Test Results using Iris and Airy disc for the BPM Alignment of SCSS (SPring-8 Compact SASE Source) Prototype Accelerator

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FEL machine Plan at SPrng-8 site

λ: 0.06 nm

Energy : 8 GeV

length : 800m

We are making basic design of the building, now.

Contents

1) SCSS prototype accelerator

2) How to align BPM for FEL?

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5) Calculation of the center

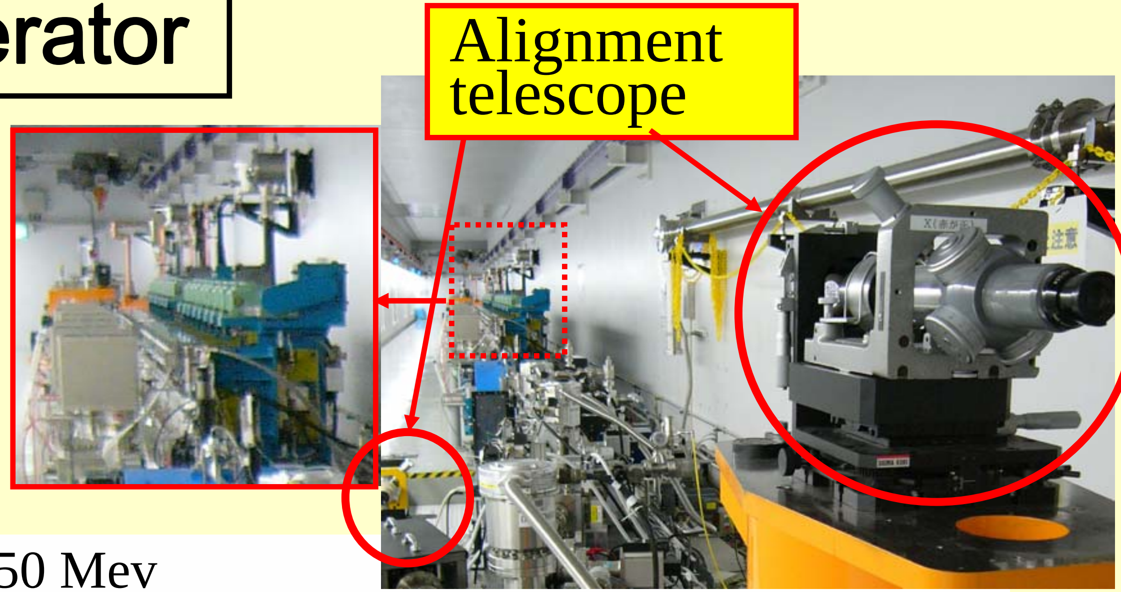
6) Test Results :

(1) Calibration between BPM and Iris, (2) Diameter and brightness of airy disc, (3)Reproducebility, (4)Fluctuation, (5) Stability, (6) Effect due to Gaussian, (7) Check of laser and Iris - airy disc system

7) Summary

8) Alignment Plan of 18 BPMs for 8 GeV

Prototype Accelerator

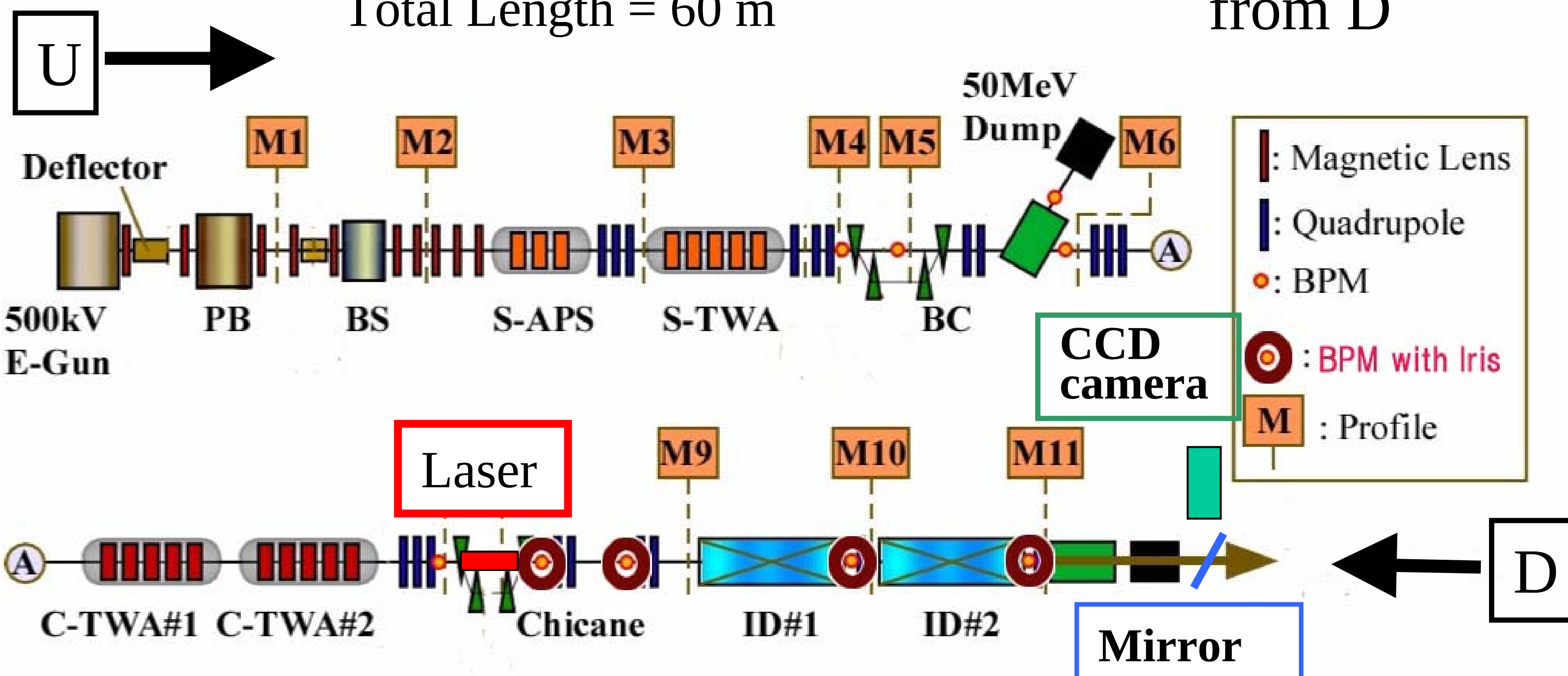


from U

Energy = 250 Mev

Total Length = 60 m

from D



How to align the BPM on the linear line?

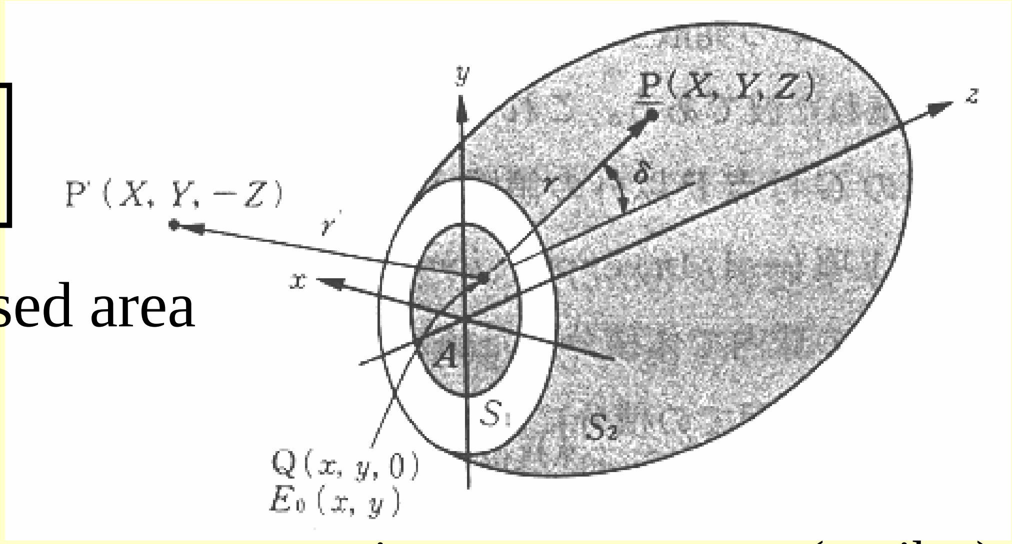
Tolerance : ~ 5 μm / 5 m
Number of BPMs : 18

1) Using outside the BPM
   - mechanical error ~ 10 μm
   - need HLS or wire or laser(in vacuum) or other
2) Using inside of BPM
   - the mechanics of sensor target for in and out
     - Reproducibility < several μm

This test case we choose 2). Laser and Iris-airy disc

Diffraction

Radiation from closed area (surface A)

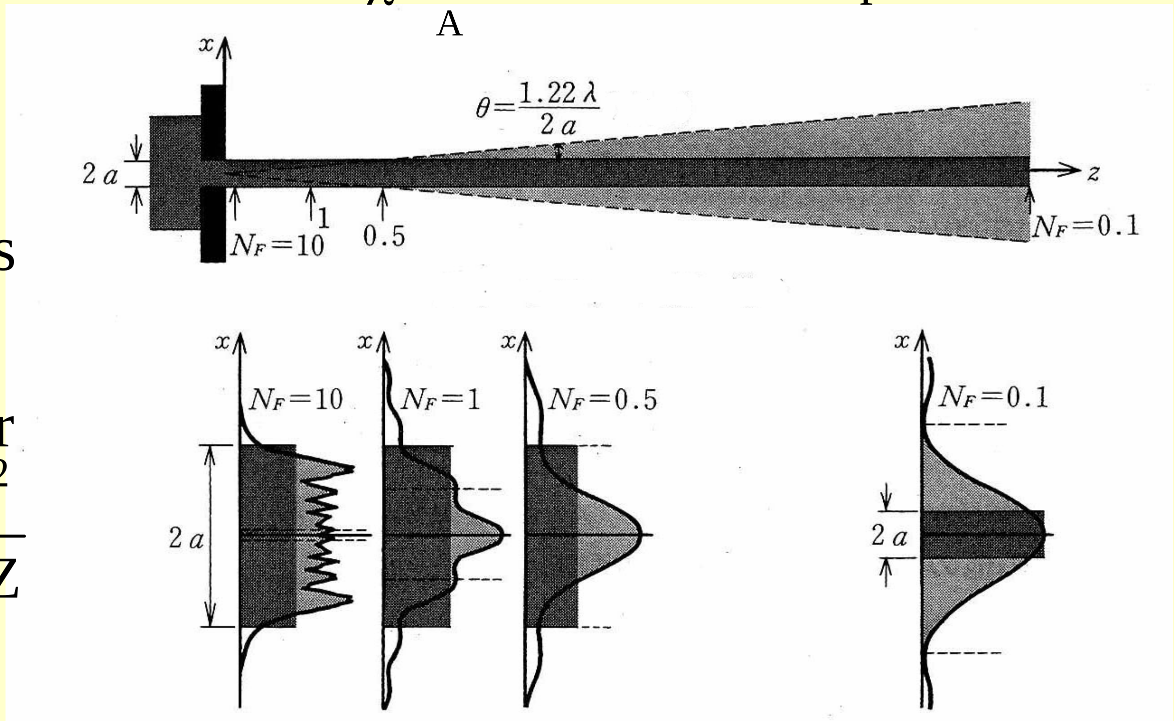


r : distance

$$k = \frac{2\pi}{\lambda}$$

$$E(X, Y, Z) = \frac{j}{\lambda} \iint_A Eo(x, y) \frac{\exp(-jkr)}{r} \cos\delta \, dx\, dy$$

A= disc case=Iris



a : radius of Iris

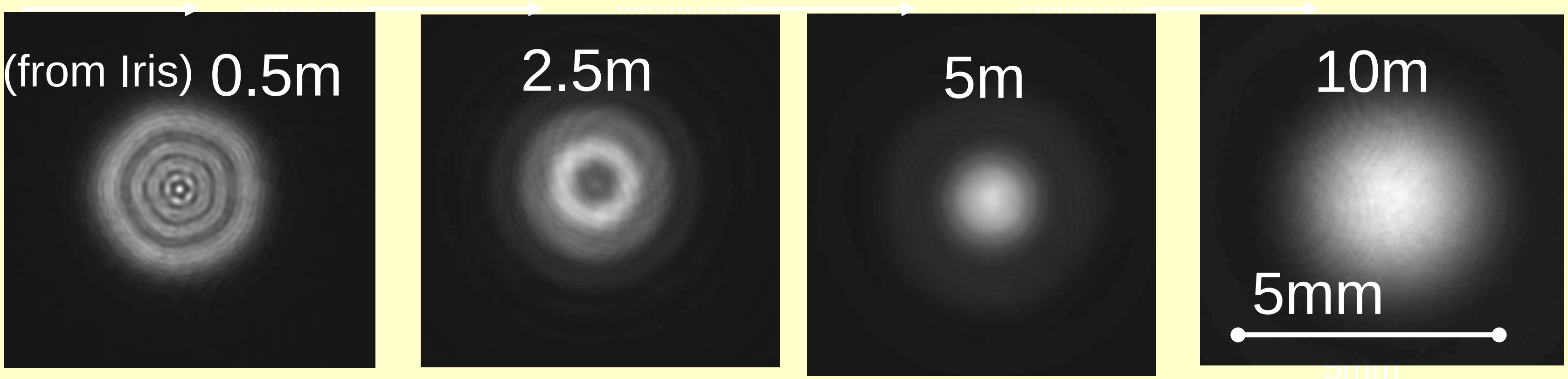
Z: distance

Fresnel number

$$N_F = \frac{a^2}{\lambda Z}$$

Images after the Iris

Iris Φ =3mm

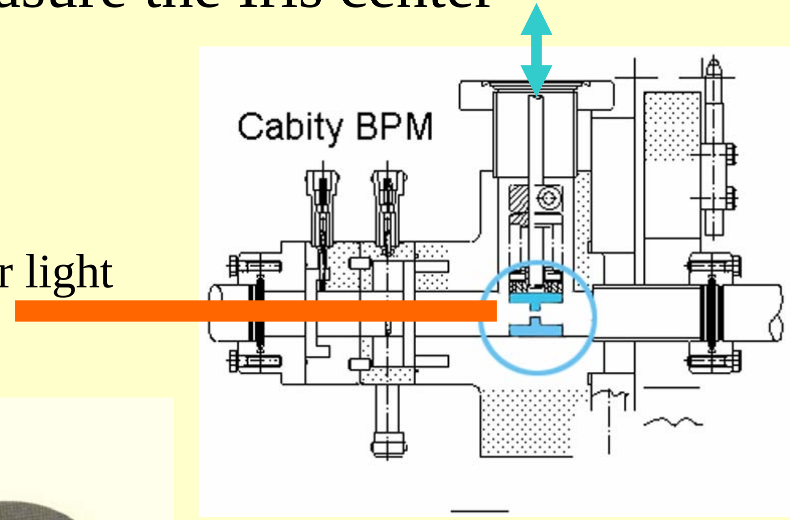


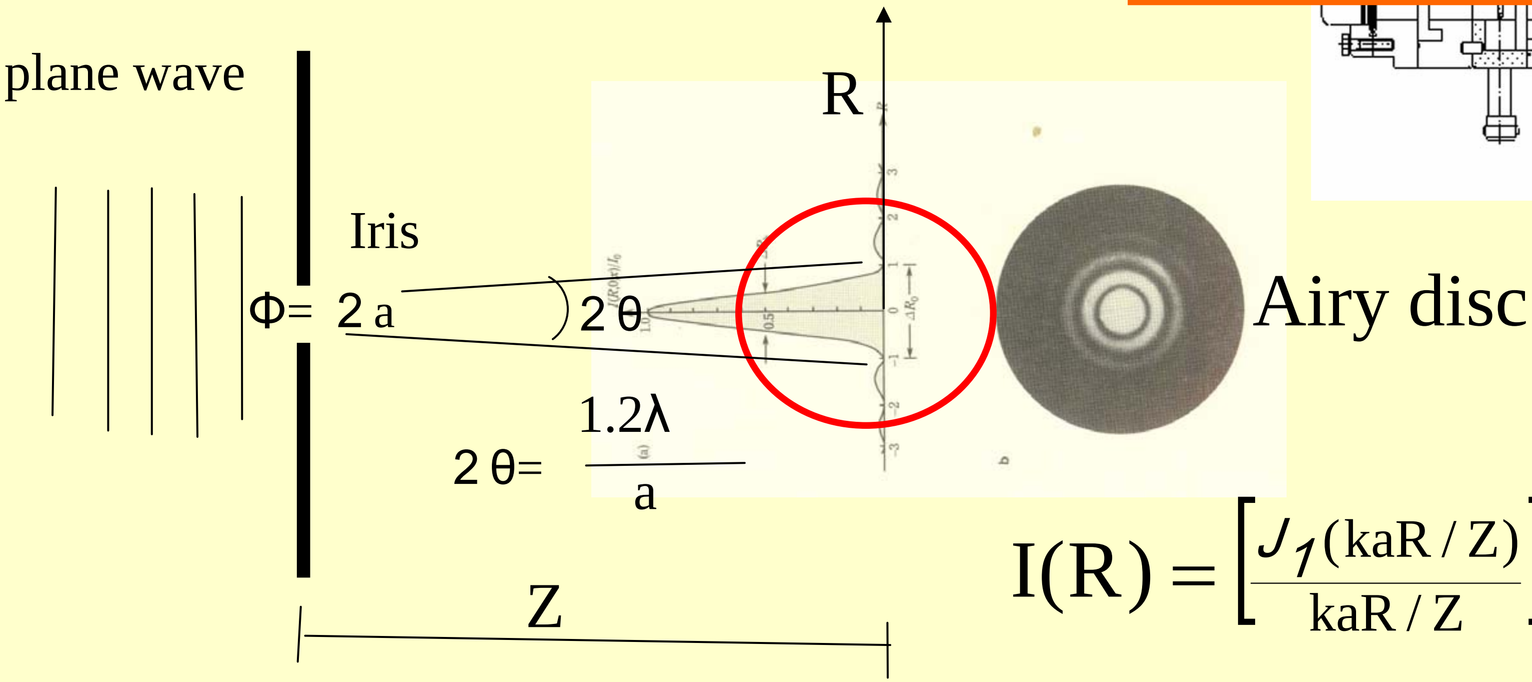
$$\frac{a^2}{\lambda Z} = 7 \qquad 1.4 \qquad 0.7 \qquad 0.35$$

Airy disc

Prinsiple for Masurement of B P M Position using Iris and Airy disc

Insert Iris in the BPM
Measure the Iris center





$$2\theta = \frac{1.2\lambda}{a}$$

$$I(R) = \left[\frac{J_1(kaR/Z)}{kaR/Z}\right]^2$$

J_1: Bessel function

condition : distance $Z \gg \frac{a^2}{\lambda}$

Instruments(1) He-Ne Laser

λ=633nm(red) Output Power=7mW

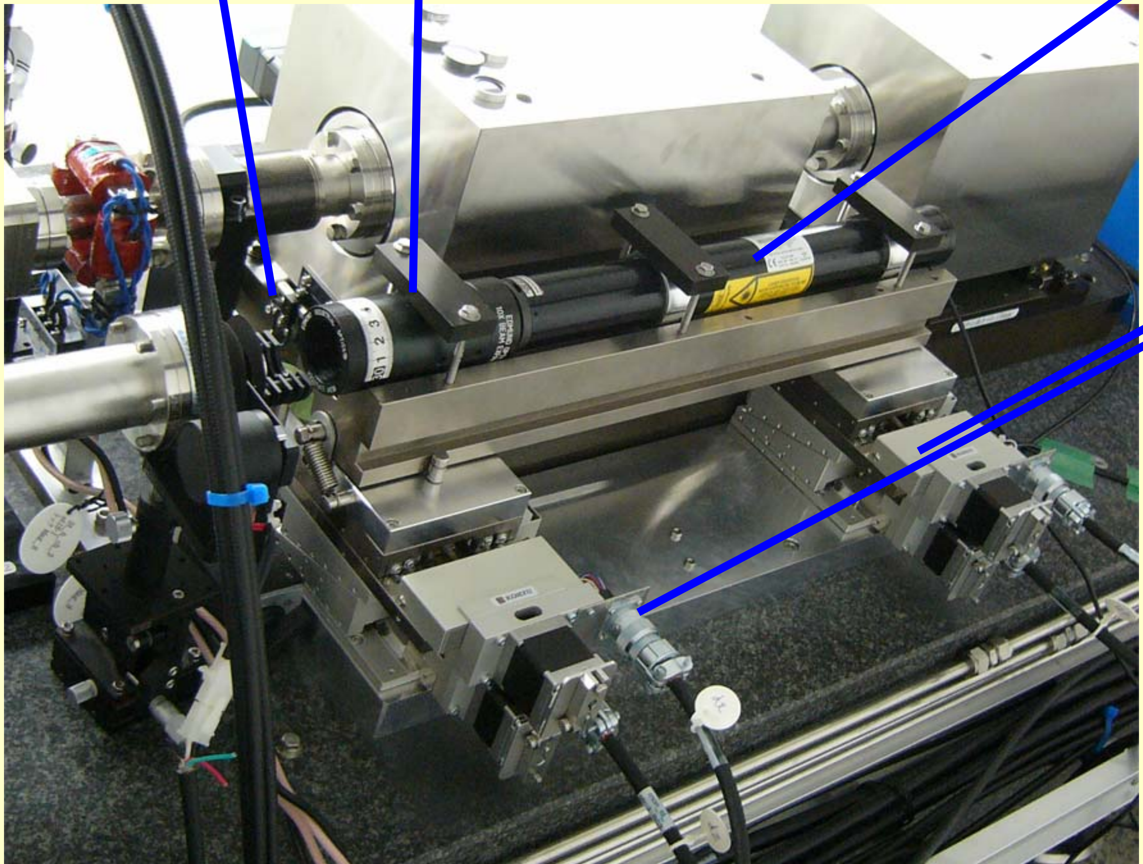
Beam diameter=0.81mm ($1/e^2$)

Beam divergence = 1 mrad

Pointing stability < 0.02 mrad

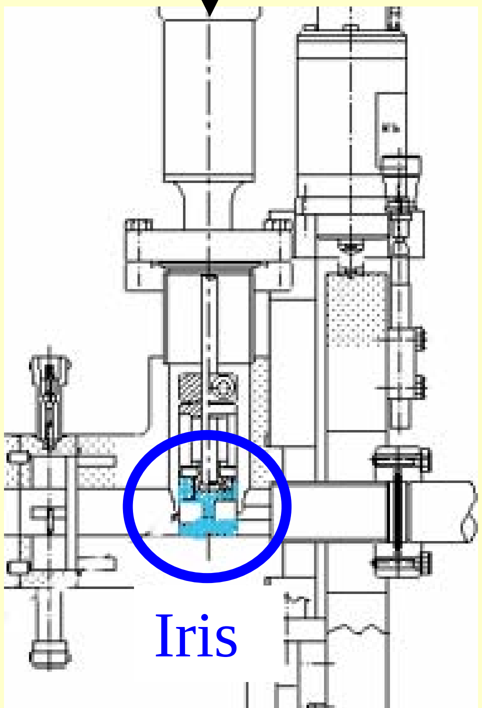
ND filter Expander 10×

Laer tube
Uniphase 1137P



XZ stage ×2
Resolution
X: 2.5μm
Z: 1.25μm

Instruments(2)
BPM with Iris

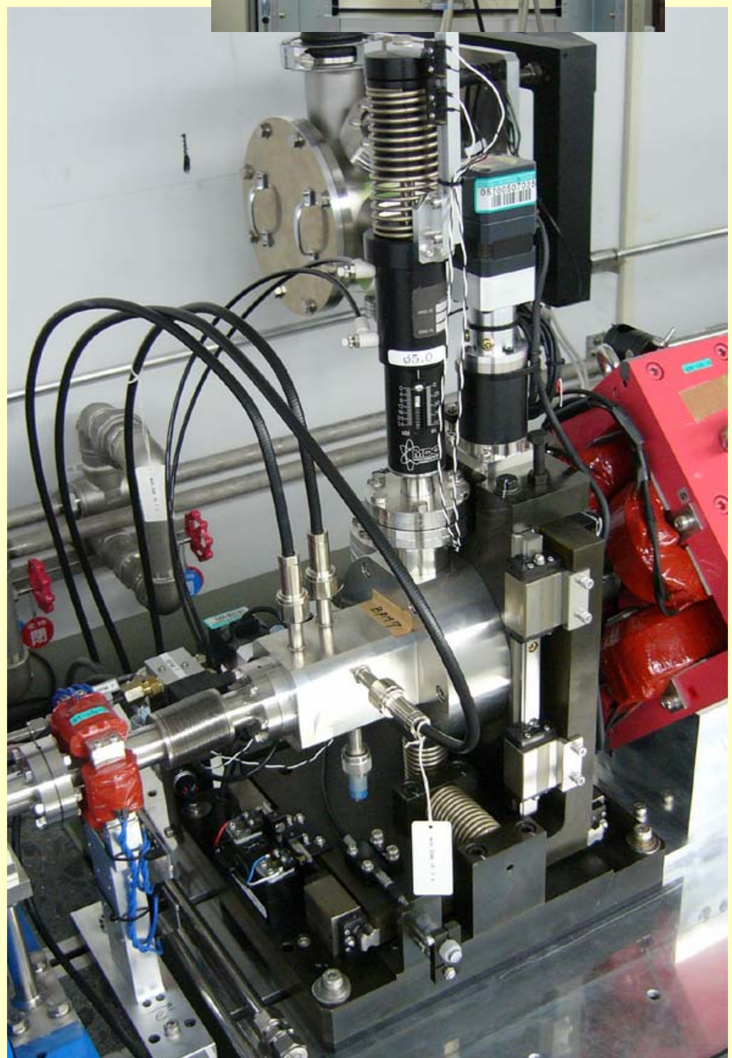


Cavity BPM

XZ stage

Iris controller

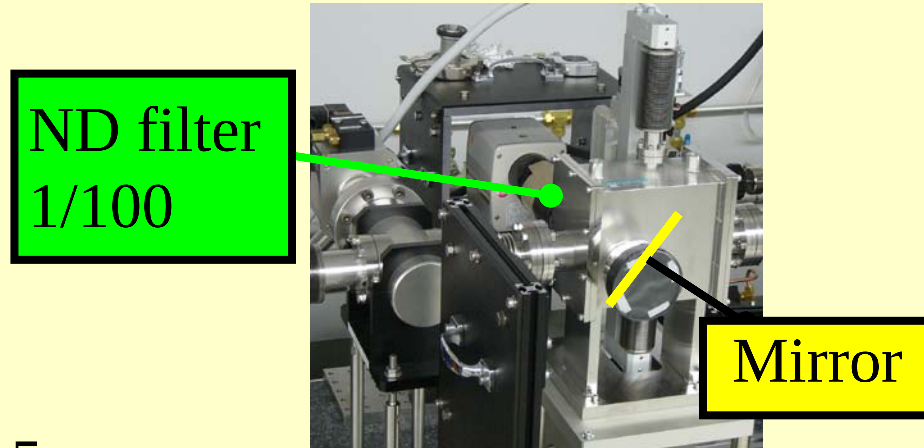
stage controller



XZ stage
Resolution
X: 0.1μm
Z: 0.1μm

BPM is on this stage.

Instruments(3) CCD Camera

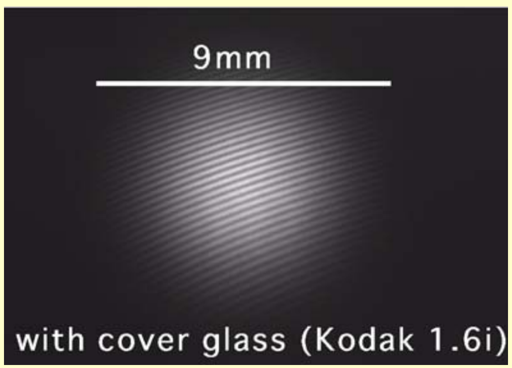


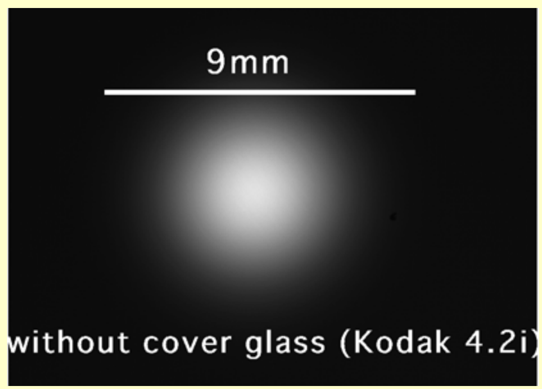
(KODAK 4.2i)

1 pixel 9μm × 9μm

total　2 K × 2 K ~ 18.5mm × 18.5mm

cover glass in front of CCD device is removed to reduce the interference





exposure time is adjustable　mechanical shutter

ADC=8bit max counts=255

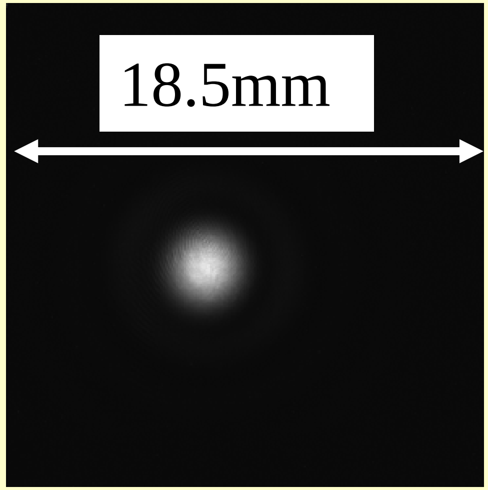
flame board is in the PC

PC is used for Data analysis.

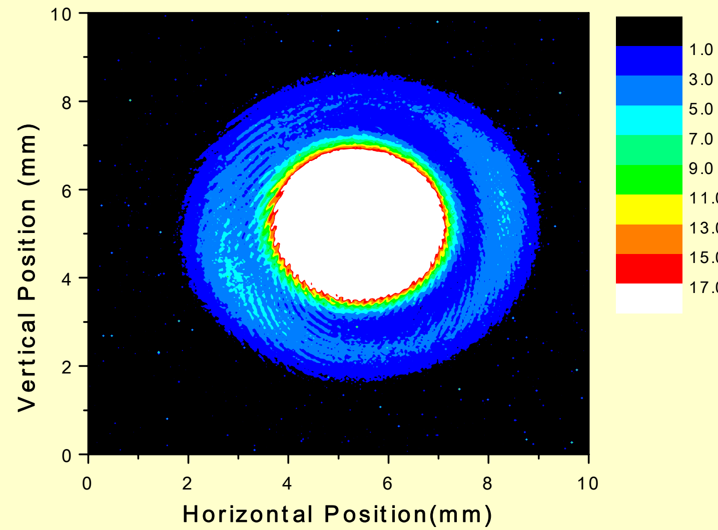
Calculation of the center

Iris 3 insertion

Exposure time 1 sec

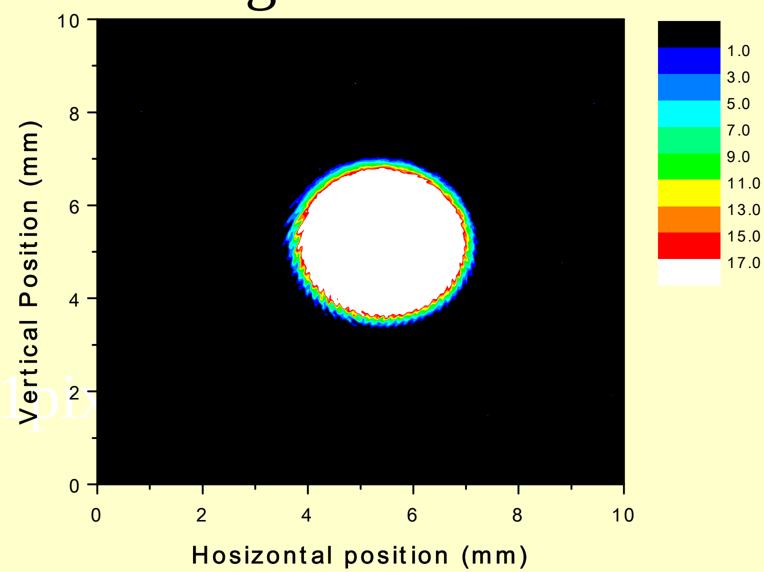


before back ground subtraction

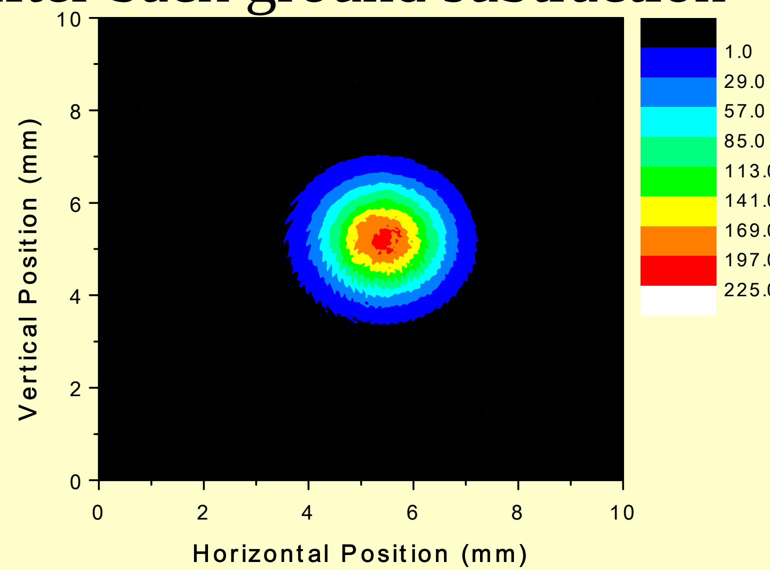


18.4mm

after back ground subtraction

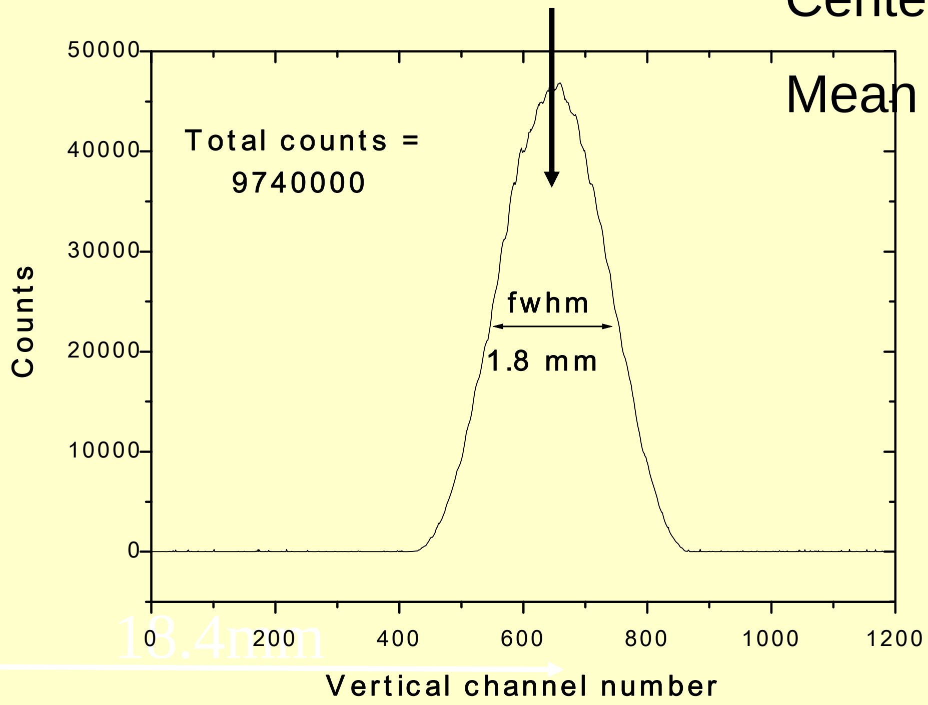


after back ground subtraction



Calculation of the Center

Center position



Center position =

Mean value(gravity center)

$$\mathrm{Resolution} \approx \frac{\mathrm{fwhm}}{\sqrt{\mathrm{Total\ Counts}}} \sim 0.6\mu\mathrm{m}$$

This value is obtained by only 1 flame.(~1 sec)

Improved by average

Test result(1)
Calibration between Cavity Center and Iris one

1)Search the center position as measuring output from cavity BPM

Wire : Cu 0.05mm RF: 4 to 6 GHz

2)Insert Iris and same search as 1)

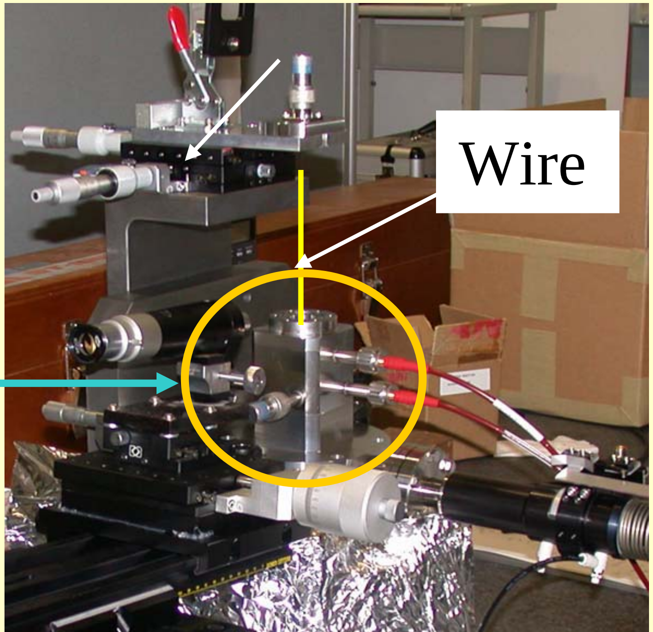
Results of 3 BPMs

RF center - Iris center = horizontal :2.5, -2, -0.5, μm

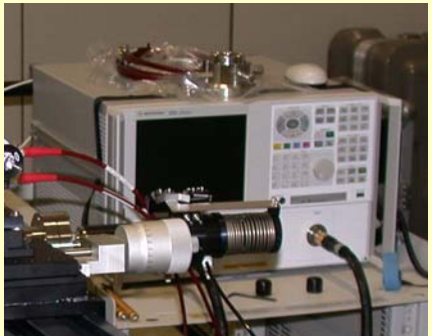
vertical : -43.5, -24.5, -46.5μm

Iris center is lower than the cavity center.

BPM

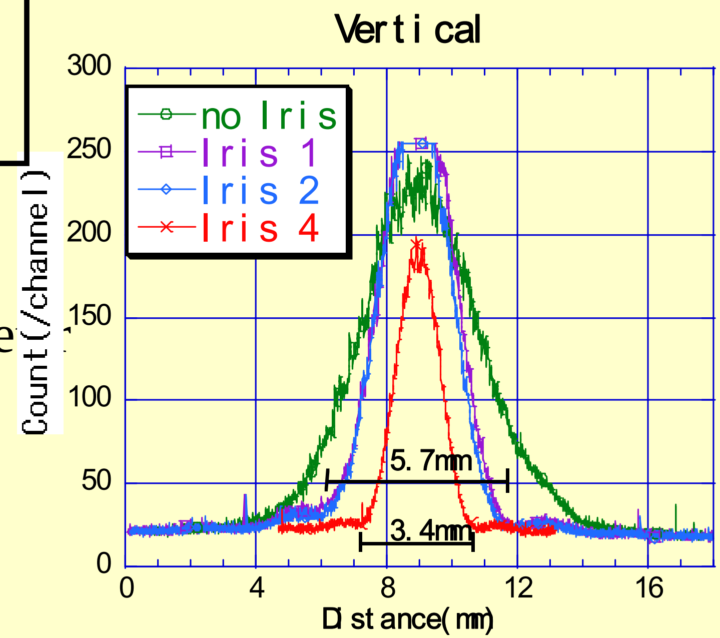


measurement



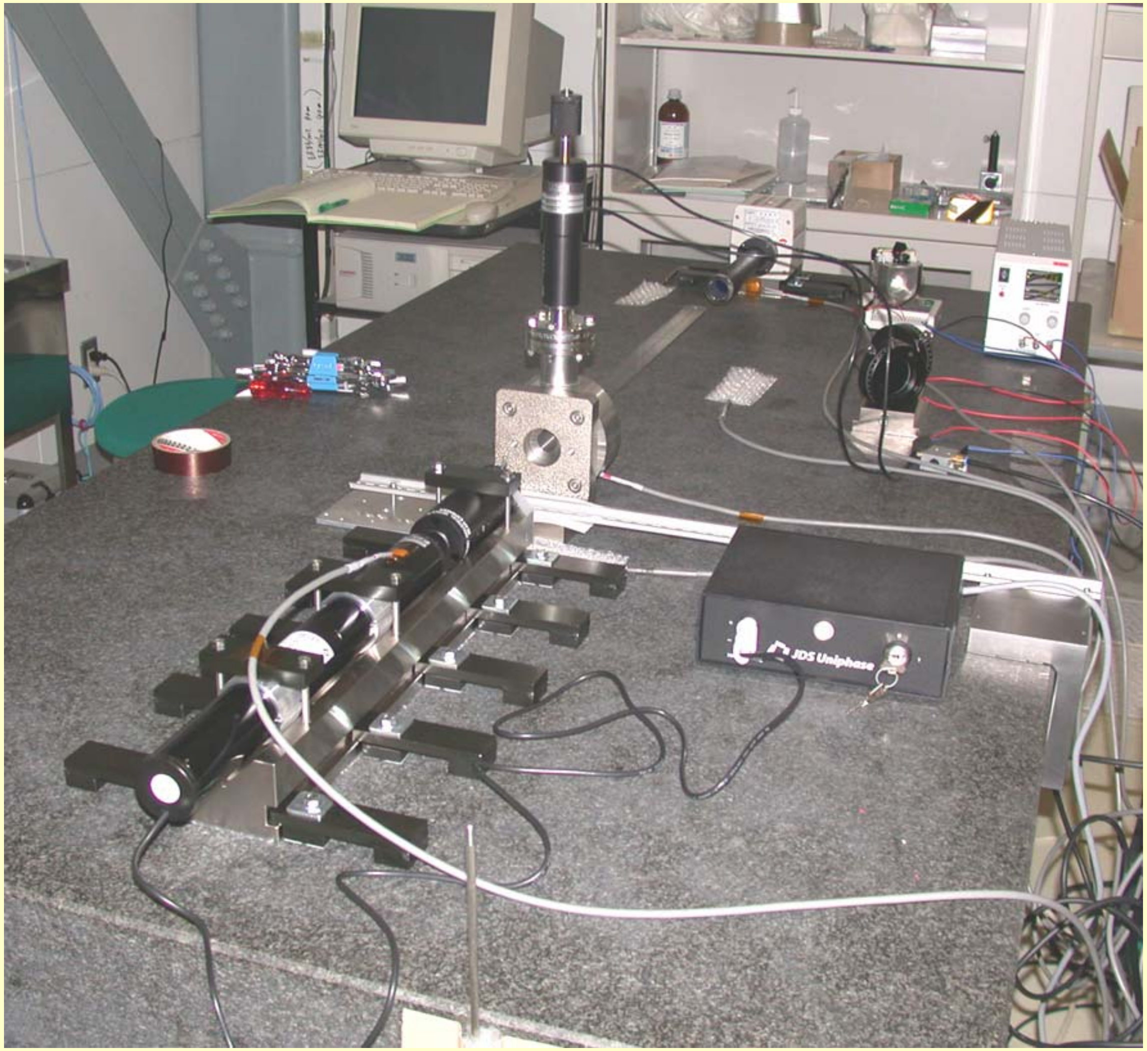
Test Results (2)
Diameter and brightness of Airy disc

Iris No	distance (Iris-ccd-camera)	Iris diameter (design)	Airy disc diame (design)
1	19m	5.0mm	5.8mm
2	16.5m	4.5	5.7
3	10.4	3.5	4.6
4	4.5	2	3.4



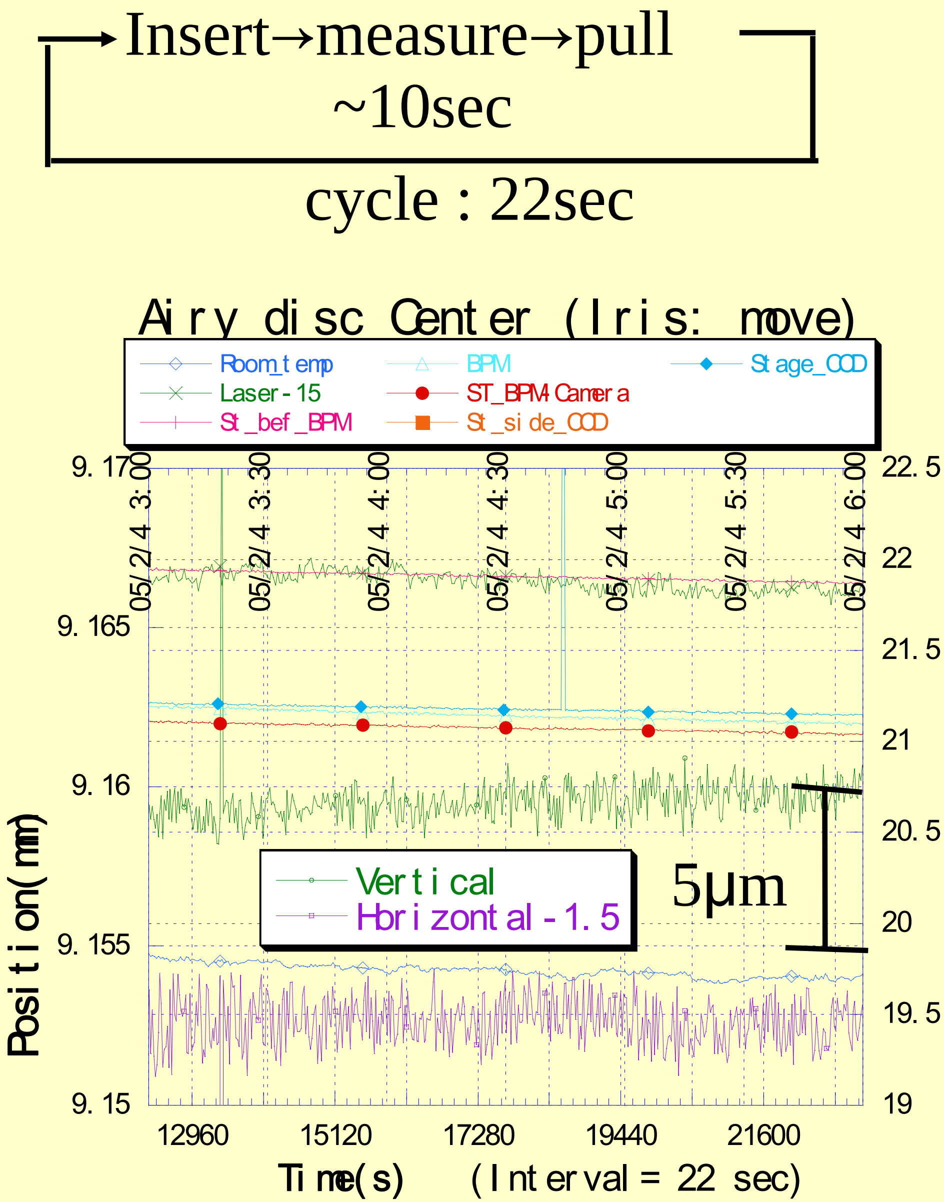
agree with experiment

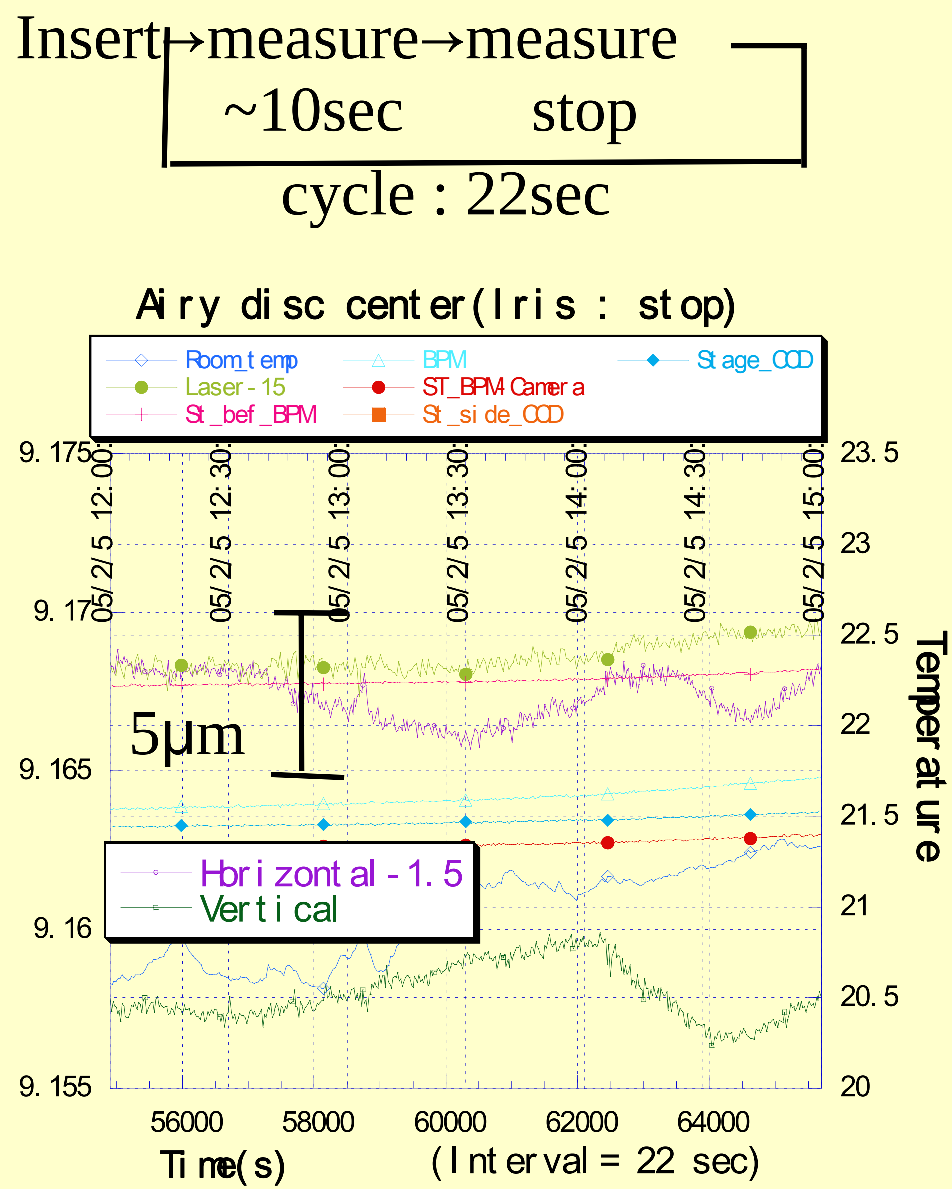
Test Results (3)
Reproducibility of Iris insertion and pull



distance Iris-CCD
camera =1 m

Test Results (3)
Reproducebility of Iris insertion and pull

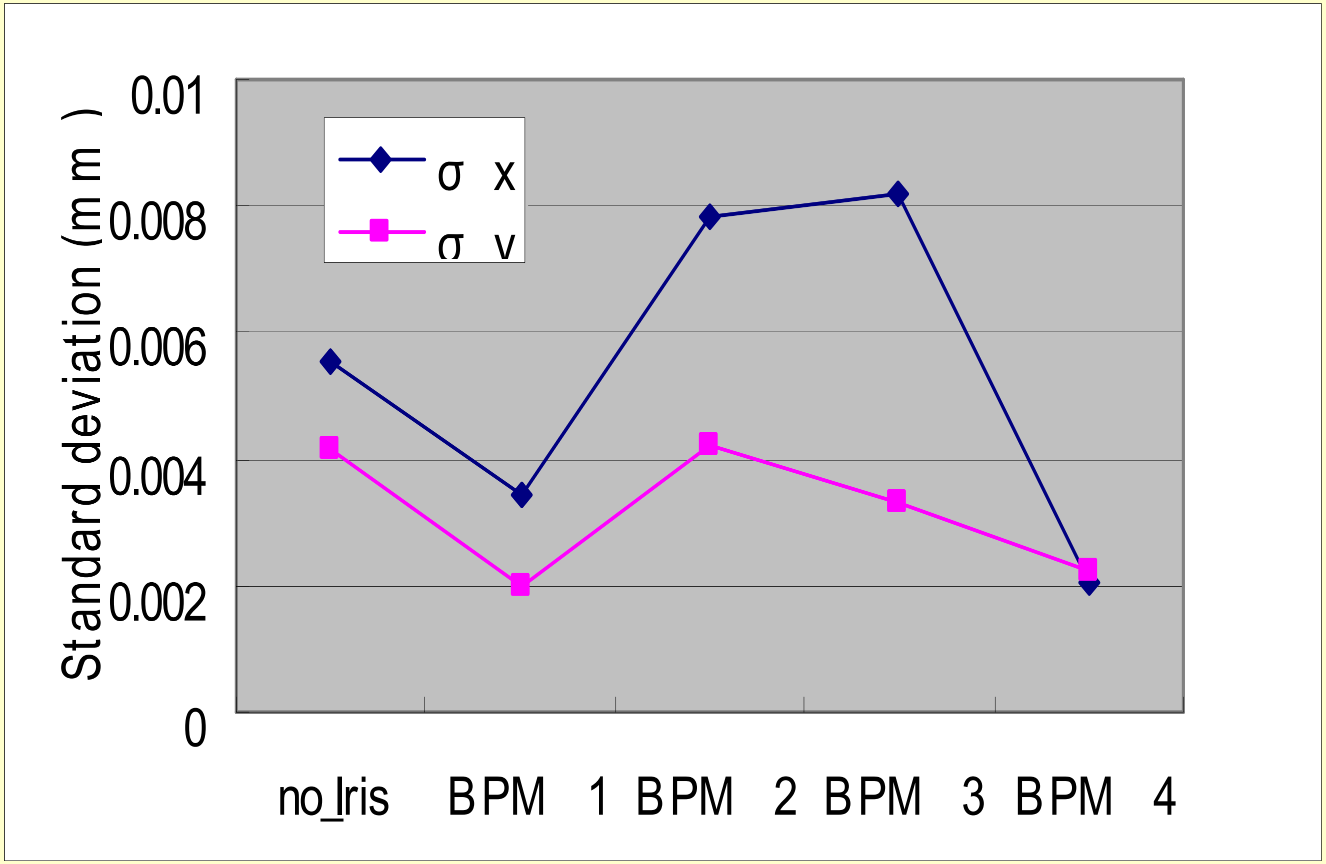




Test Results(4) Fluctuation

1 time: Average of centers among 10 flames ~15sec

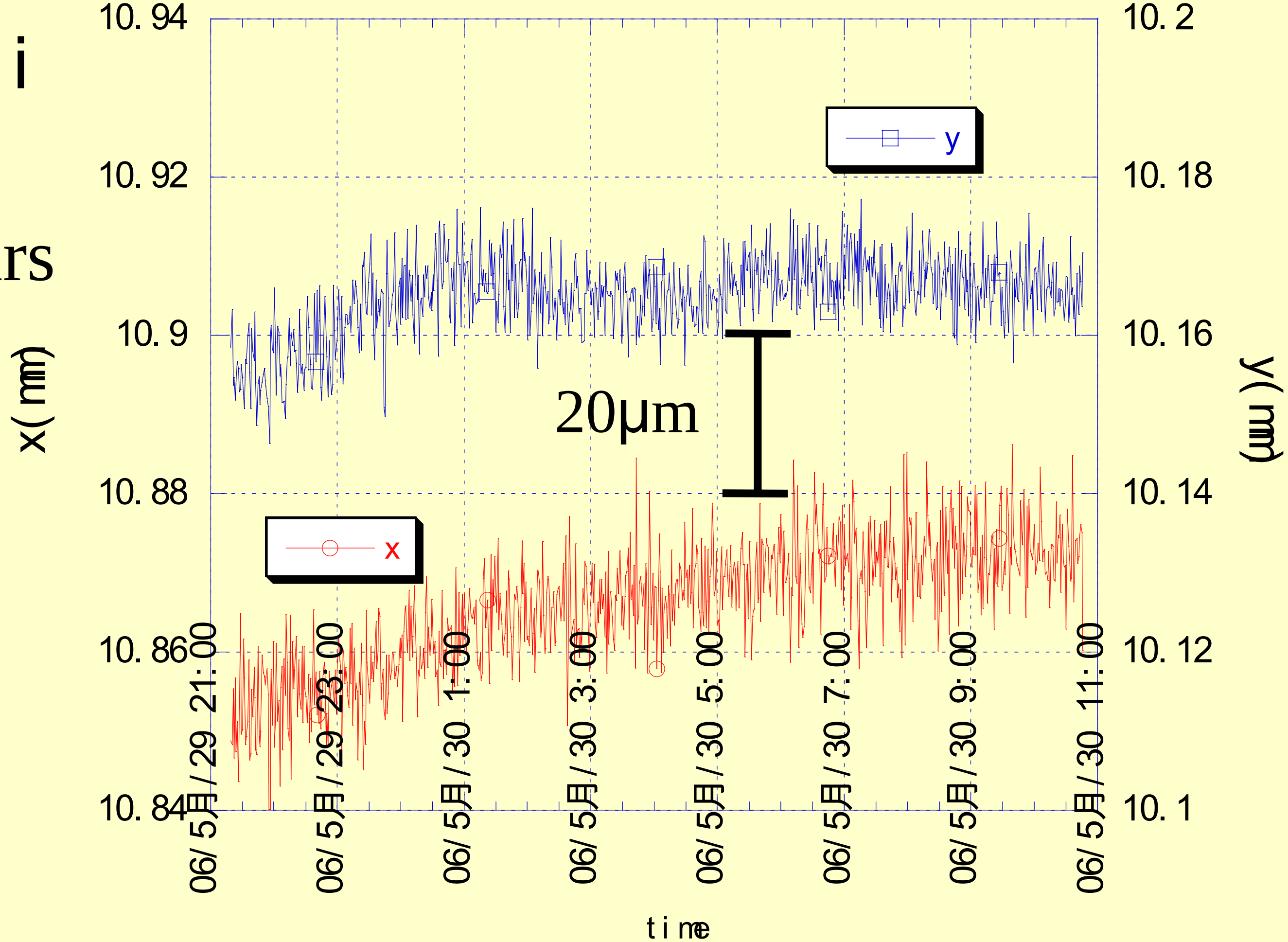
Standard deviation of 4 times ~1 minute



Test Results(5)
Stability

distance (laser - camera)~20m

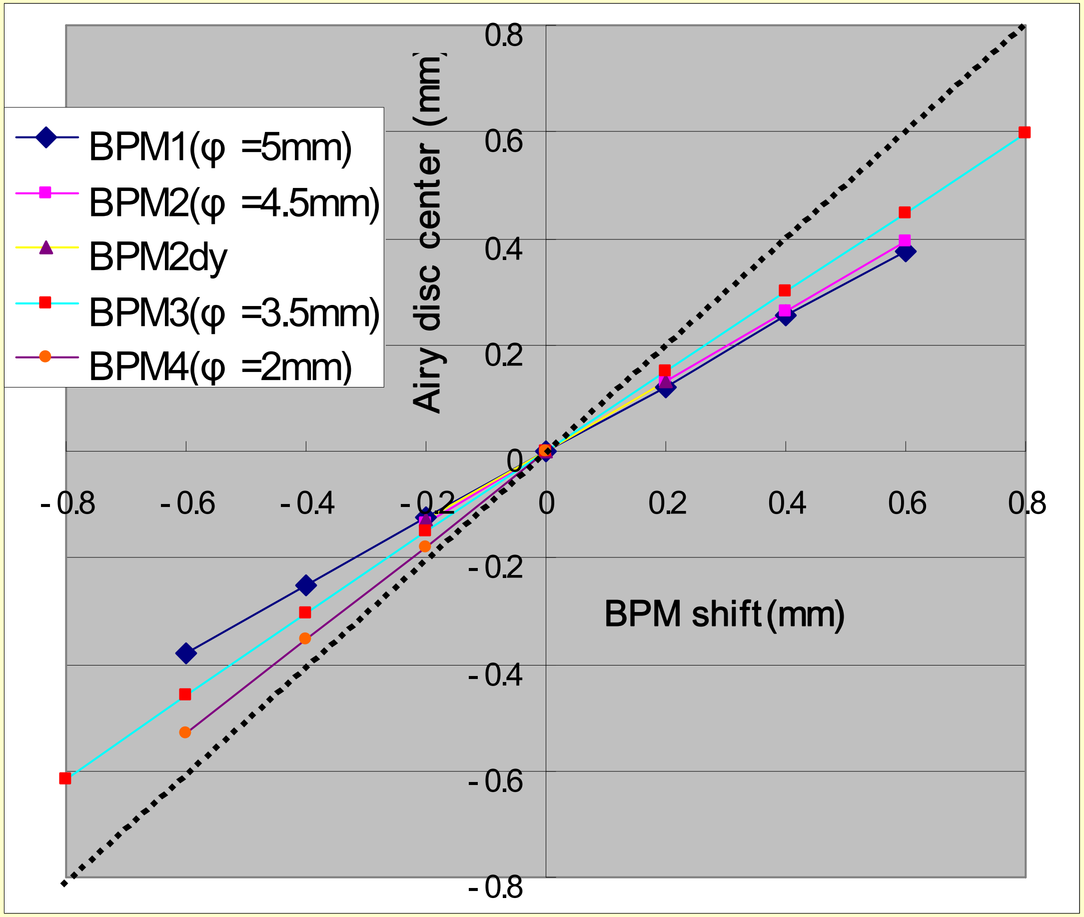
- no Iris
- 14 hours



Test Result(6)
Effect of Gaussian (not plane wave)

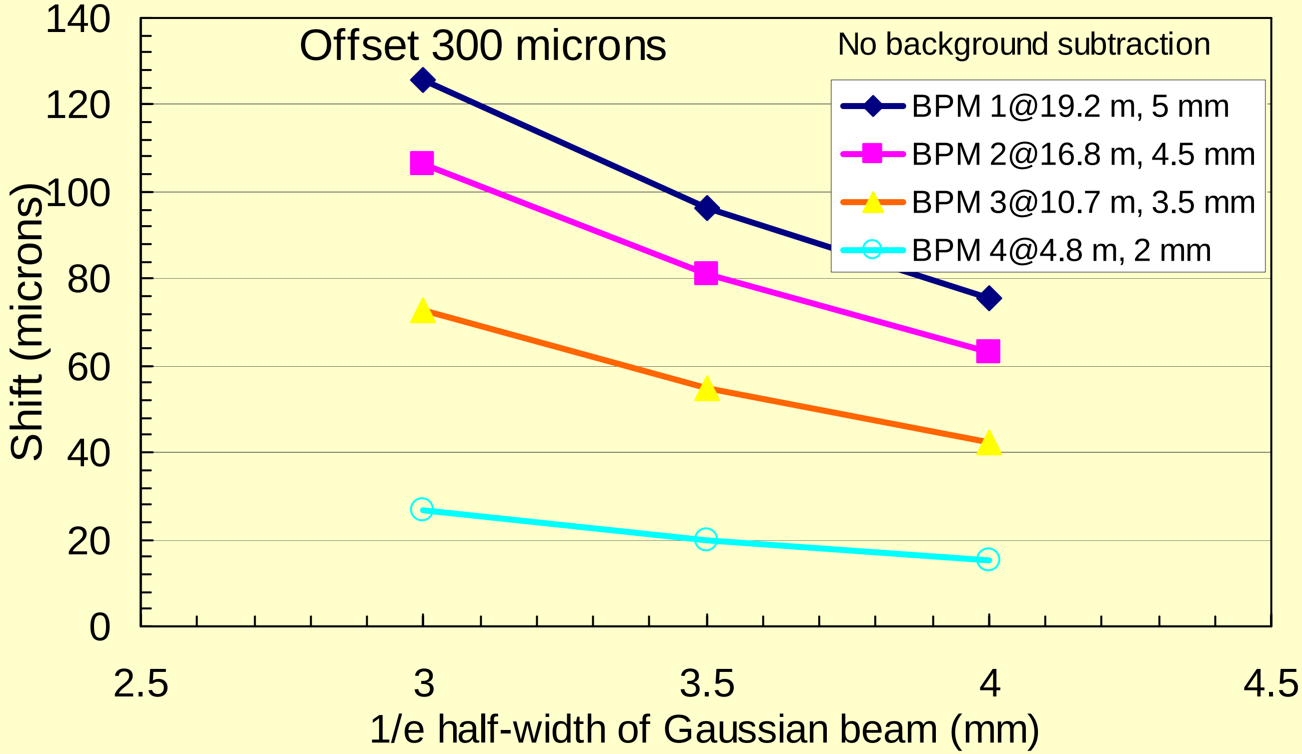
Measure the center as moving Iris

If Iris diameter is large, the effect becomes also large.



Test Result(6)
Effect of Gaussian (not plane wave)

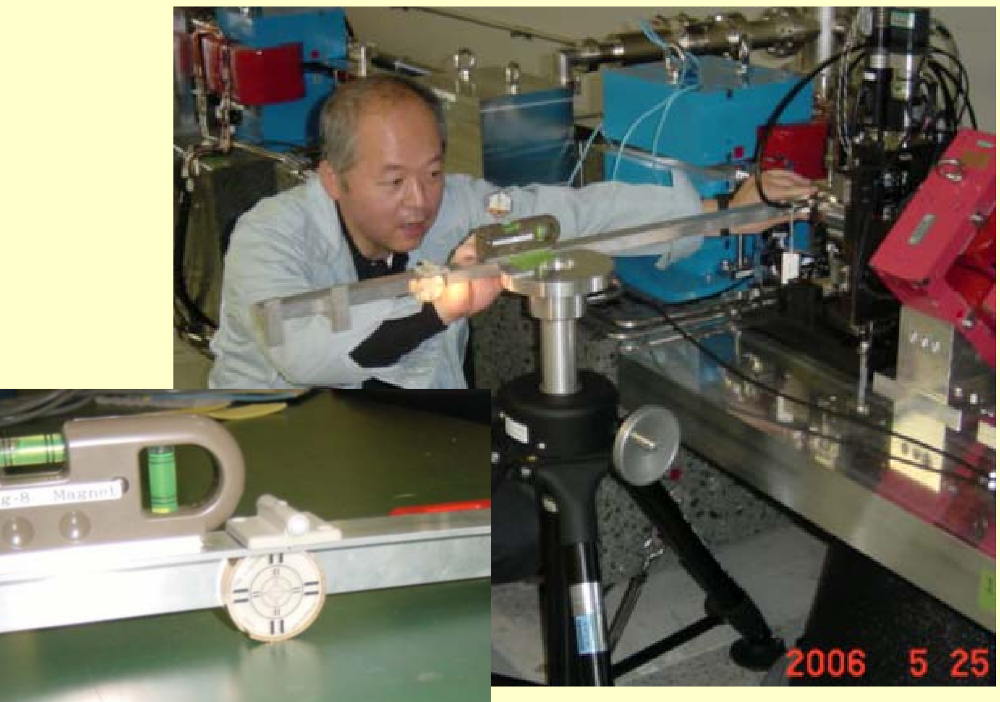
calculation results



Test Results(7)
Check of Laser and Airy disc system

Bar with target is attached to the BPM

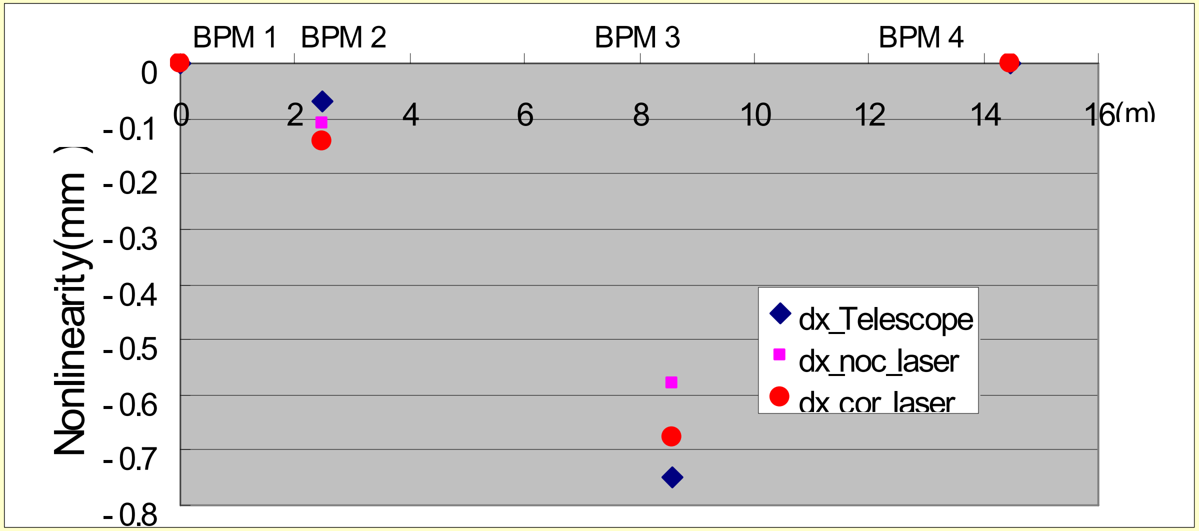
Using alignment telescope (Taylor Hobson) measure the target position from the end of the accelerator



Nonlinearity of BPM2 and BPM3

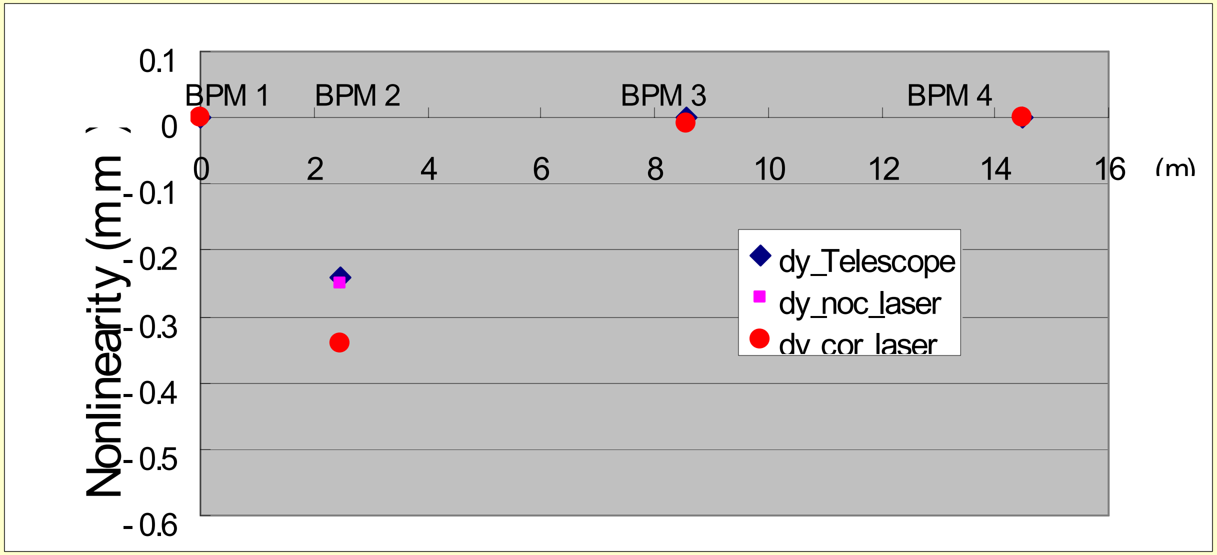
(Reference : BPM1 and BPM4)

Horizontal position



Vertical position

don't include calibration result

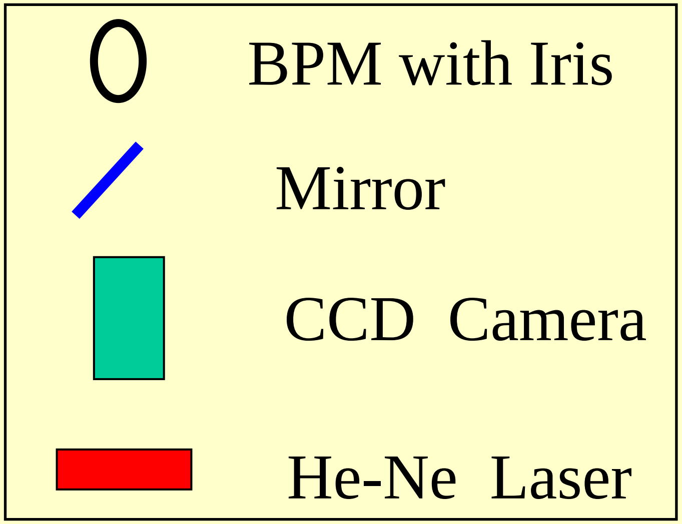


Summary

- It is possible to measure the position of Iris inside the BPM chamber (diameter 20 mm) using airy disc for 20 m range.
- If using red He-Ne laser, it is difficult to travel through 20mm inner diameter for more than 30m at one time.
- It is necessary to estimate the accuracy of this Iris-airy disc system.

  It is necessary to get the flatness of the response in the CCD device. Defect pixels are corrected using next pixel values.
- Check by the other method is also necessary. For example, WPS, HLS, and so on.
- It is important to align the vacuum chamber so that the laser light is not blocked.
- The effect of Gaussian beam must be considered.
- It is necessary to improve the reproducibility of Iris insertion and pull out.
- The fluctuation should be improved by searching the reason.

Alignment Plan of 18 BPMs for 8 GeV

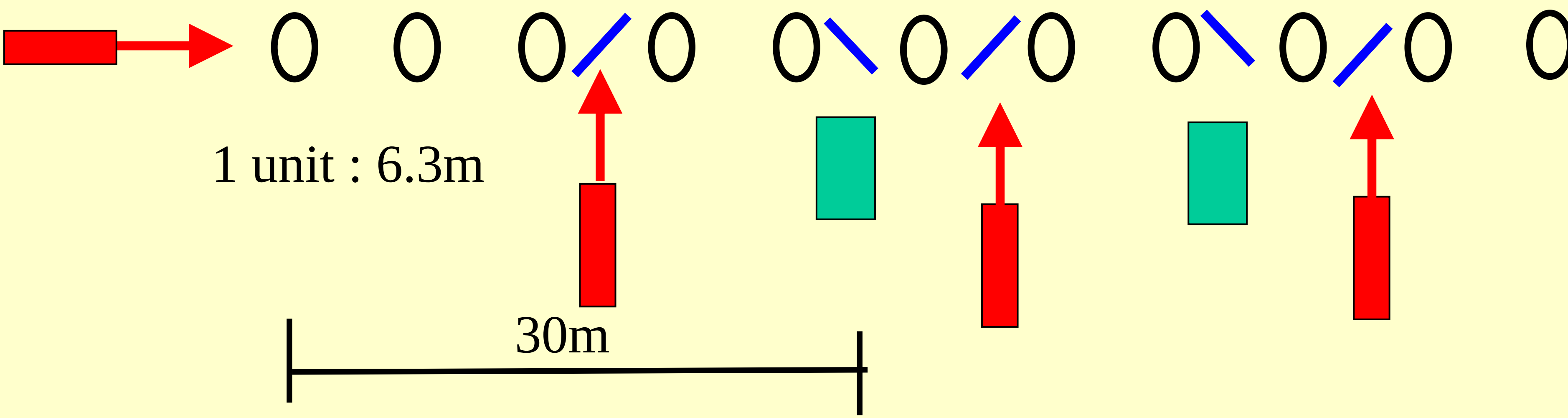


size of parallel light

λ=633nm(red)

distance	diameter
5m ~	3 mm
50m ~	9 mm
100m ~	14 mm

tail part is not included



Thank you