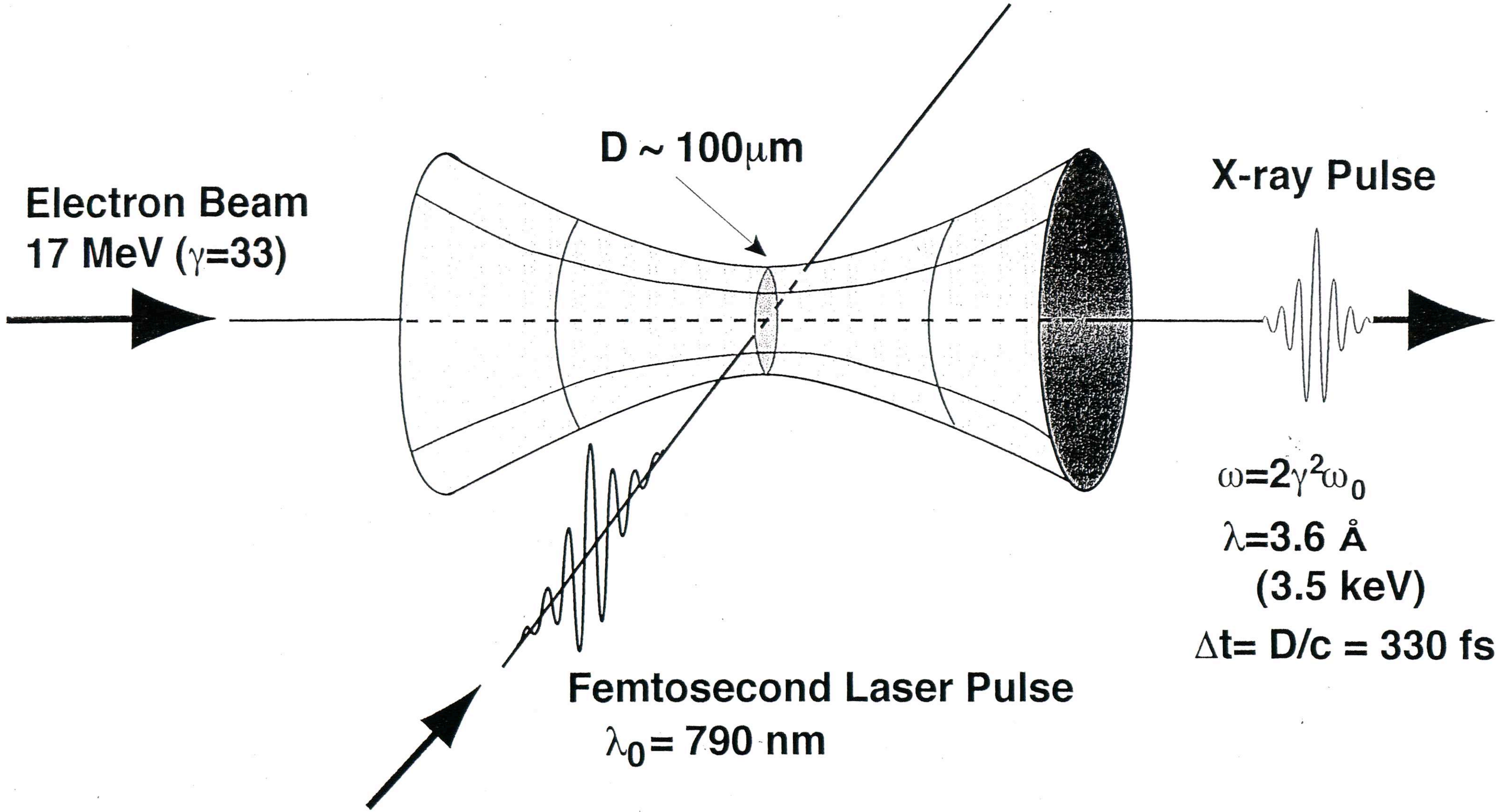
(SMA)

Thomson Scattering Experimental Setup

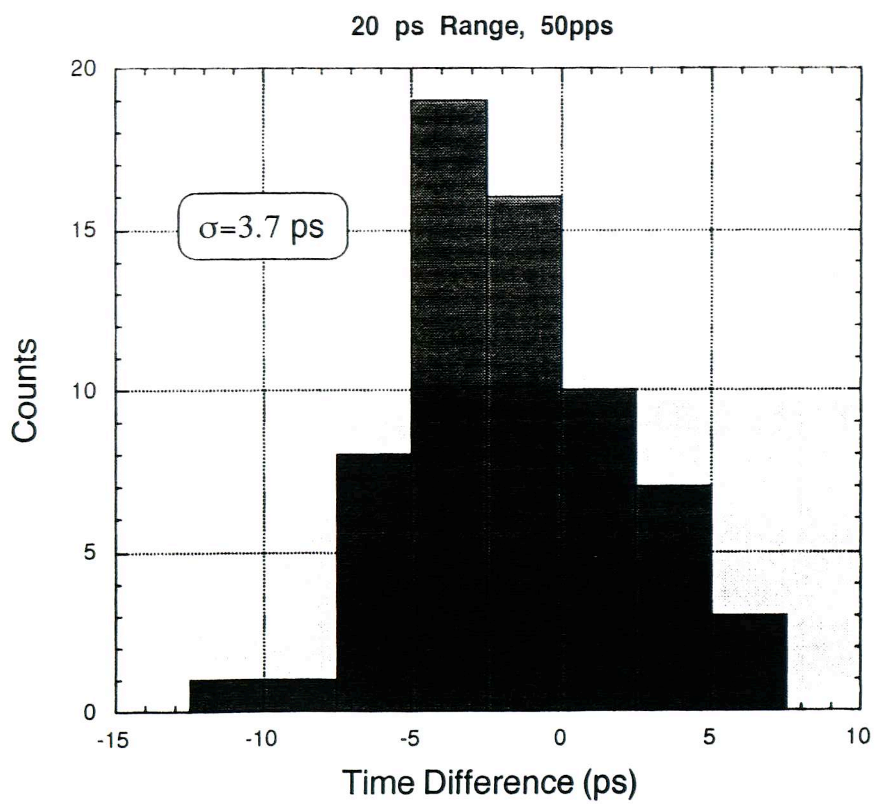


Subpicosecond X-ray Generation by Thomson Scattering

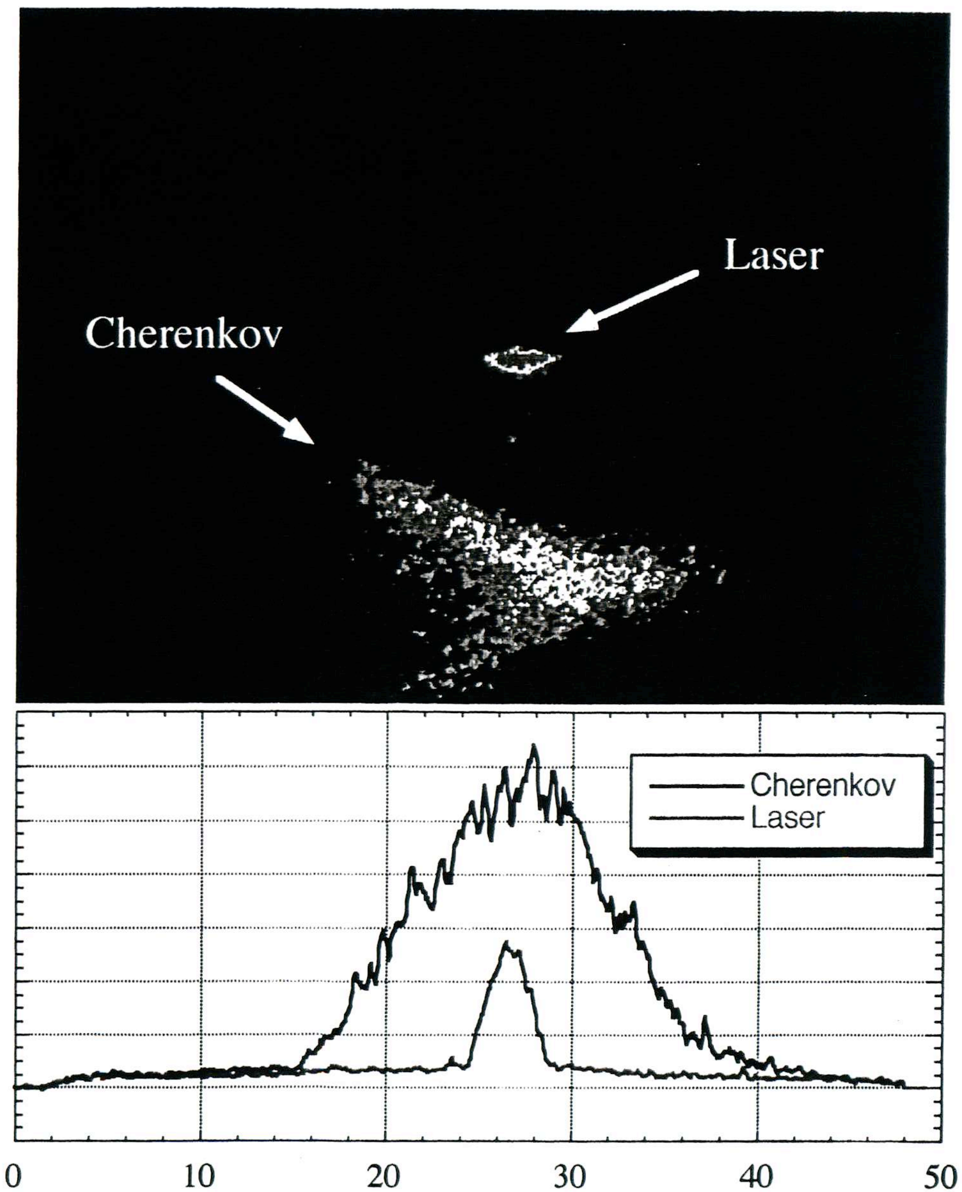
K. J. Kim et al., Nucl. Instr. and Meth., A341 (1994) 351-354



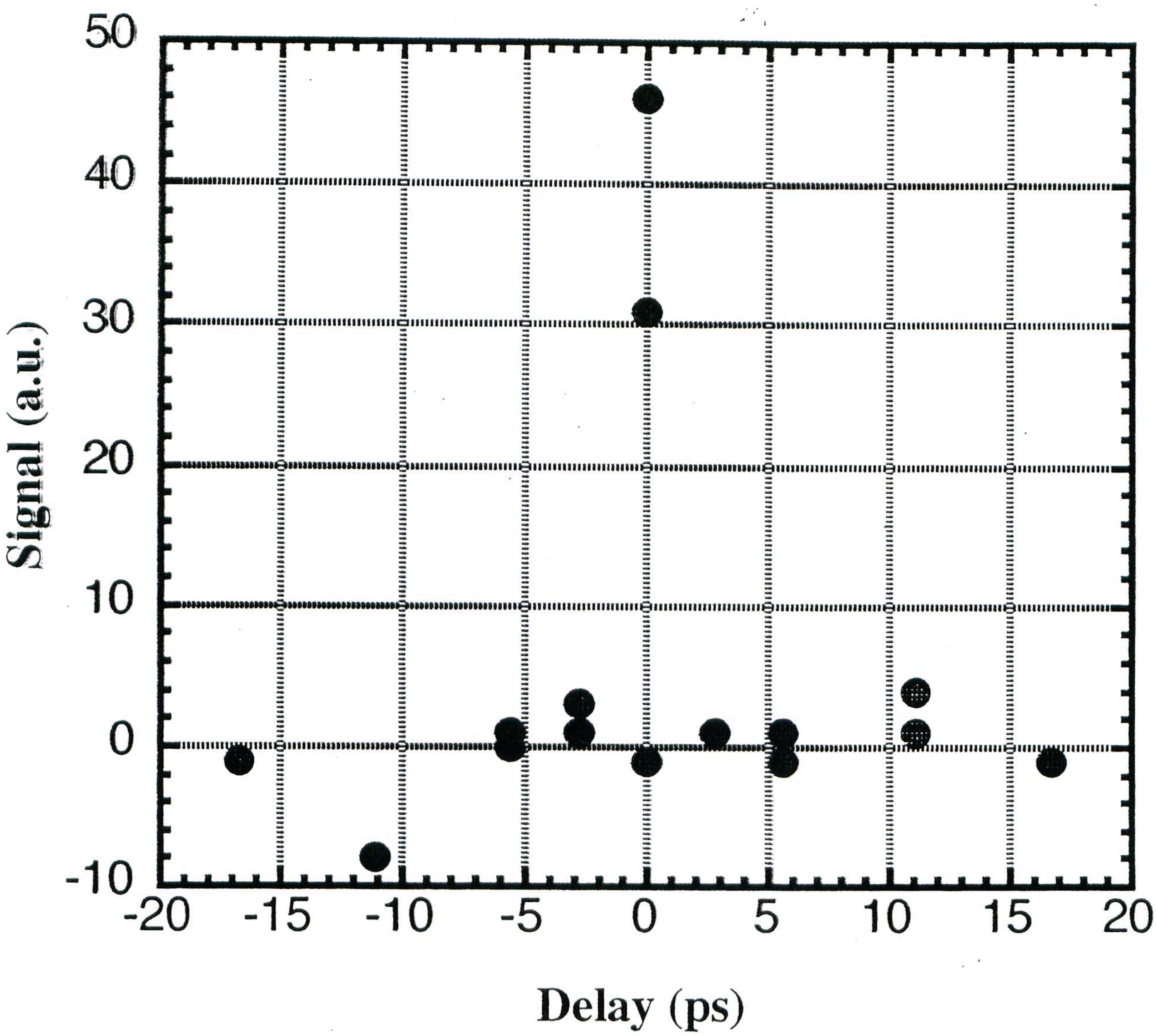
Measurement of Timing Jitter between Laser and Electron



Streak Image of Synchronized Cherenkov Light and Laser



X-ray Signal from Thomson Scattering



Test of Bunch Current Monitor in AR