KEKB Accelerator Review, June 7-10. '95

Beam Instrumentations

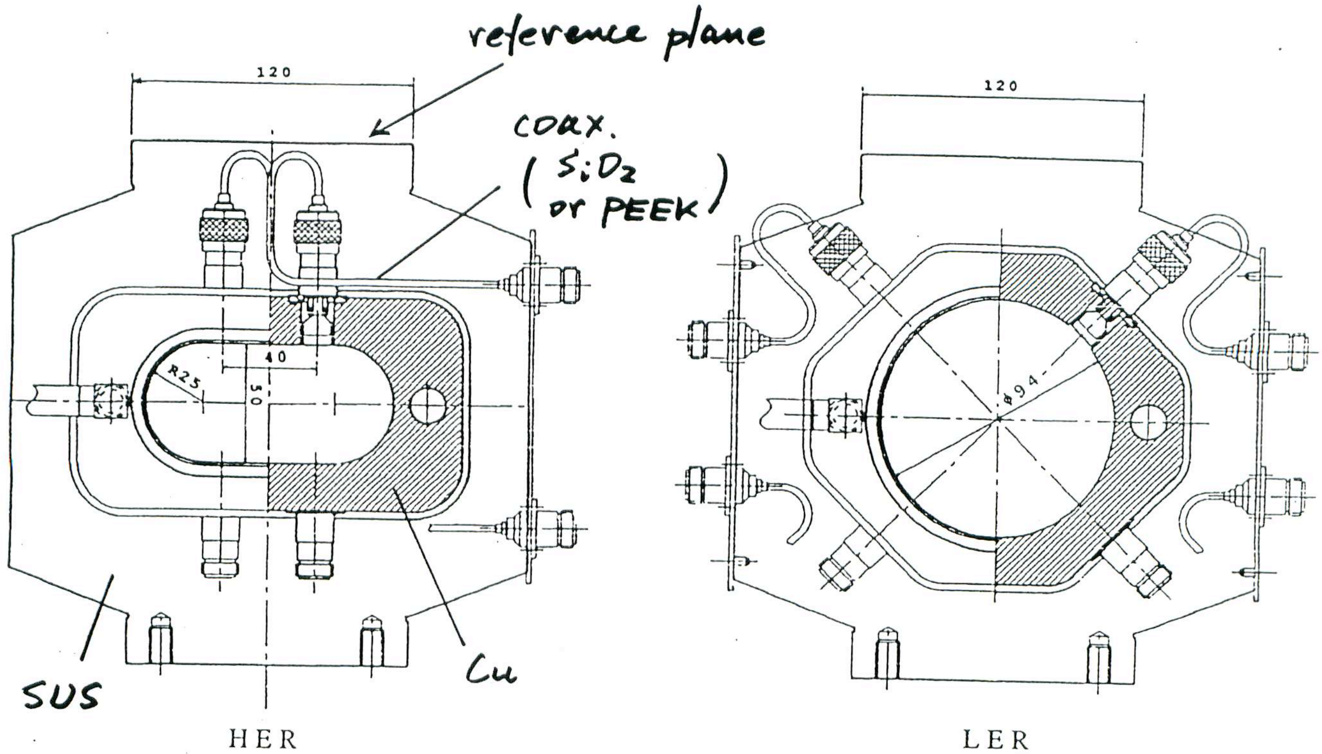
Beam Monitor Group
S. Hiramatsu

1. Beam Position Monitor (BPM)
2. Synchrotron Radiation Monitor (Beam profile)
3. Laser Wire Monitor (Beam size)

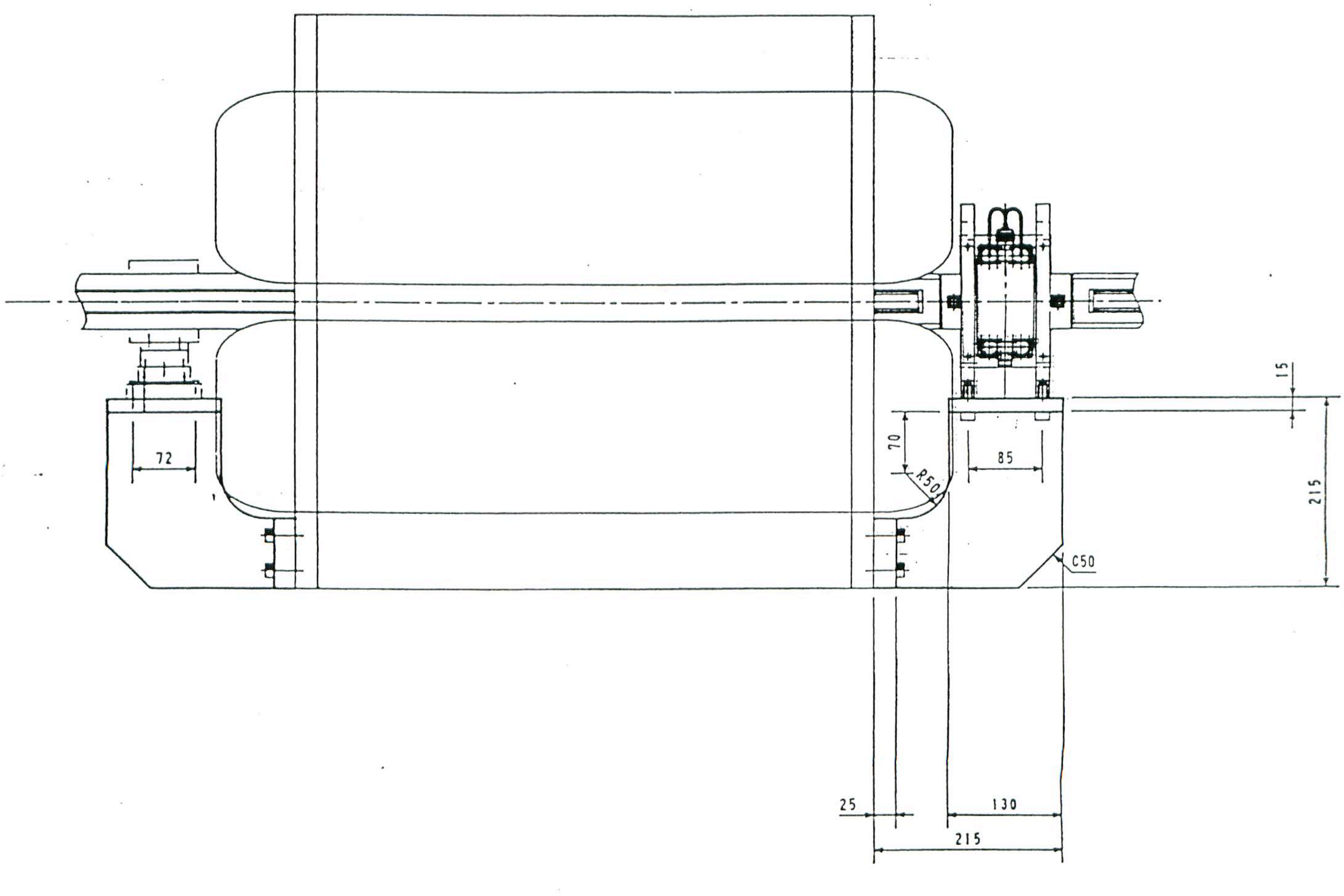
BPMs

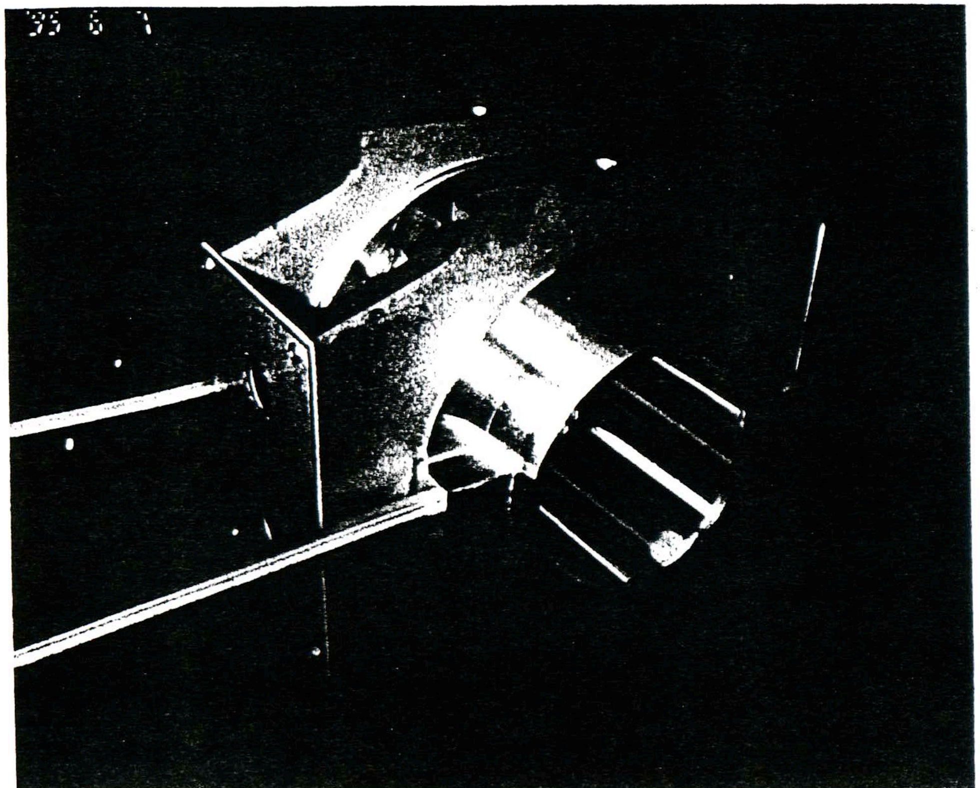
- ~ 450 BPMs / ring
- Electrostatic pick-up with 4 buttons
- Position resolution $\lesssim 10\mu m$
- Measurable range : $\begin{cases} 10\mu m < x, y < 10\ mm \\ 10\ mA < i_b < 2.6A \end{cases}$
- Closed orbit measuring time ~ 1 sec

  (~ 2.5 sec : 1st phase

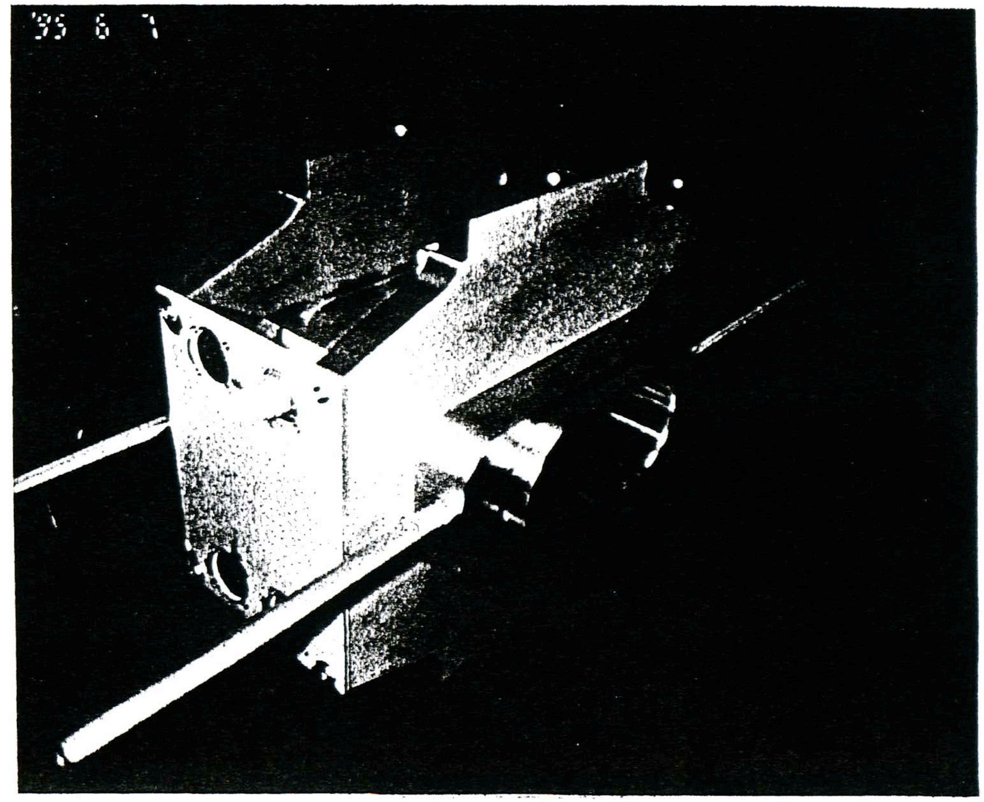


BPM block for the BF ring

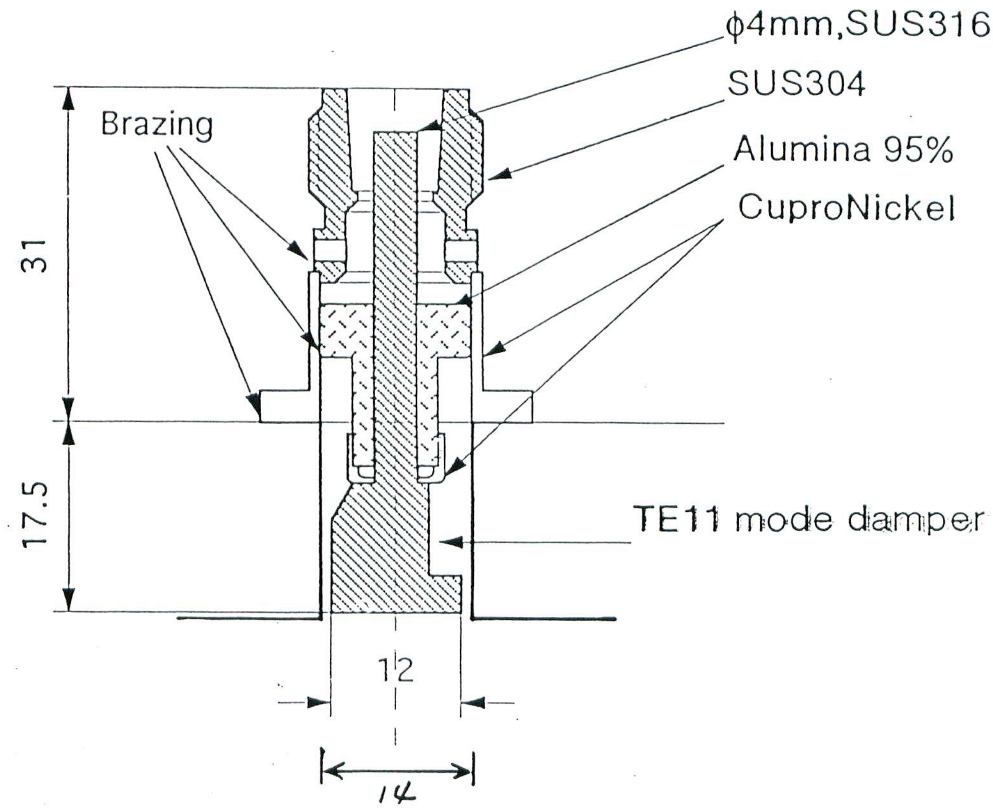




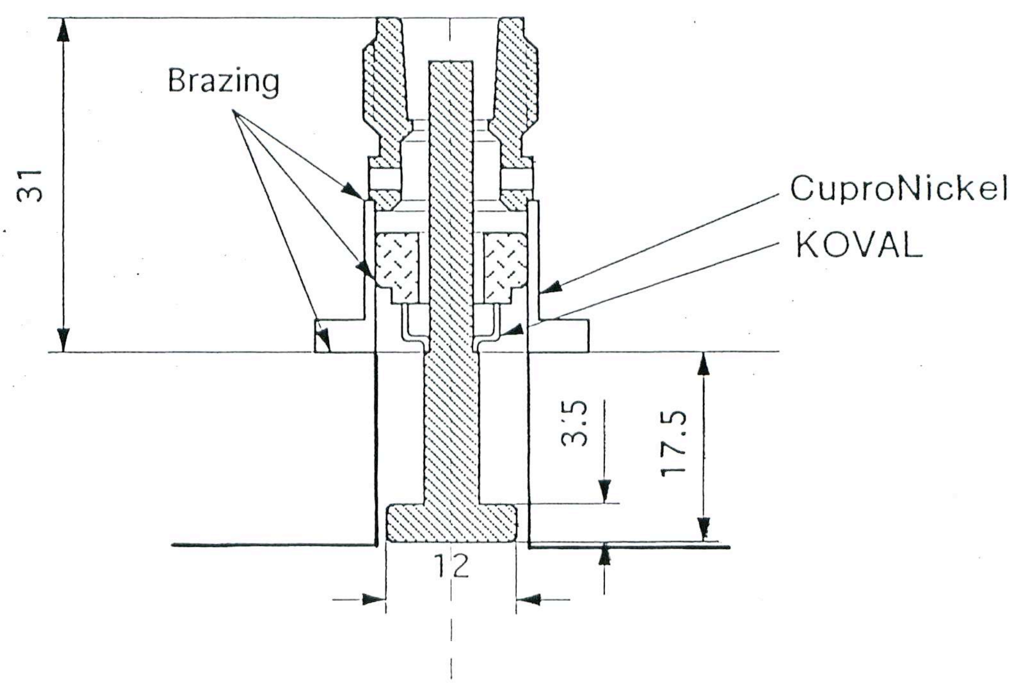
BPM block for the LER



BPM block for the HER



N-Type Connector



BPM electrode ~~for BPM~~

Dipole Mode Measurement for Symmetric Structure

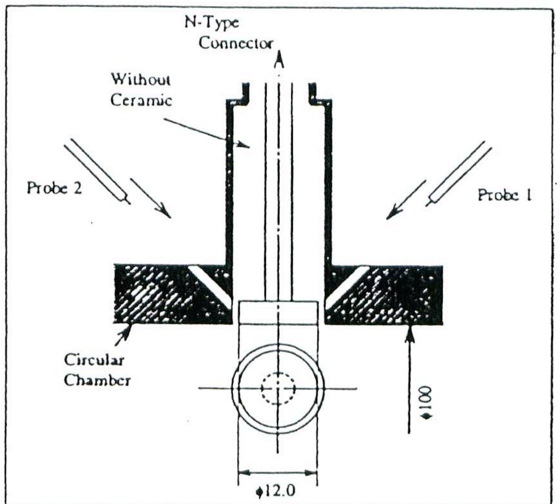
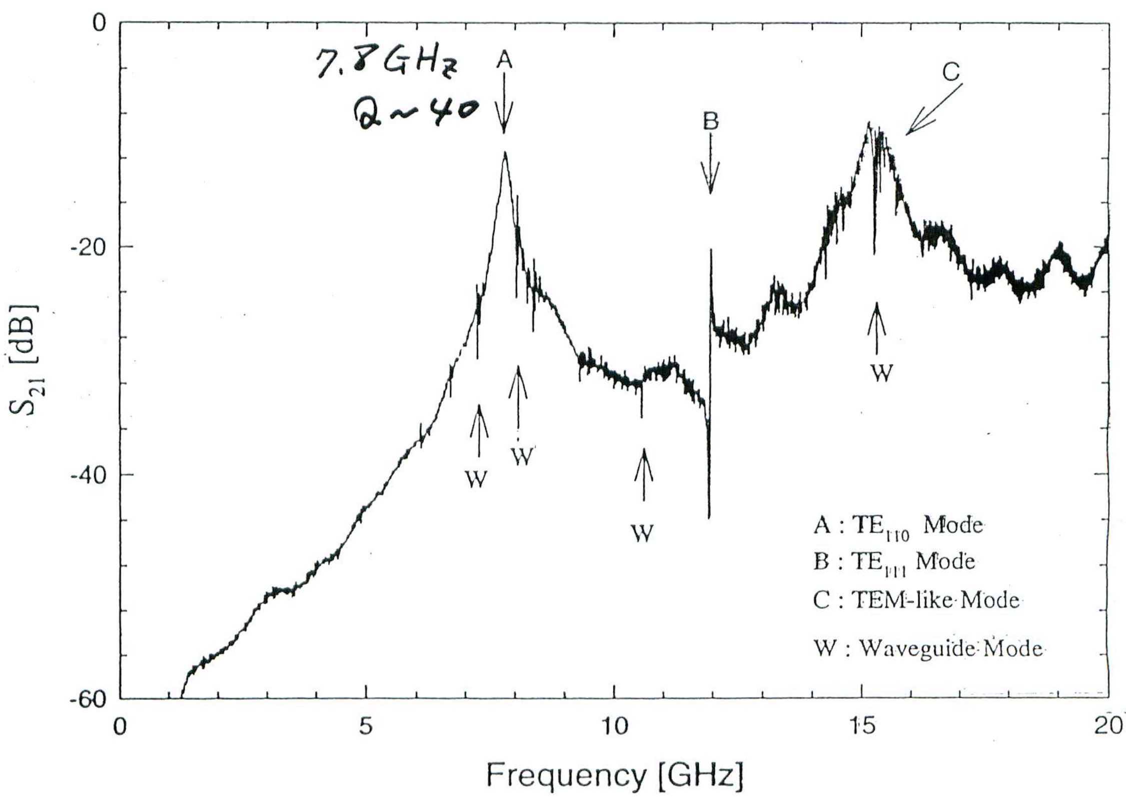
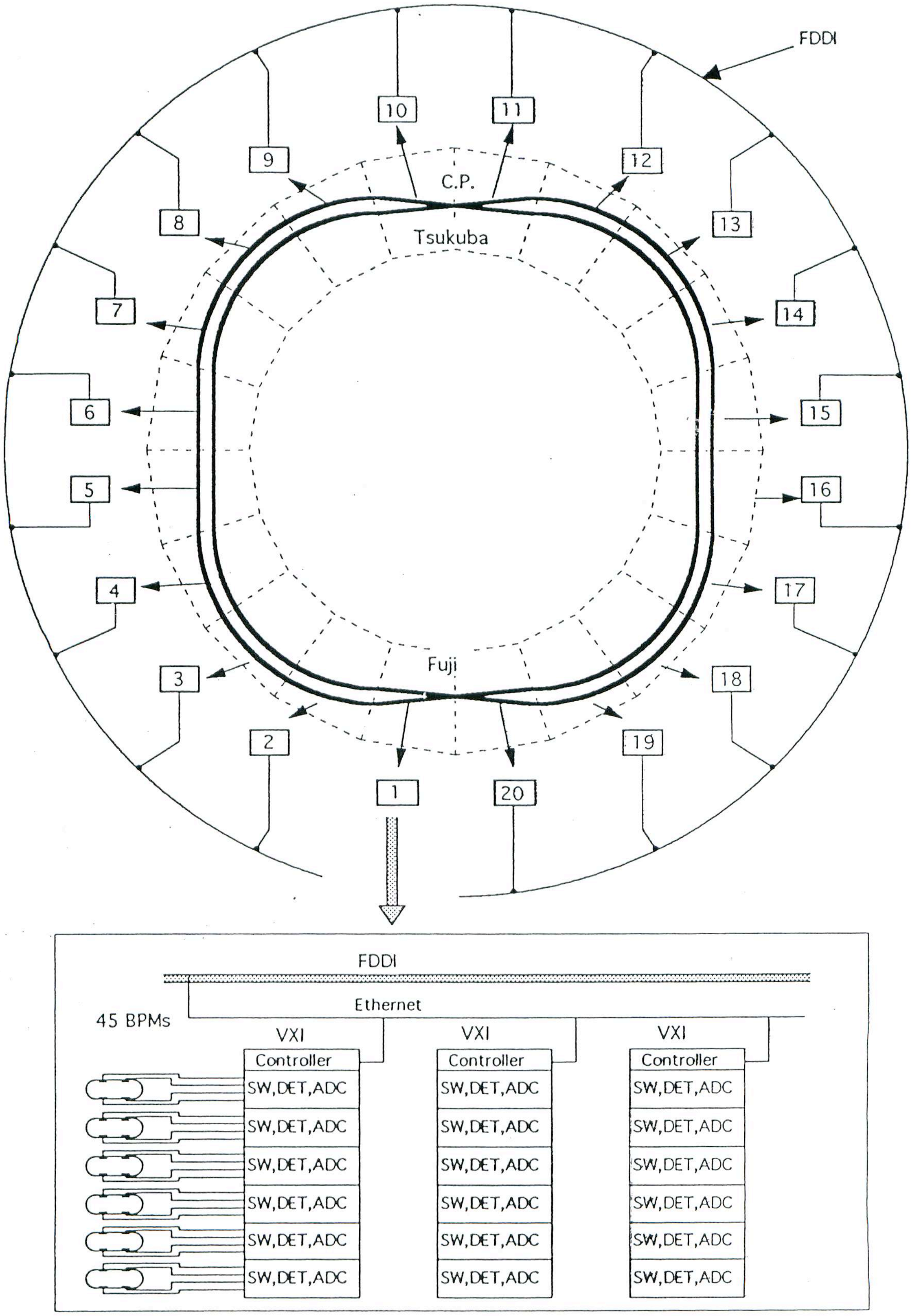


Figure. 5. Experimental setup of the TE110 measurement. Two semi-rigid cable is used as an antenna to excite the TE110 mode at the disk. The BPM was mounted on ϕ100 mm circular beampipe, at those ends absorbers were loaded.





Beam Position Monitor System for B-Factory

Signal Detection

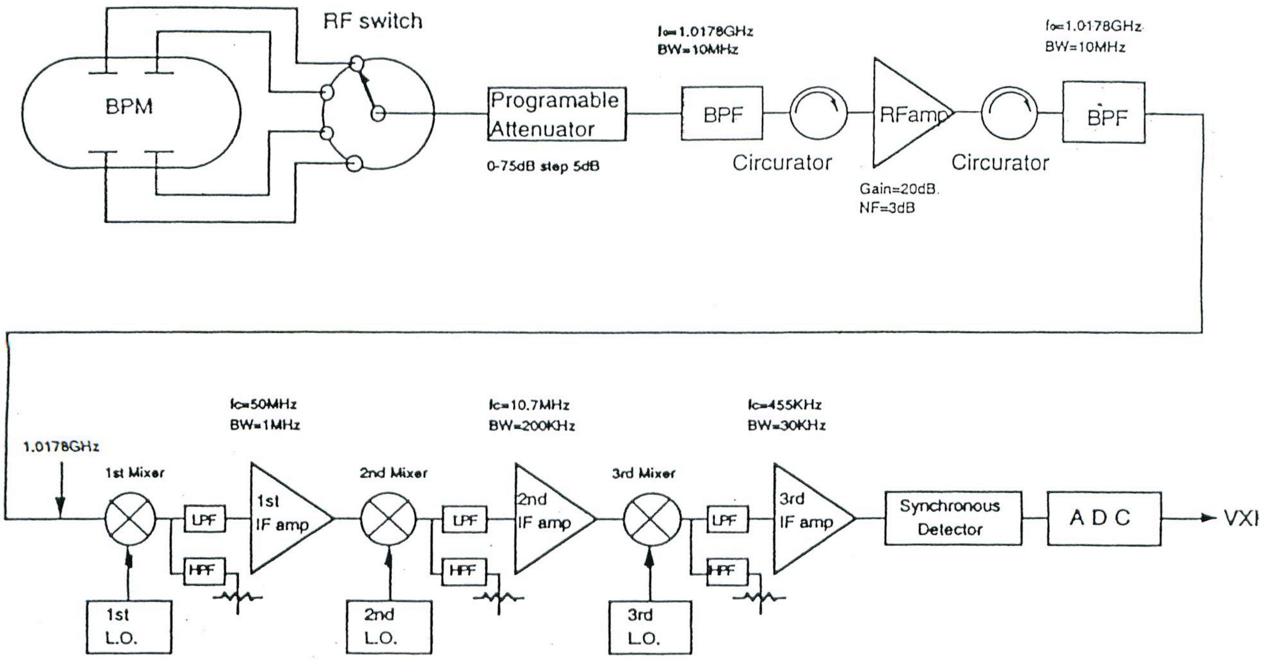


Figure 11.7: Block diagram of the front-end signal processor.

$$x = K \frac{(V_A - V_B) - (V_C - V_D)}{V_A + V_B + V_C + V_D} \qquad K \approx \begin{cases} 33\,\text{mm} & (LER) \\ 25\,\text{mm} & (HER) \end{cases}$$

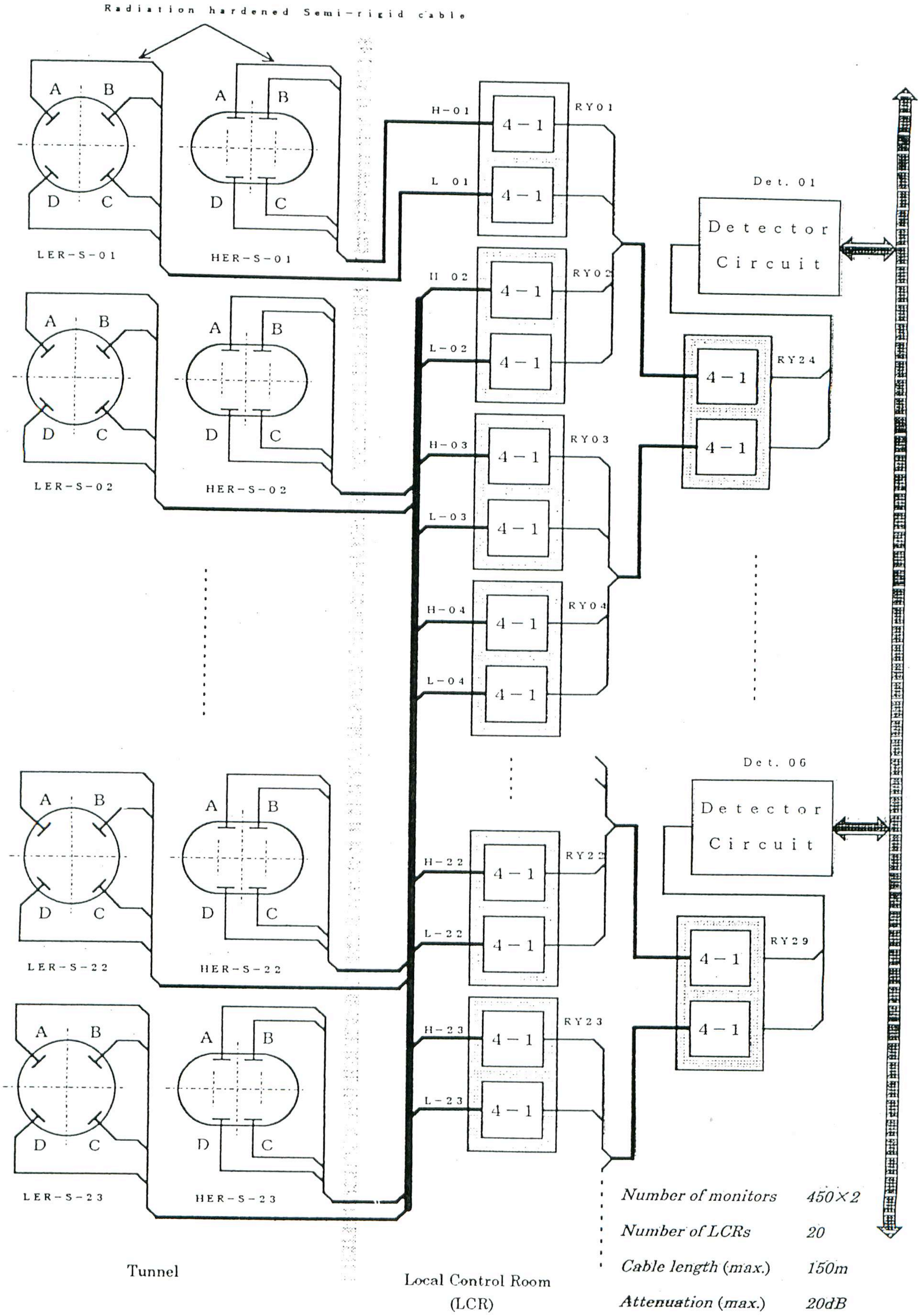
- Separate signal cables for $V_A, \cdots, V_D$ to the el. hut
- RF switch — mercury sw or PIN diode SW
- Detect 1 GHz ($2 \times f_{rf}$) component — super-heterodyne
- Response time

$4 \times$ (2 ms + 15 ms + 120 ms) $\lesssim$ 0.6 sec/BPM

2 ms: RF SW; 15 ms: BPF, $\Delta f = 100$ Hz; 120 ms: ADC ($\Sigma \cdot \Delta$ 20 bit)

1st phase: COD measurement $\lesssim$ 2.5 sec/ring

4 BPMs of LER, 4 BPMs of HER } share one det. circuit.



Layout of monitor system

S/N and Resolution

- thermal noise

$$\Delta x = K \frac{1}{(S/N)} = 0.9 \times \frac{\sqrt{B(Hz)}}{i_b(mA)} \ [\mu m] \qquad (K = 25\,mm)$$

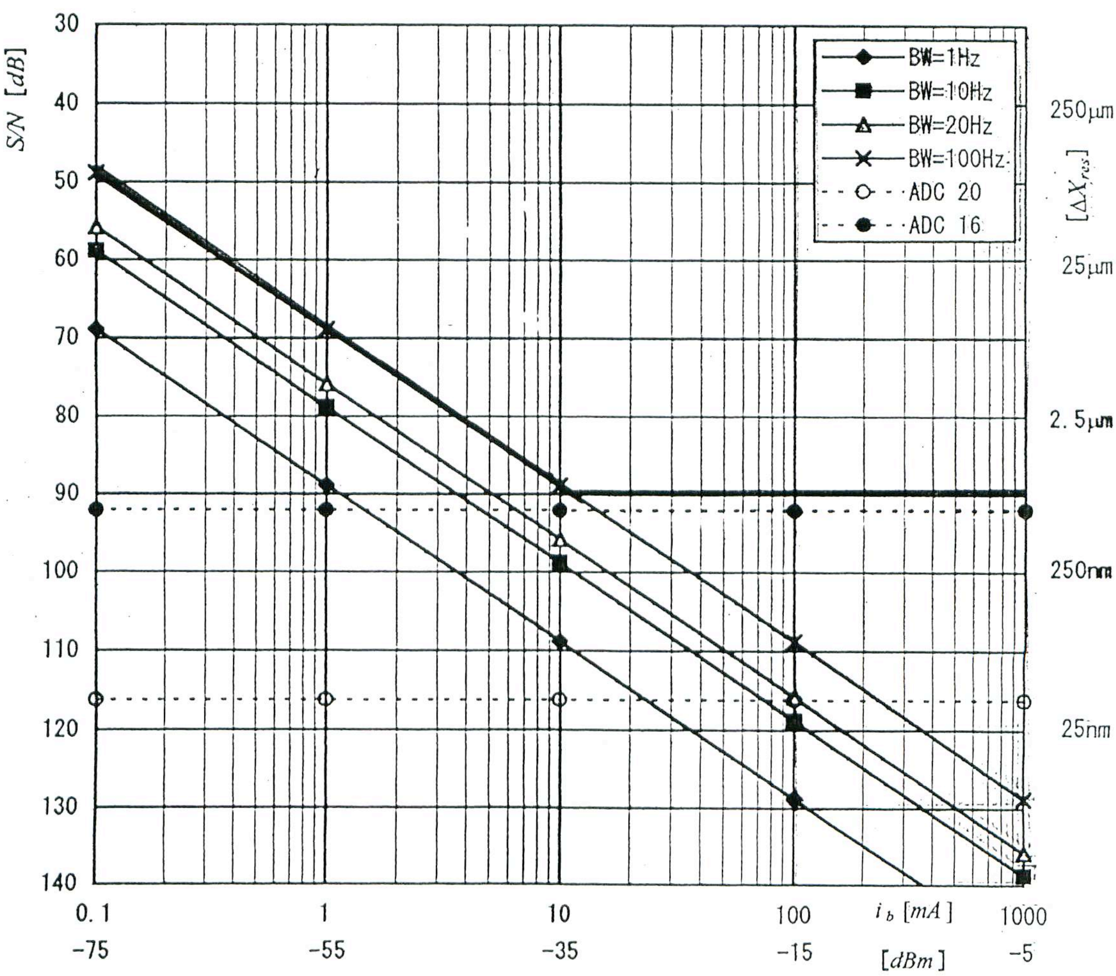
- resolution by ADC

$\Delta x = 2\mu m$ ⟶ Real 16bit ADC (bi-polar) is required.

---- difficult in commercial base

candidate : 20bit Σ-Δ type ADC

responce time ~120 msec

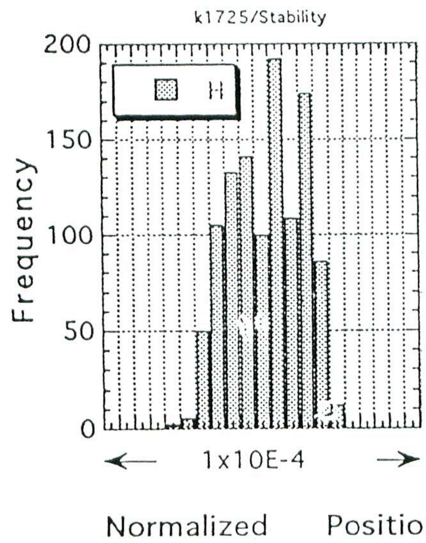


B = 100 Hz

upper limit of dynamic range at 0dB att. = 10 mA

} ⟶ $\Delta x \sim 1\,\mu m$ for $i_b > 10\,mA$ (full bunch op.)

Distribution of Δ/Σ in 1000 on/off cycles



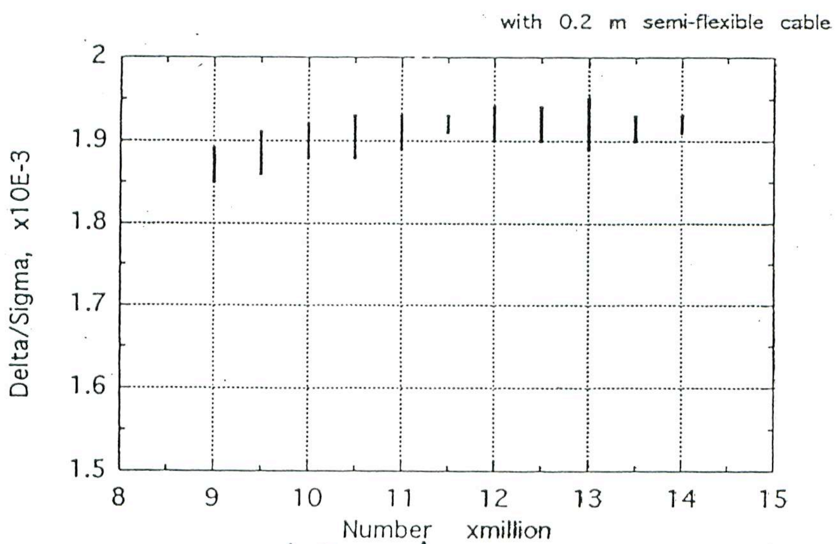
mercury switch

(Δ/Σ)

$\pm 3\times10^{-5}$ ~ $\pm 1\mu m$ error

Long run test

mercury switch



on/off cycle

fluctuation of (Δ/Σ) ~ 1×10^{-4}

$(\Delta x \sim 3.5\mu m)$

ON/OFF Test of Coaxial Switches at 1 GHz

Diagram of the on/off test :

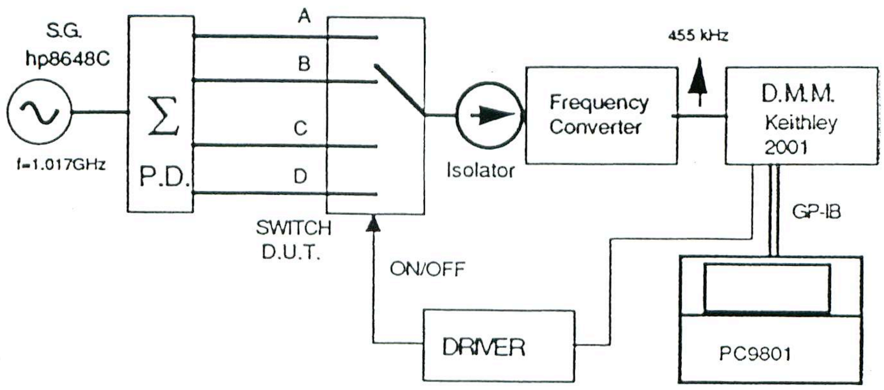


Table 1 Insertion losses of sampled switches measured at 1.0GHz.

Type	Model	Ch1	Ch2	Ch3	Ch4
Mechanical	CS38S(1)	0.9969	0.9972	0.9967	0.9966
Mercury	UCL1G (2)	0.9368	0.9204	0.9289	0.9252
PIN diode	TS503(3)	0.9402	0.9418	0.9419	0.9400
GaAs FET	SW254 (4)	0.8574	0.8564	0.8630	0.8587

(1):Teledyne,USA (2):Sanyu, Japan
(3):Tokimec, Japan (4):Anzac, USA.

$$\Delta x = K\left(\frac{\Delta}{\Sigma}\right)$$: equivalent position error

$K \approx 35$ mm (LER)

$$\left(\frac{\Delta}{\Sigma}\right) = \frac{(V_A + V_B) - (V_C + V_D)}{V_A + V_B + V_C + V_D}$$

Dose to the BPM Cable Connector estimated by EGS4

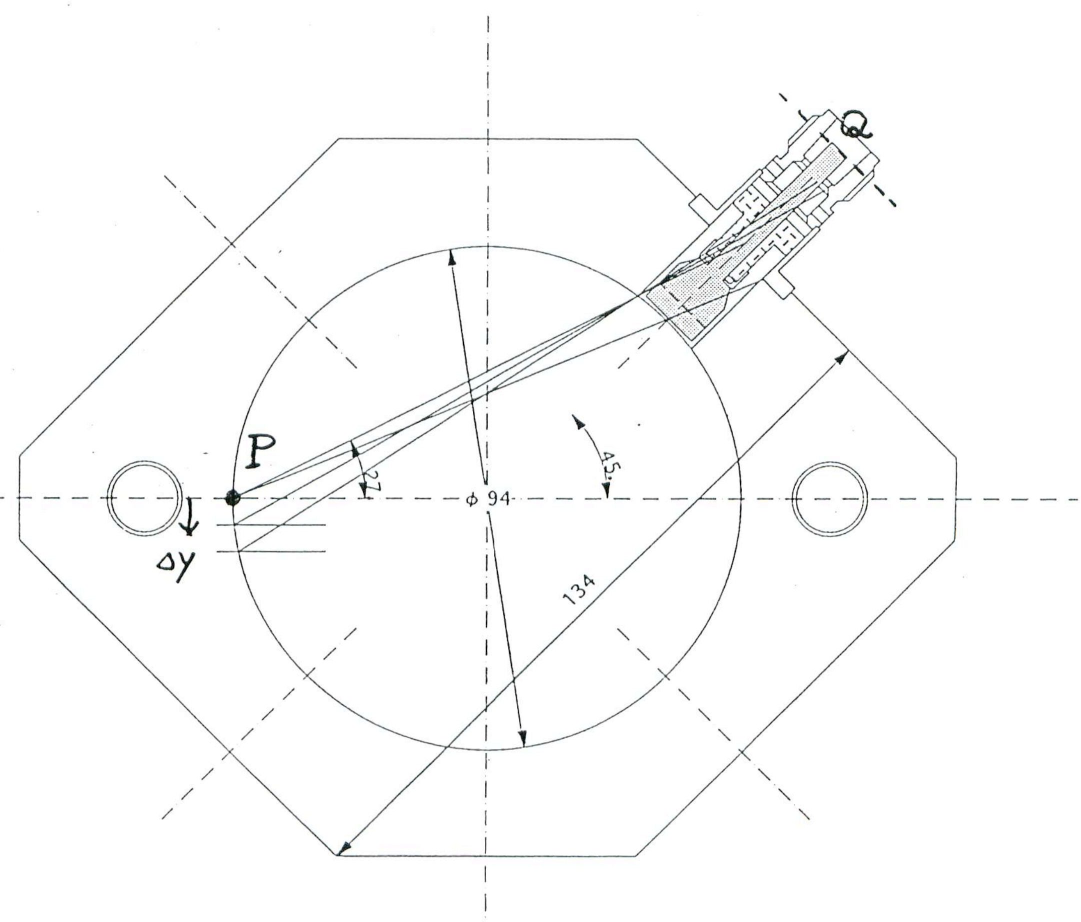
	ρ (bend)	SR incident angle on P	source corr. factor
LER	16.31 m	0.95°	0.092
HER	104.46 m	1.13°	0.56

Dose at Q :

	penetration (3.5mm SUS+5mm Al)	streaming (1mm gap)*	total dose	
LER	0.35×10^5	6.97×10^5	7.3×10^5	rad/y
HER	4.7×10^7	4.34×10^7	9.1×10^7	rad/y

(* effective solid angle $4\pi\times0.091$)

Button
diameter 12mm
thickness 3.5mm
gap 1mm



Synchrotron Radiation Monitor (Beam Profile Monitor)

Design issues :

1. Dedicated weak bend magnet to relax the heat load of SR extraction mirror.

   EX mirror (effective area) { LER 10 mm (H) × 50 mm (V) ; HER 10 mm (H) × 44 mm (V)

   at 10 m from SR source

2. Active mirror to correct Ex mirror deformation.

   w.f.d. < $\lambda/8$ ~ 0.07 μm

   feedback by { point response & interferometer

3. Diffraction limited (aberration free) optics.

   Focusing system optimized at <u>480 nm</u> :

   objective system (~5 m) + relay system (30 m)

   magnification 0.0714

σ_x/σ_y (μm)	image (μm)	
472 / 69	33.7 / 4.93	LER
650 / 120	46.4 / 8.57	HER

4. Evaluation of PSF (diffraction pattern)

rms spread (μm)	observed σ_x/σ_y (μm)	
13.1 (H) / 5.36 (V)	506 / 102	LER
13.1 (H) / 7.32 (V)	675 / 158	HER

observed image ⟶ real image

↑

(deconvolution with PSF)

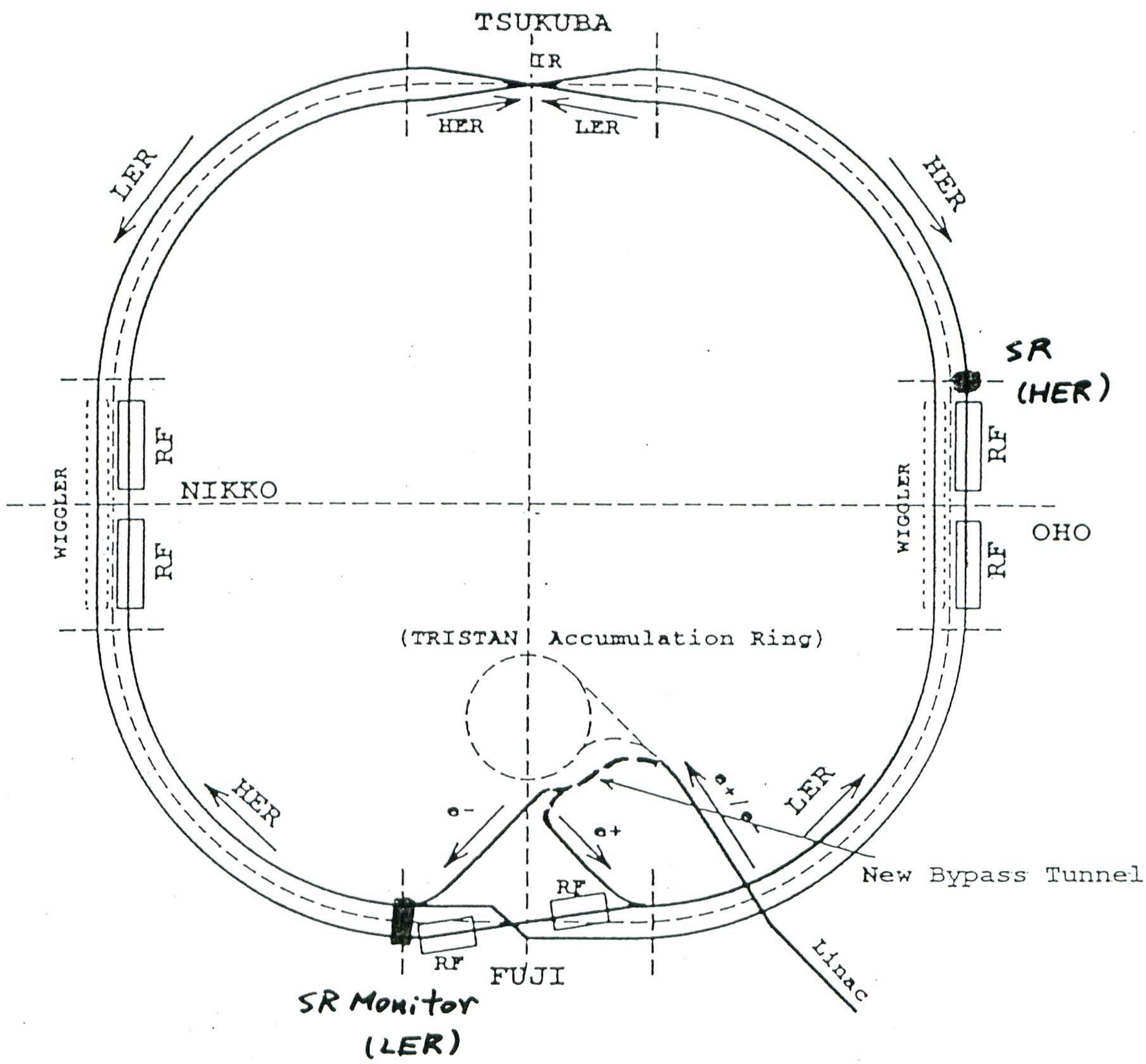
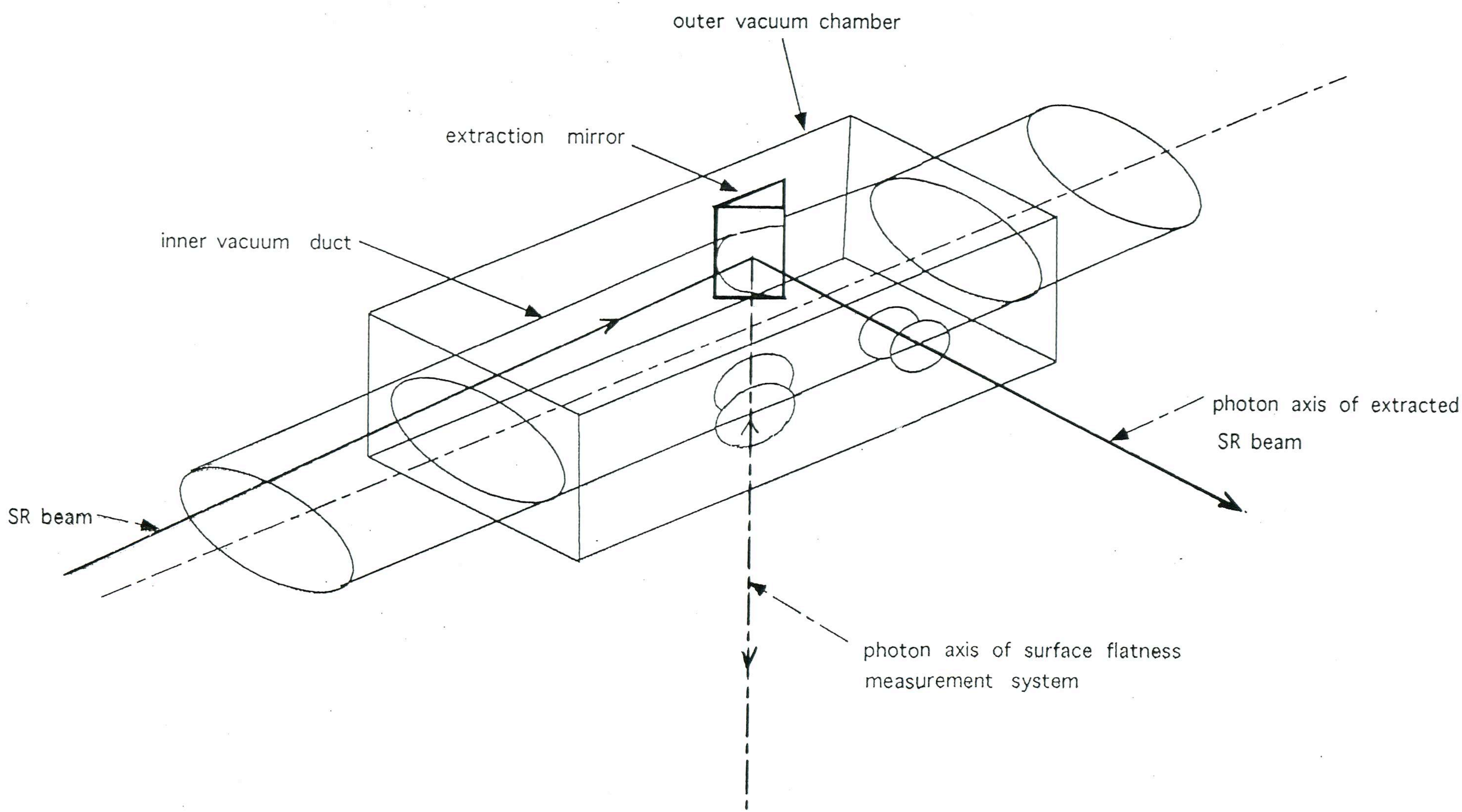


Fig. 3. Arrangement of two rings.


outer vacuum chamber
extraction mirror
inner vacuum duct
SR beam
photon axis of extracted SR beam
photon axis of surface flatness measurement system

	Bend Radius	Dipole Field	Angular Power of SR		Source Size
LER	183 m	0.0638 T	28.86 W/mrad at 2.5 A	σ_x	472 μm
				σ_y	69 μ m*
HER	1172 m	0.0228 T	49.31 W/mrad at 1 A	σ_x	650 μm
				σ_y	120 μm*

Table 11.1: Preliminary parameters of the weak bend magnets that are used as synchrotron light source for the profile monitors. Theoretical total angular power of the synchrotron light is also listed. *The quoted beam size as the light source assumes the emittance coupling of 2 %.

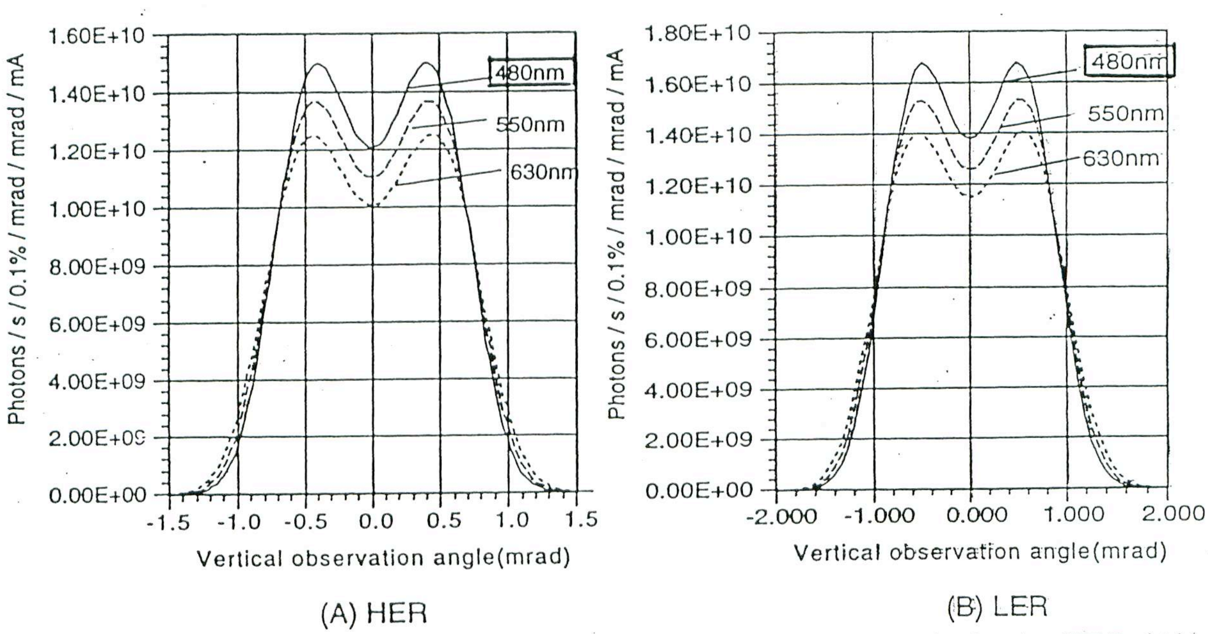


Figure 11.8: Theoretical angular distribution of the synchrotron light in the HER (A) and the LER (B).

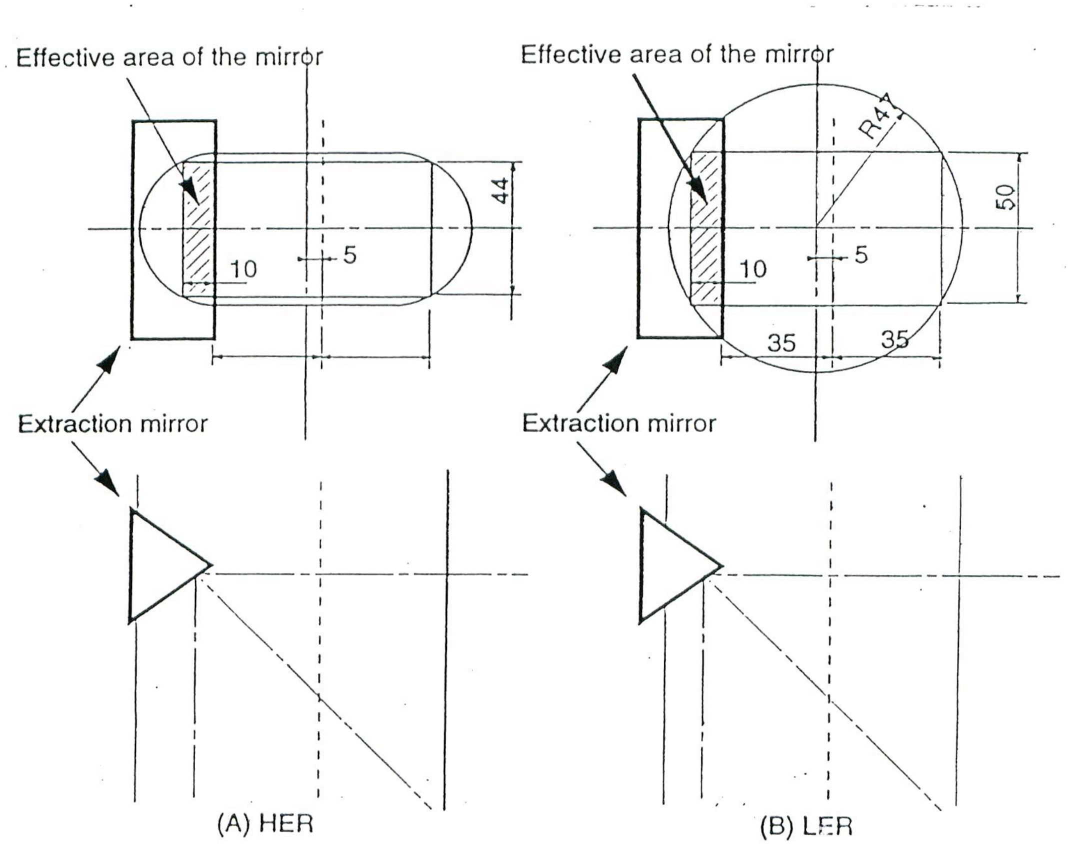


Figure 11.10: Configuration of the extraction system for the visible synchrotron light.

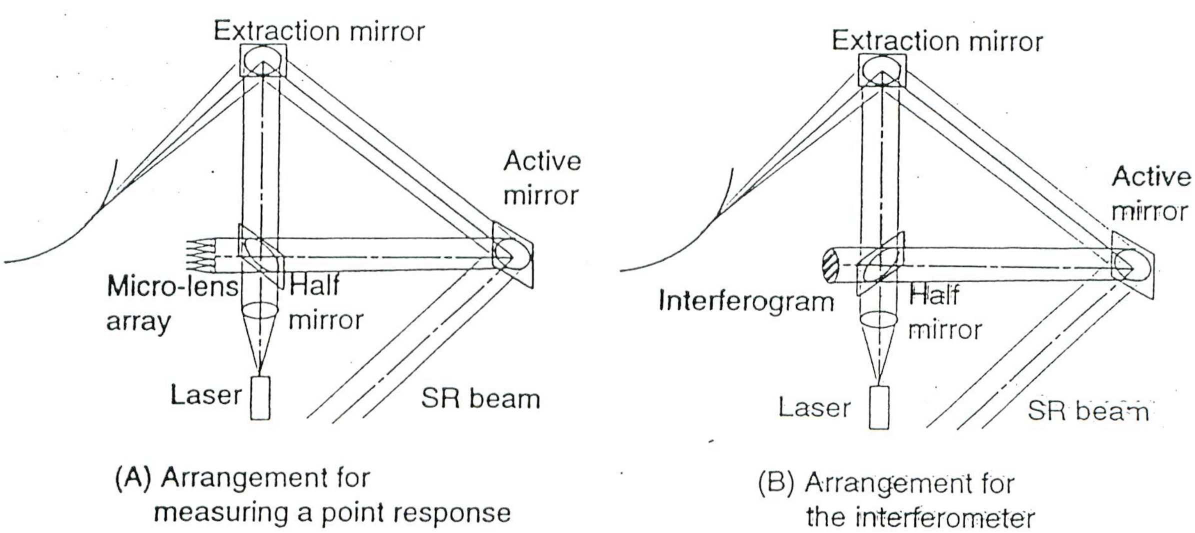


Figure 11.11: The schematic design diagram of the corrective system.

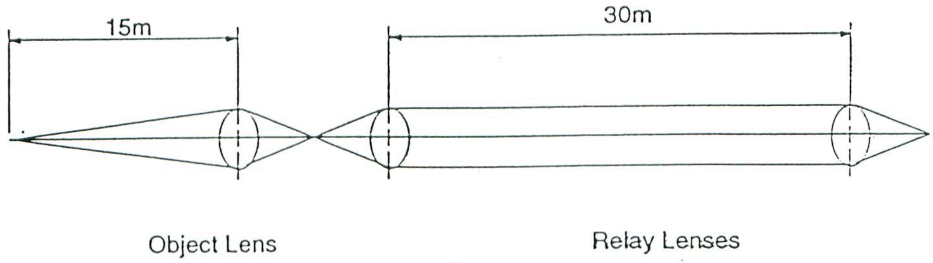


Figure 11.12: A schematic diagram of the focusing system.

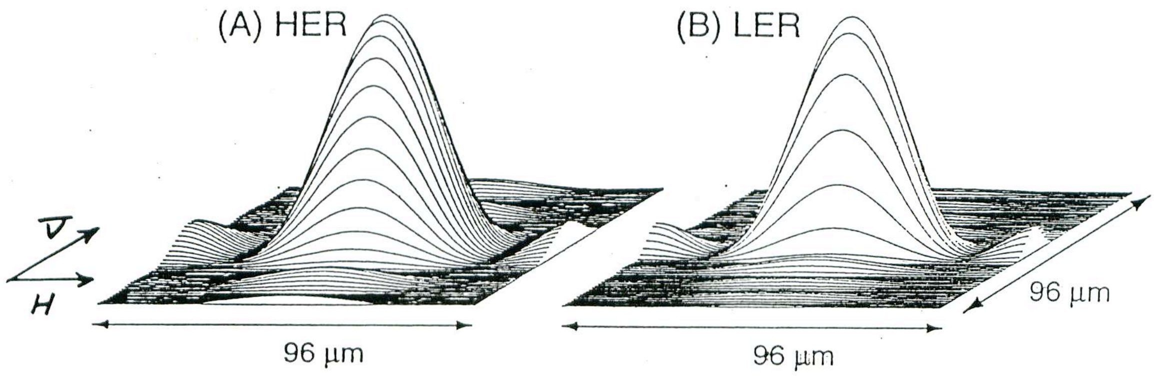


Figure 11.15: The Point Spread Function (PSF) of the focusing system. The side length of the 3-dimensional density plots is 96 μm.

	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.

Laser Wire Monitor (under consideration)

- Individual bunch size measurement

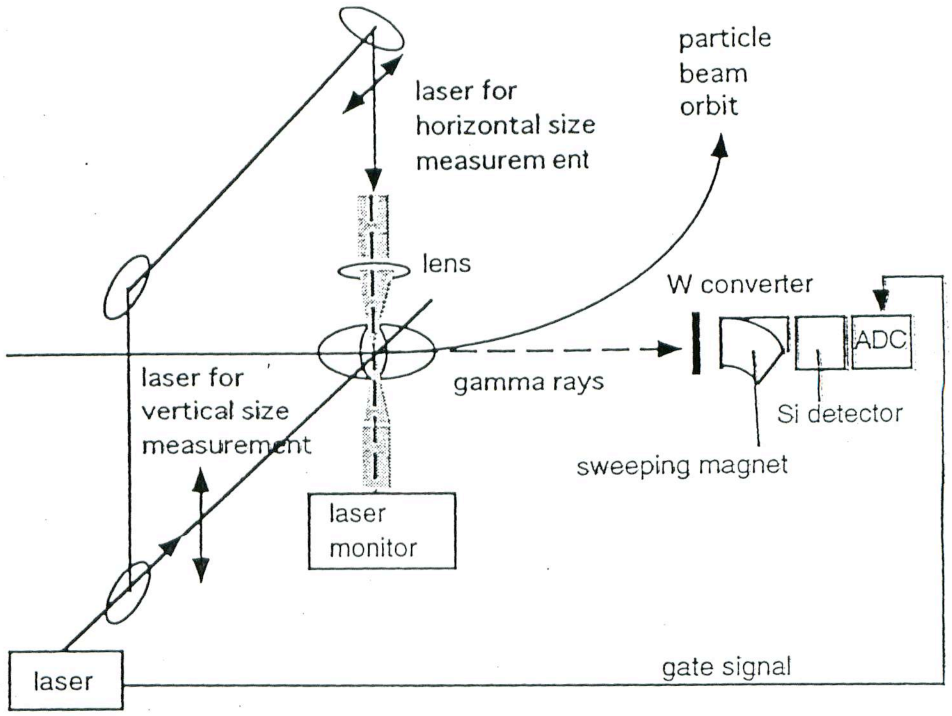


Figure 11.17: Concept of the beam size measurement by laser wires. The lens and laser monitors are necessary for the vertical size measurement as well, although they are not shown in the figure.

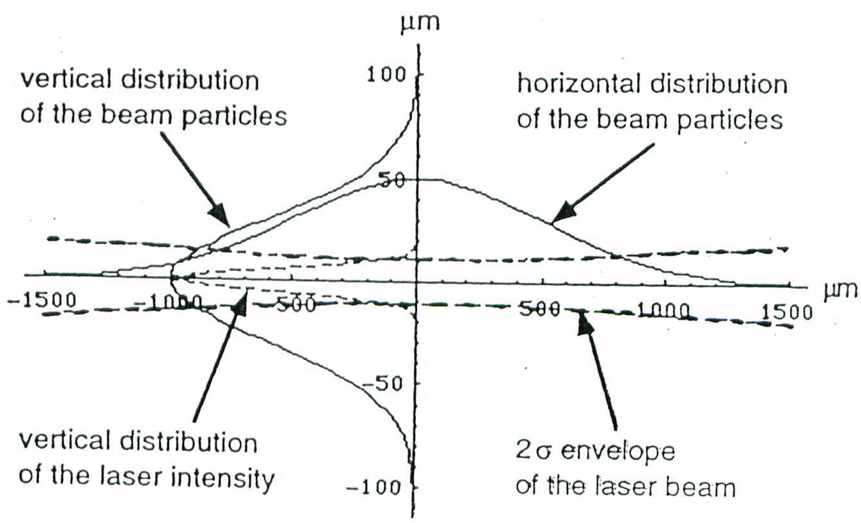


Figure 11.18: A design example of laser-wire dimensions at a typical vertical beam-size measurement. Assumed beam sizes are 30μm vertically and 500 μm horizontally. Laser wavelength λ_L is 355nm and the minimum rms spot size is 5.3μm.

laser : $\lambda_L = 355\,nm$ (3rd YAG)
20 mJ, 100 Hz, 100 ps ($\sigma_{Lz} = 30\,mm$)
$\sigma_L = 5.3\,\mu m$ (spot size at $e^\pm$ beam)
$L_R = 4\pi\sigma_L^2/\lambda_L = 2\sigma_x = 1\,mm$

$e^\pm$: bunch current $\begin{cases} 0.5\,mA & LER \\ 0.2\,mA & HER \end{cases}$
$f_r = 100\,kHz$
$\sigma_x/\sigma_y = 500\,\mu m/50\,\mu m$
$\sigma_z = 5\,mm$

- γ-event
  $N_\gamma \lesssim 1.65 \times 10^5\ sec^{-1}$
- background (bremsstrahlung ; $E_\gamma > 20\,MeV$)
  $\lesssim 50\ sec^{-1}$ $\left(\begin{array}{l} P = 10^{-8}\,torr \\ I_b = 2.5\ A \end{array}\right)$

$\longrightarrow$ statistical error < 1 % in a few minutes

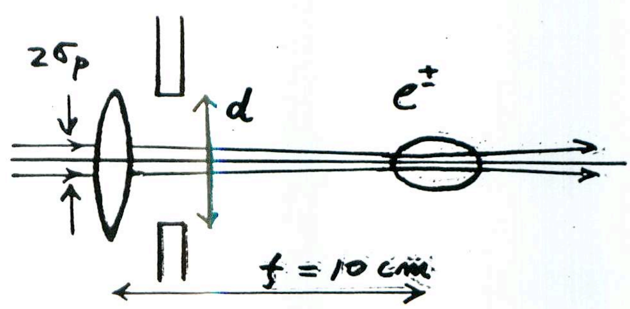
- minimum vertical size $\approx 30\,\mu m$

$\longrightarrow$ $(30^2 + 5.3^2)^{1/2} = 30.4\,\mu m$ (observed)

- laser window size

$d \sim 6 \times (\sigma_{x,y}^2 + \sigma_p^2)^{1/2}$

$= \begin{cases} 5.4\,mm & (Hori.) \\ 4.5\,mm & (Vert.) \end{cases}$



$\sigma_p = \frac{4}{3}\frac{\lambda_L f}{4\pi\sigma_L} = 0.75\,mm$