

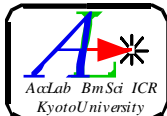


**ACCELERATOR LABORATORY**  
**ADVANCED RESEARCH CENTER FOR BEAM SCIENCE**  
**INSTITUTE FOR CHEMICAL RESEARCH**  
**KYOTO UNIVERSITY**

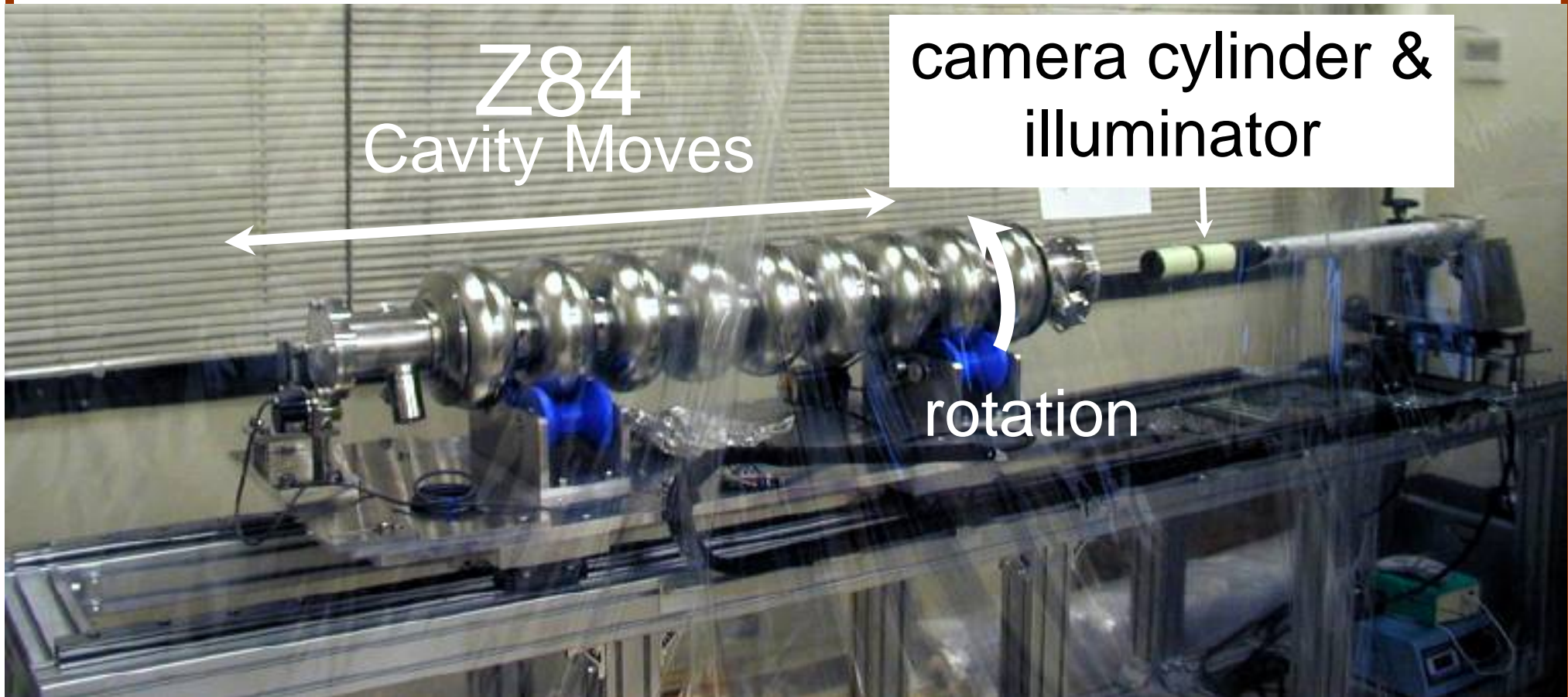


# Development of High Resolution Camera and Observations in TESLA Cavities

Y. Iwashita, Y. Tajima and H. Hayano

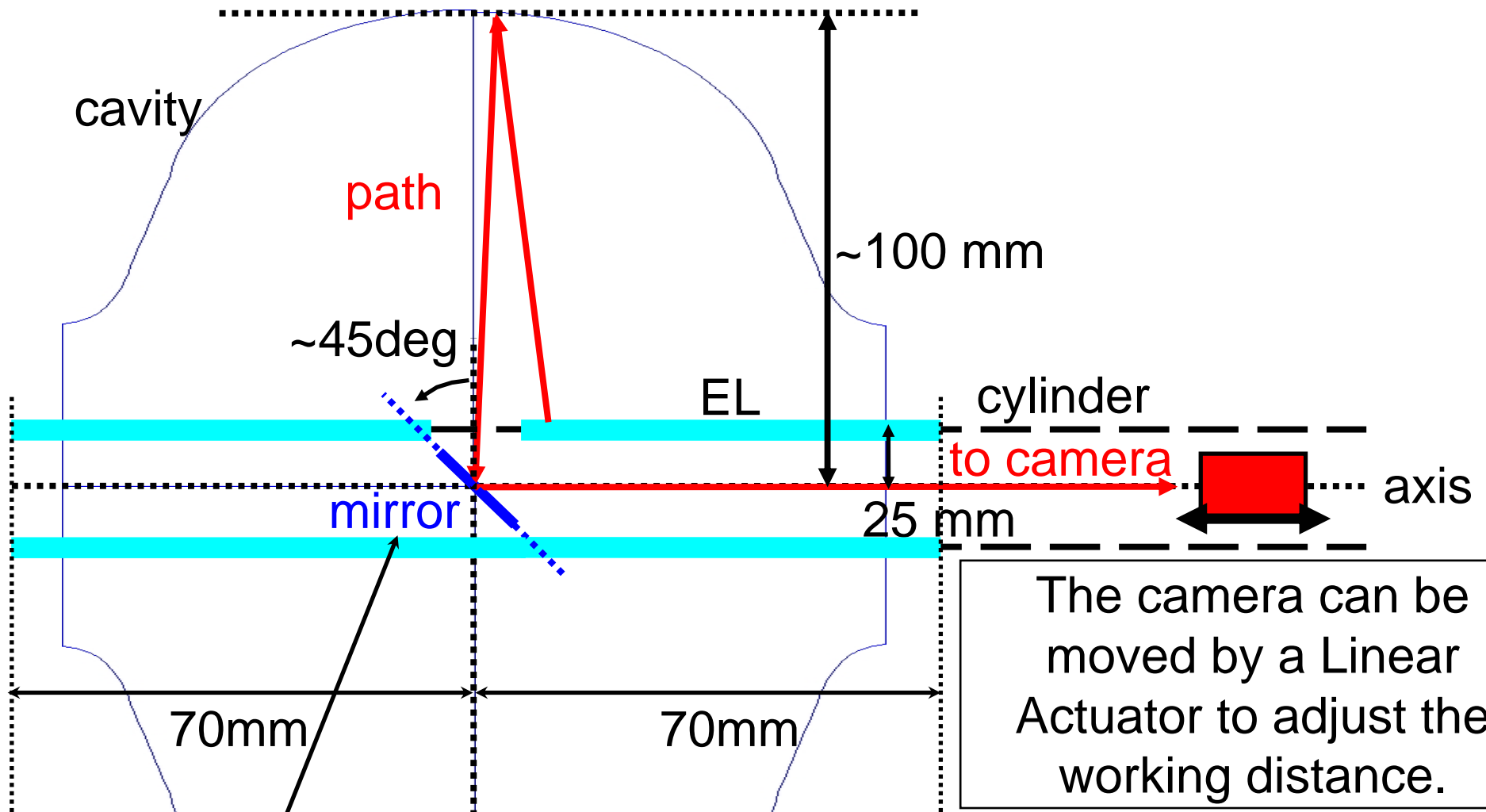


# Early System



Cavity is rotated and moved longitudinally.  
The cavity moves to swallow the camera cylinder.

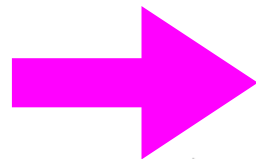
# Inside the Cylinder



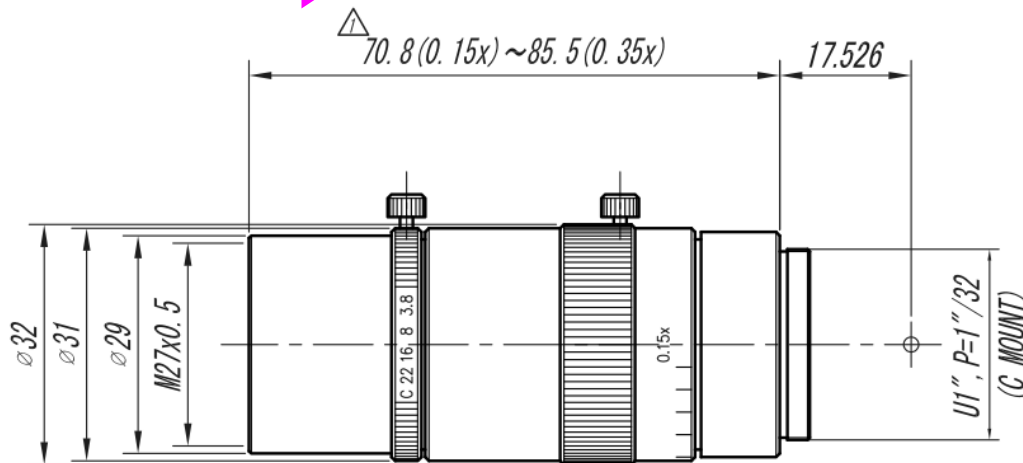
Mirror can be tilted by a Pulse Motor.

# Camera Specification

- 1.5M-pixel CMOS Color Camera  
1400px X1000 px: 5.0 $\mu$ m/px  
Toshiba teli CSF5M7C3L18NR
- Distortionless Lens(0.15x ~ 0.35x, f75mm)  
V.S. Technology Corp. VS-LD75
- 40mm Extension Tube (later)



Maximum resolution: ~0.70x, ~7 $\mu$ m/px (~15 $\mu$ m/px)  
Limited by the Working Distance~120mm



VS-LD75



CSF5M7C3L18NR



# Setup of Illumination

Blue Electro-Luminescence (EL) sheet



mirror: ~40deg

Blue EL sheet

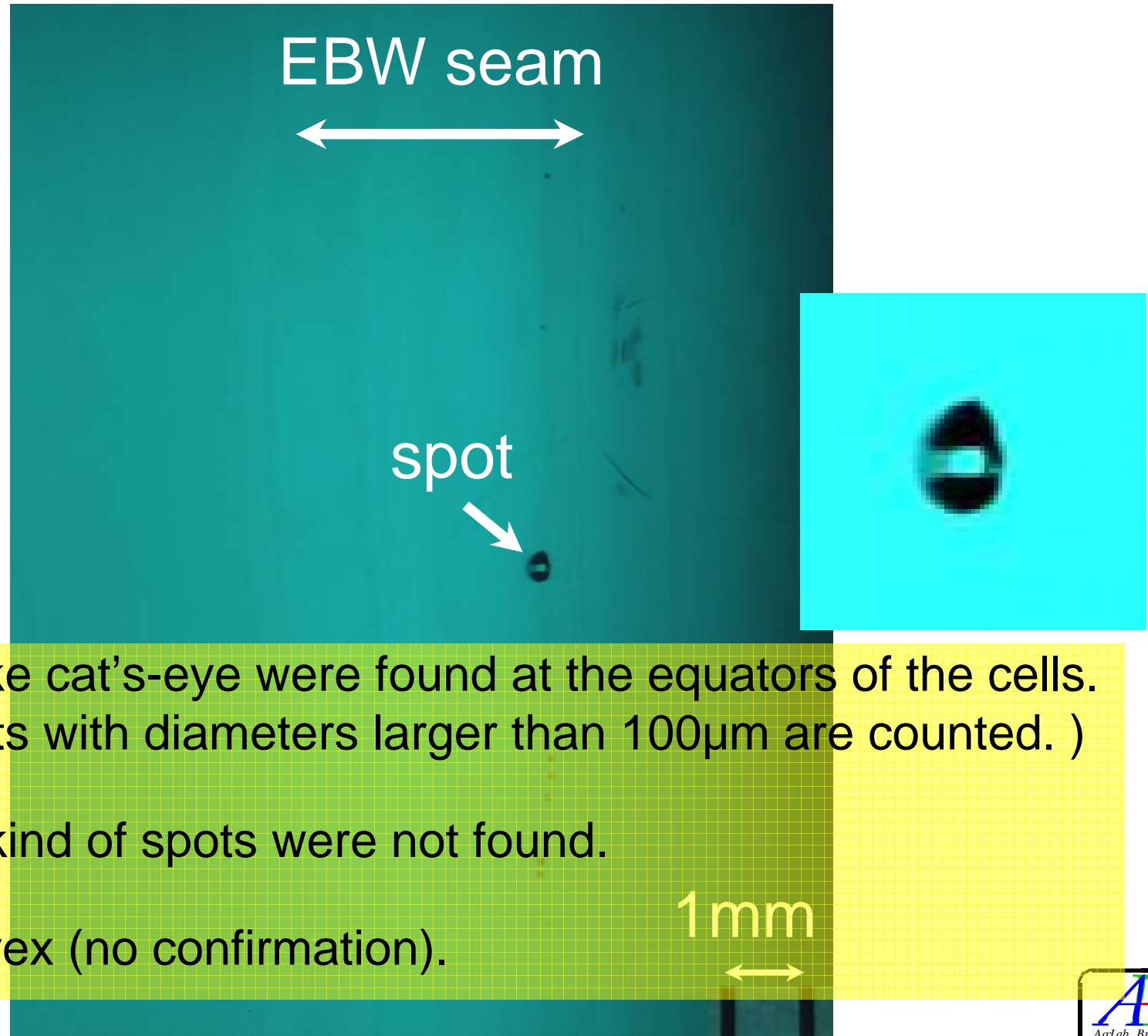


# Zanon #84 cavity



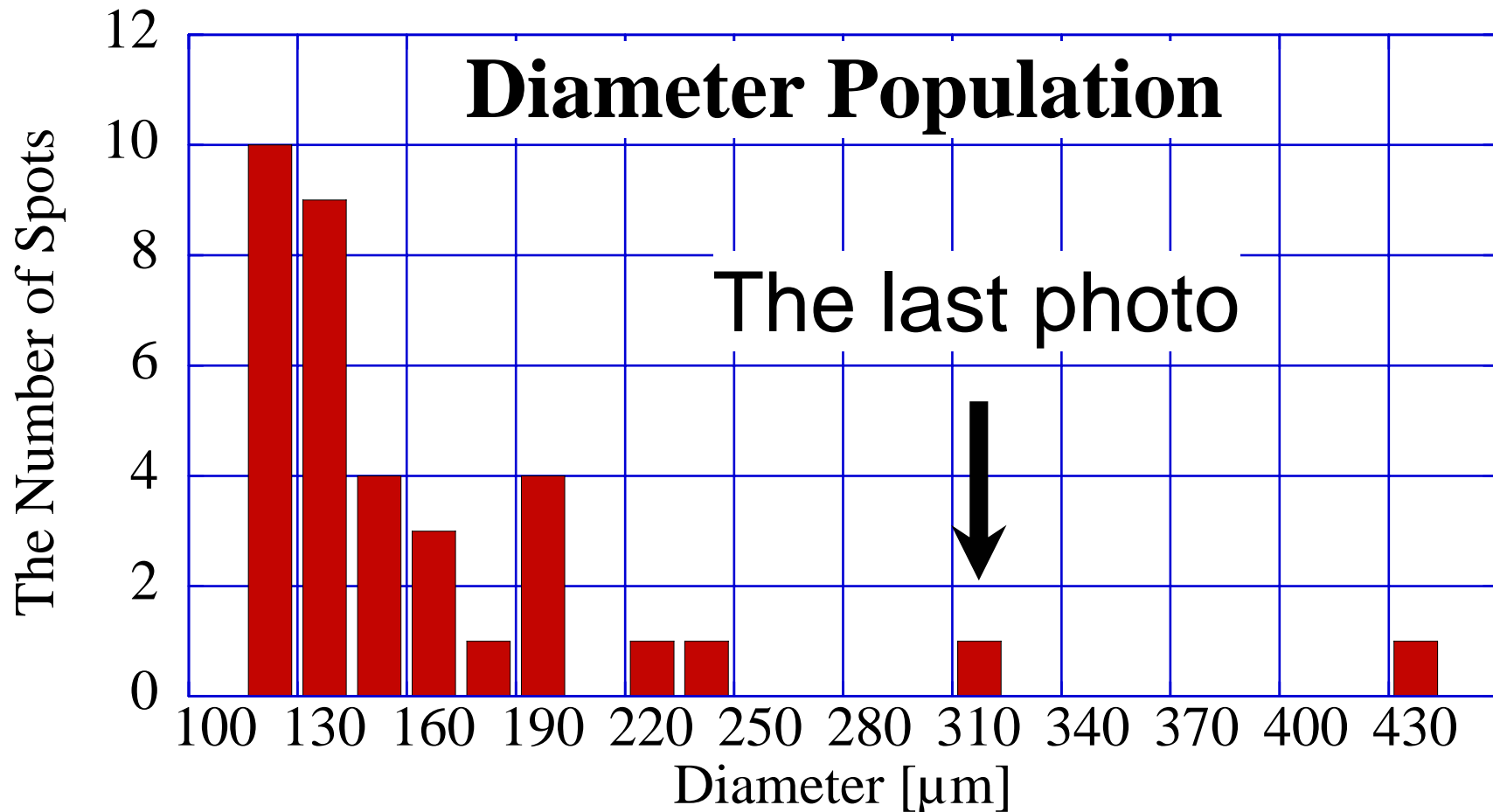
- Maximum  $E_{acc} \sim 27 \text{ MV/m}$
- Q-disease?
- Electro-Polished 7 times

# Interior Surface of Zanon #84



- 28 spots like cat's-eye were found at the equators of the cells. (only the spots with diameters larger than 100 $\mu$ m are counted. )
- Any other kind of spots were not found.
- Likely convex (no confirmation).

# Statistics of spots(>100 $\mu\text{m}$ ) in Z84



**REMARK:** All the spots were found at the input coupler side of the EBW seam.



# Modification

- 💡 Zanon #84: by the first inspection system.  
Only sizes of spots were observed.

Rebuilt the tube after this observation,

New drive mechanism for better positioning

The extension tube for 2X magnification

New illumination system

A height estimation method was also  
established after this.

- 💡 AES001: will be explained ...

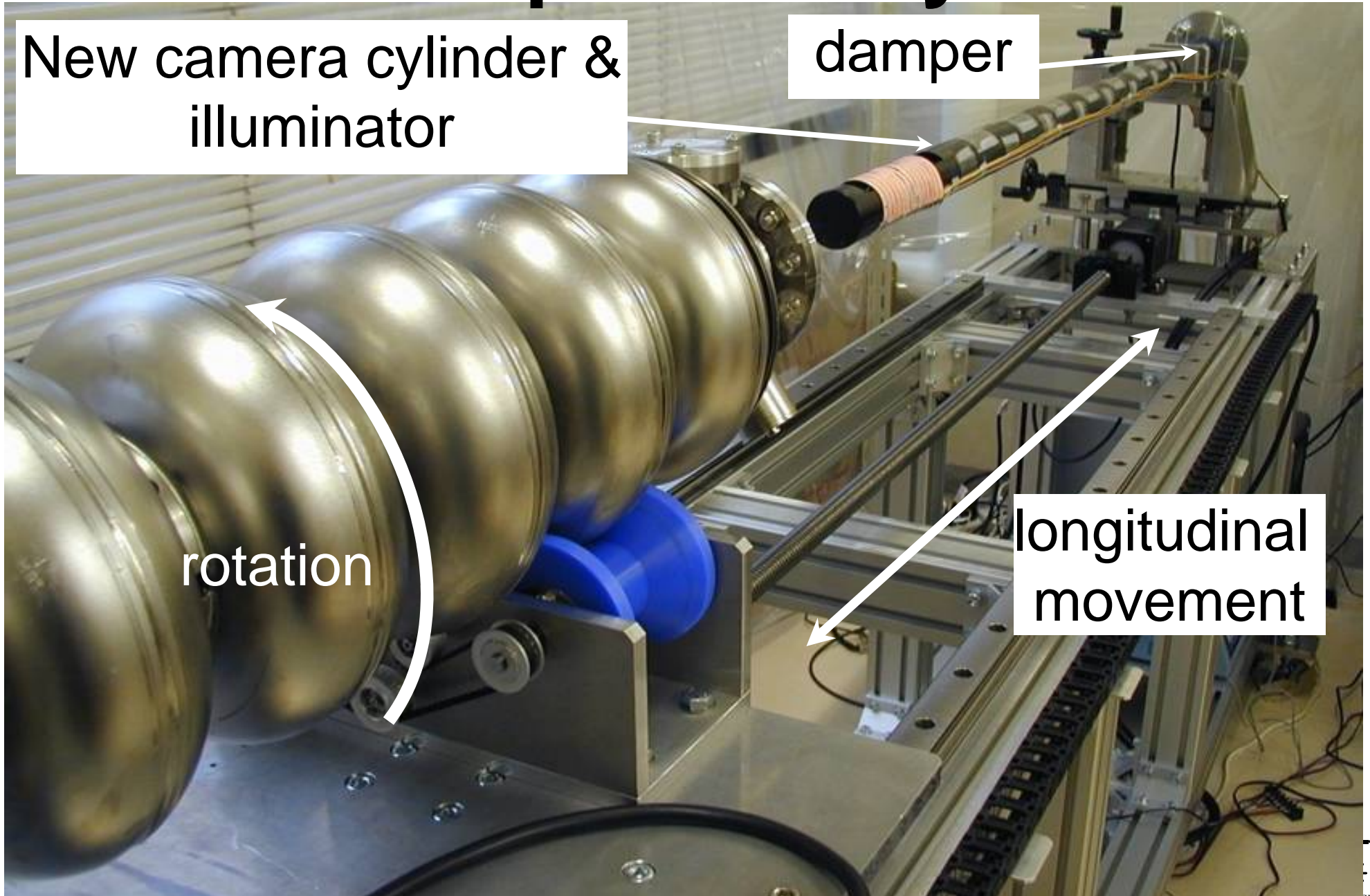
# New Inspection System

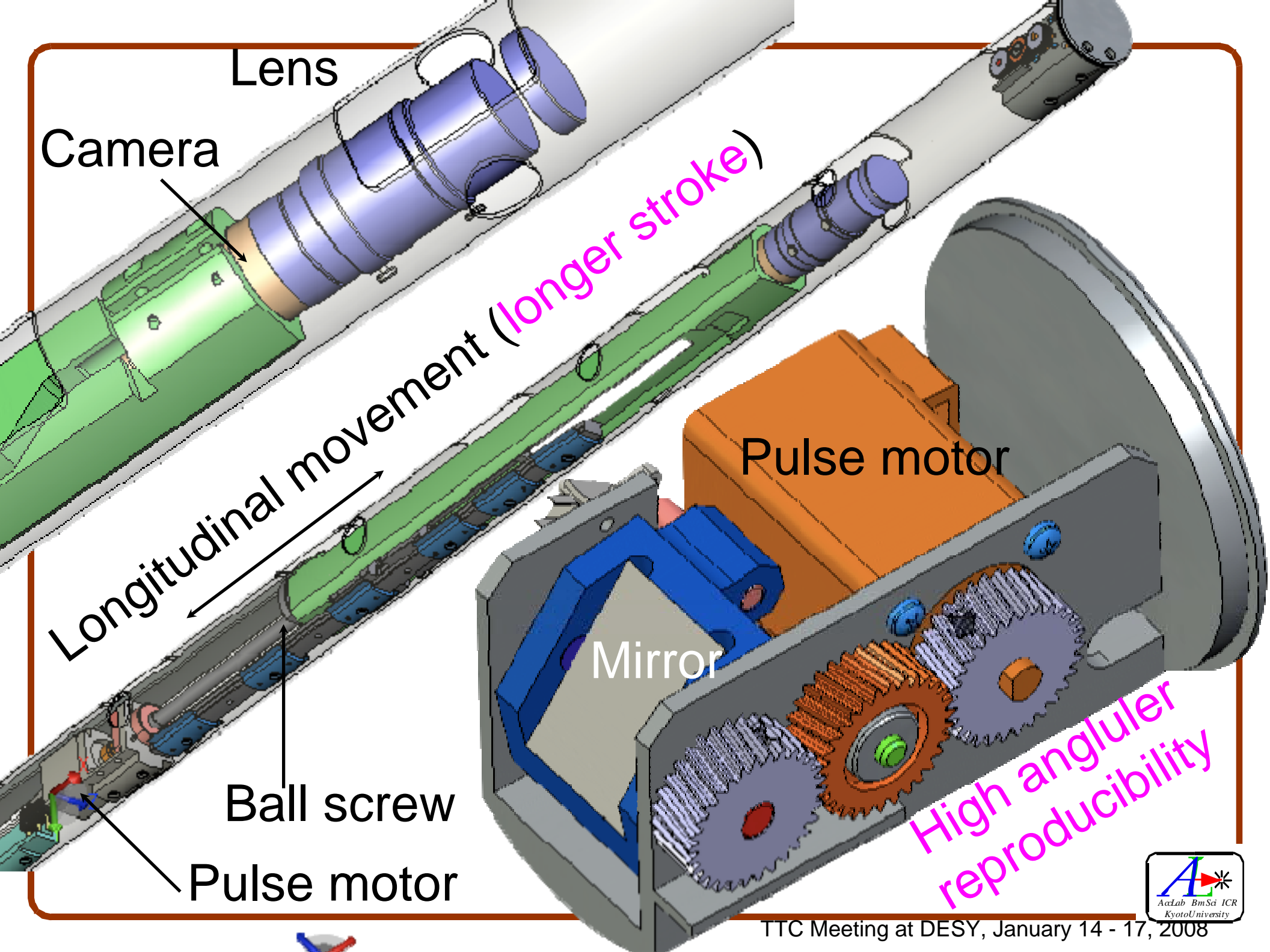
New camera cylinder & illuminator

damper

rotation

longitudinal movement





Lens

Camera

Longitudinal movement (longer stroke)

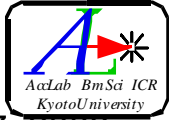
Pulse motor

Mirror

Ball screw

Pulse motor

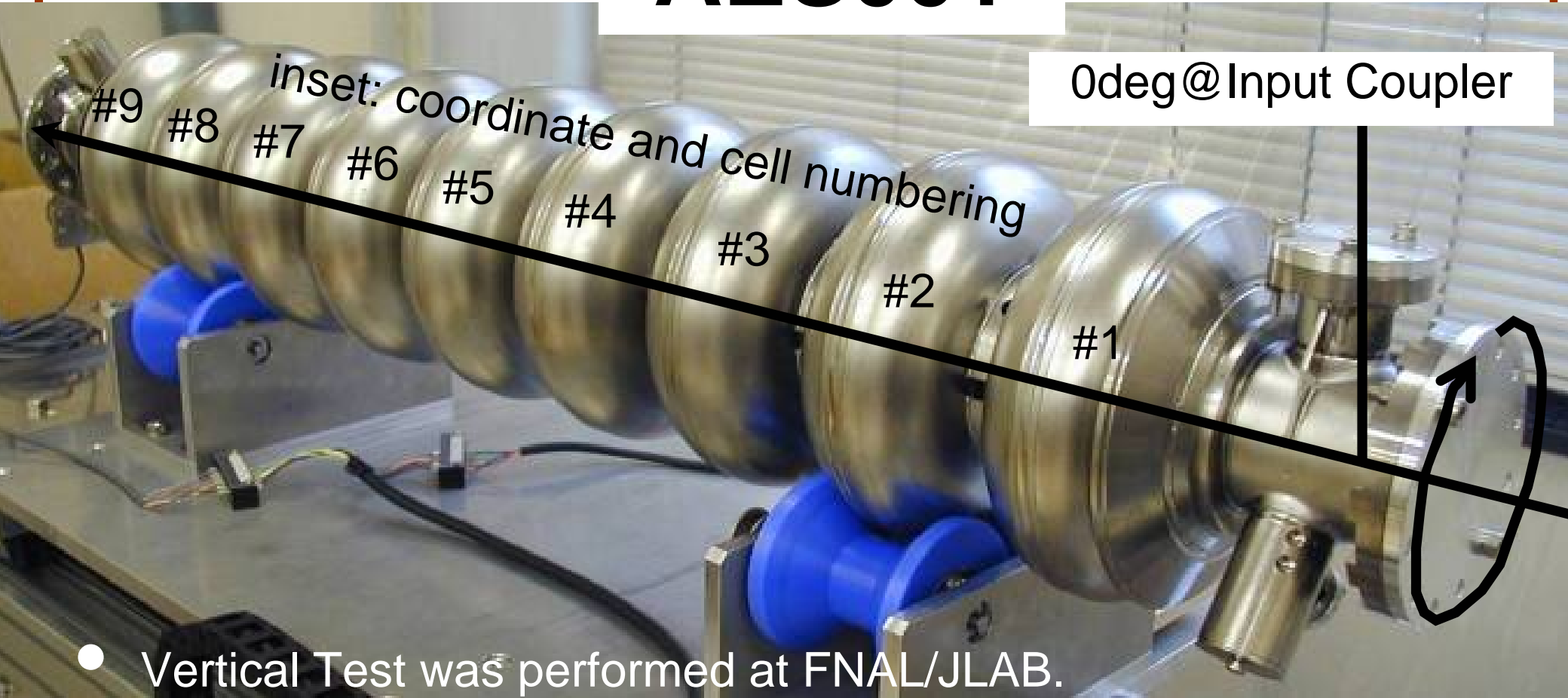
High angular reproducibility





# AES001

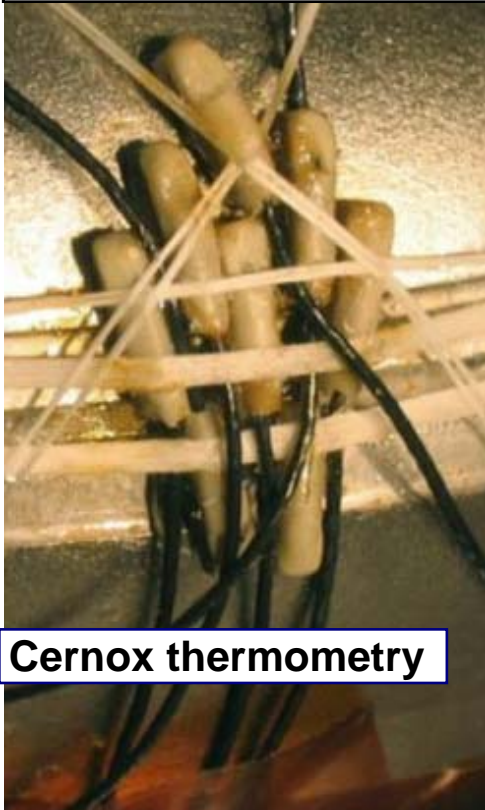
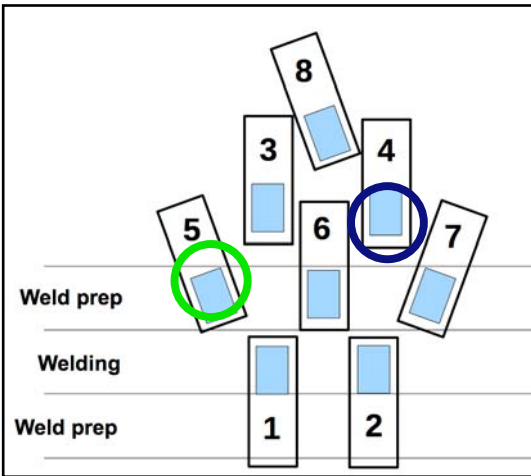
0deg@Input Coupler



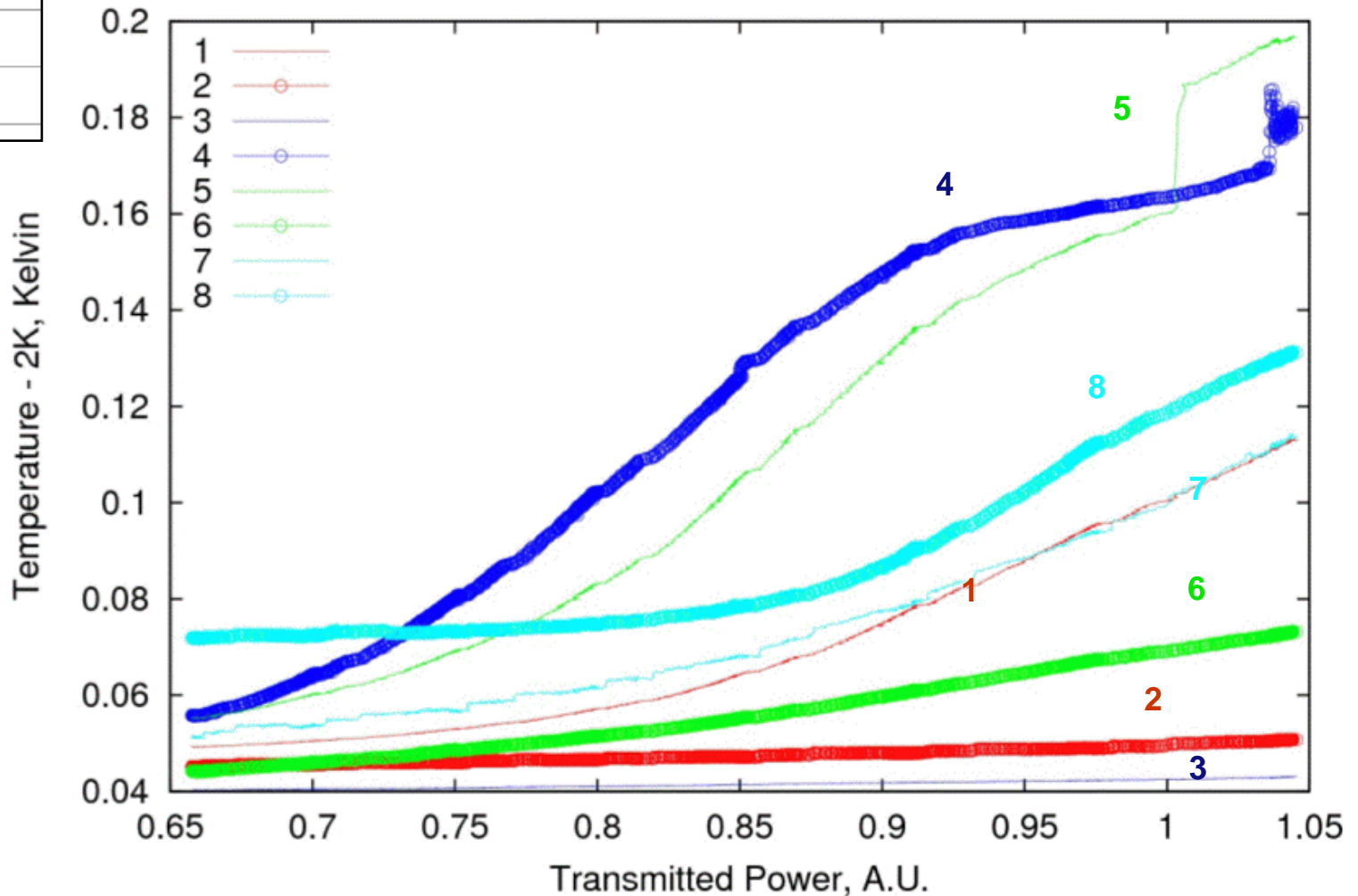
- Vertical Test was performed at FNAL/JLAB.
- Quenched at  $E_{acc} \sim 15 \text{ MV/m}$  without field emission (no Xray).
- Passband mode measurements shows that #3 and #7 cell are suspicious.
- In CERNOX measurements two hot spots were found at the equator region of #3 cell.



**AES001 has hard quench at 15MV/m, where its location was identified by Cernox at FNAL.**



aes01 11-08-07-10-52-59



AES001 #3 cell 169°

Larger grains

Fine grains

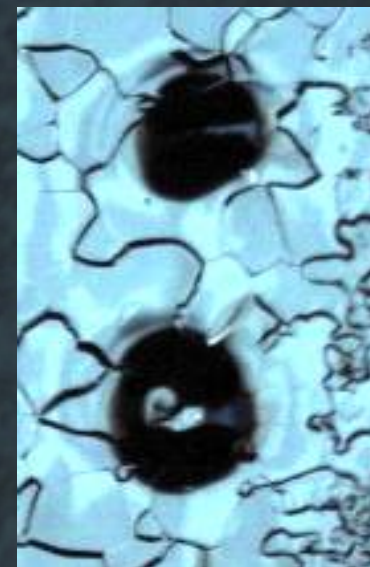


EBW area: Larger Grain

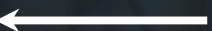
Twins

spot(a) @ 168°

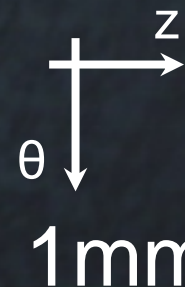
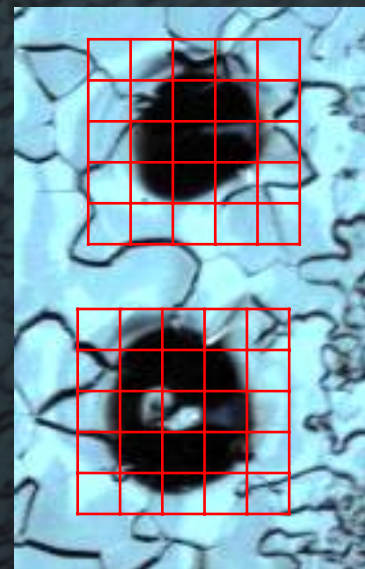
spot(b) @ 169°



200µm/div



to Equator  
and #2 cell





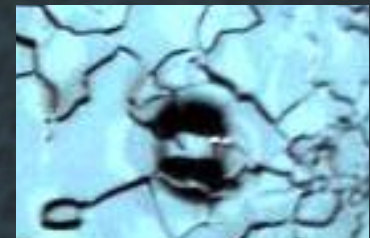
AES001 #3 cell 181°



EBW affected area

Larger grains      Transition?

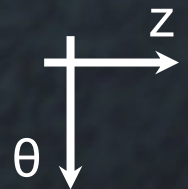
Fine grains



200  $\mu\text{m}/\text{div}$

↑  
spot

←  
to Equator  
and #2 cell



1 mm

AES001 #7 cell 325°

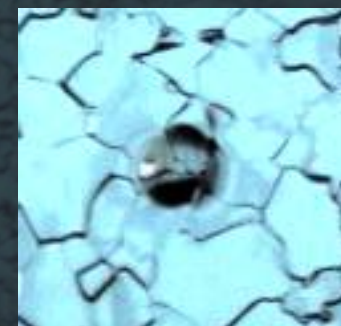
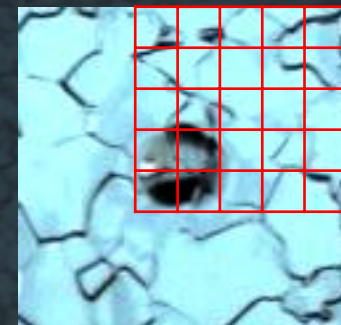
EBW affected area

Largest grains

to Equator  
and #6 cell

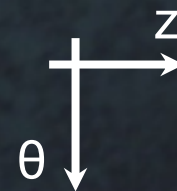
Larger grains  
Transition?

Fine grains



200μm/div

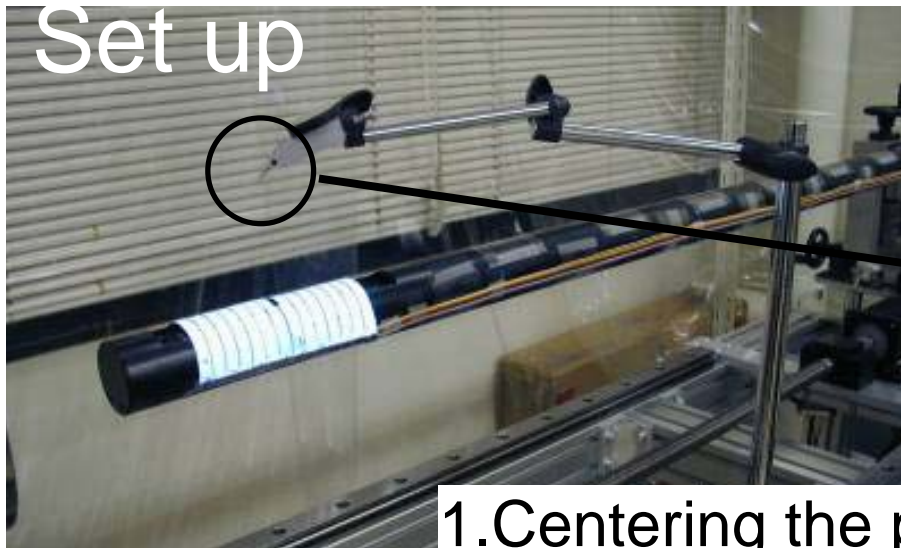
spot



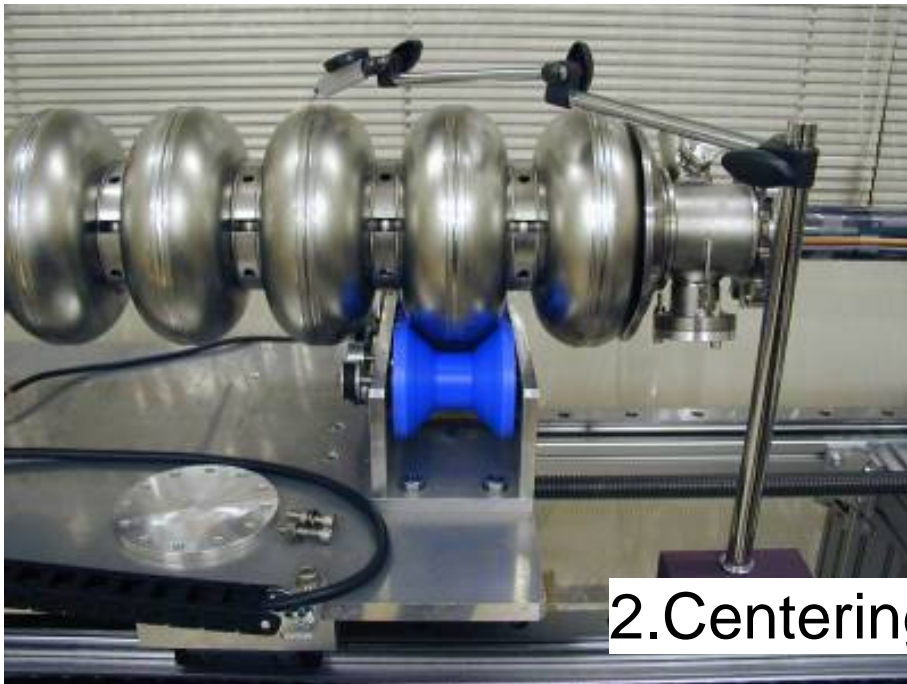
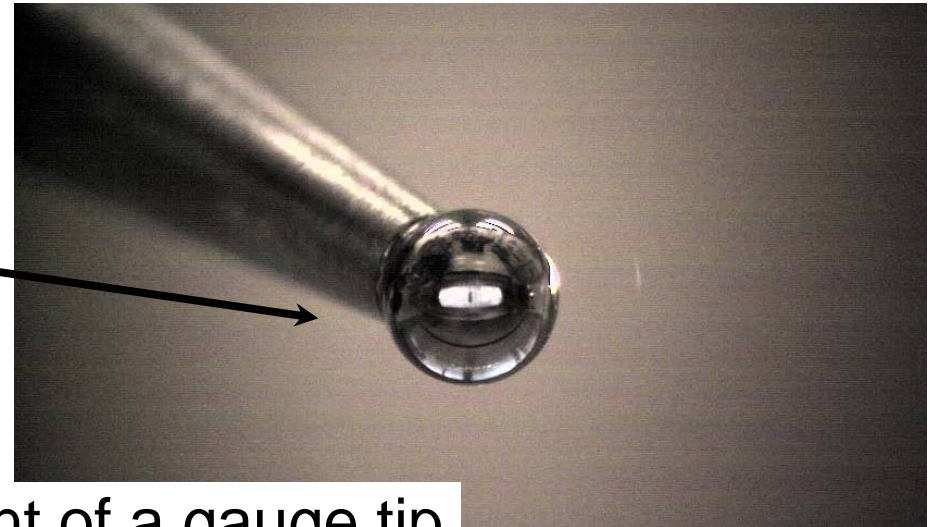
1mm



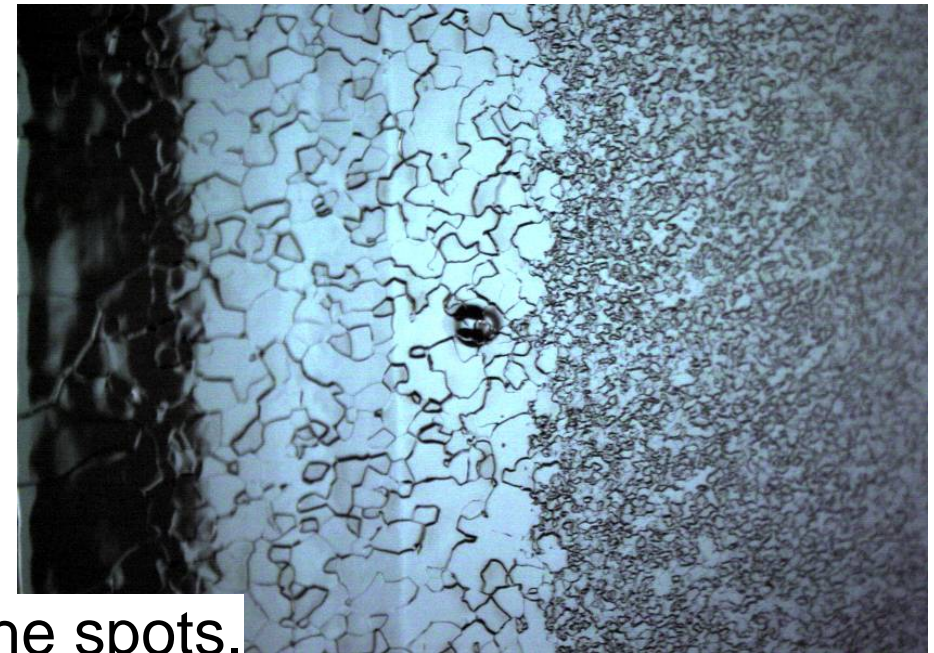
# Determination of Spot Positions



1.Centering the point of a gauge tip.



2.Centering the spots.



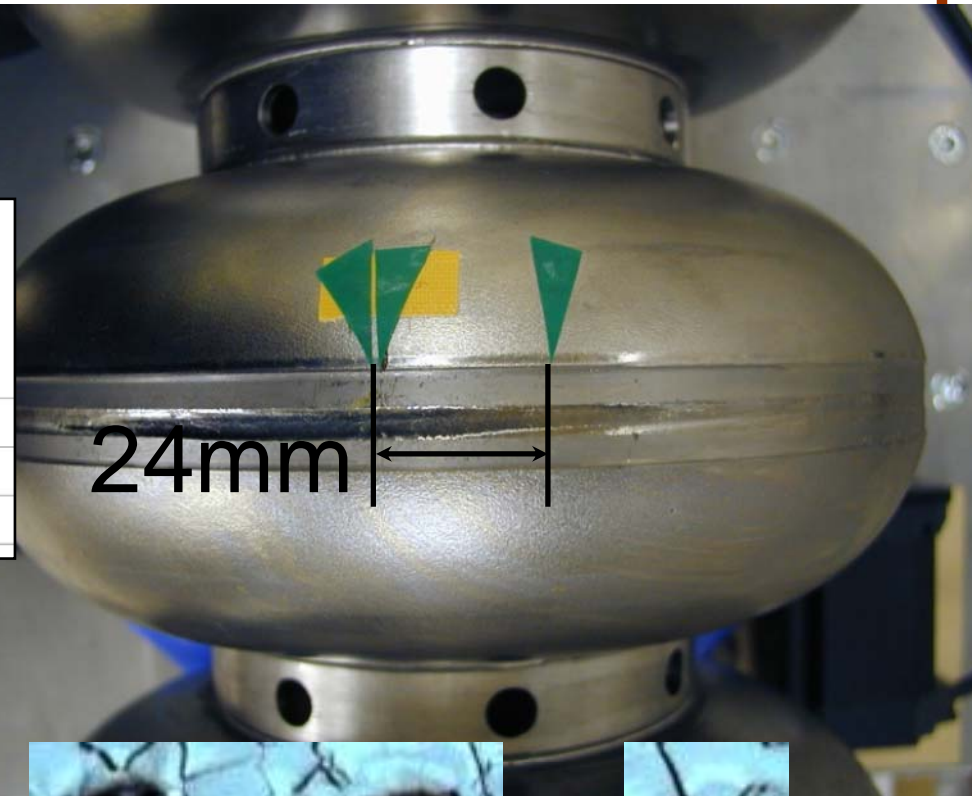
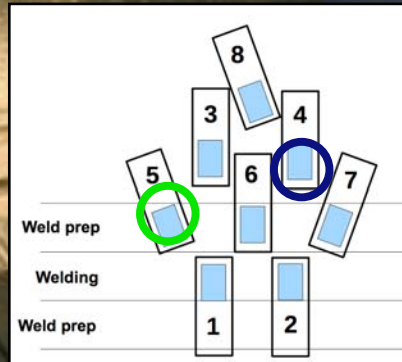


# Correlation with Thermometry

Two thermometers shows the temperature rise.

24mm?

The width of the themometers are about 5mm.

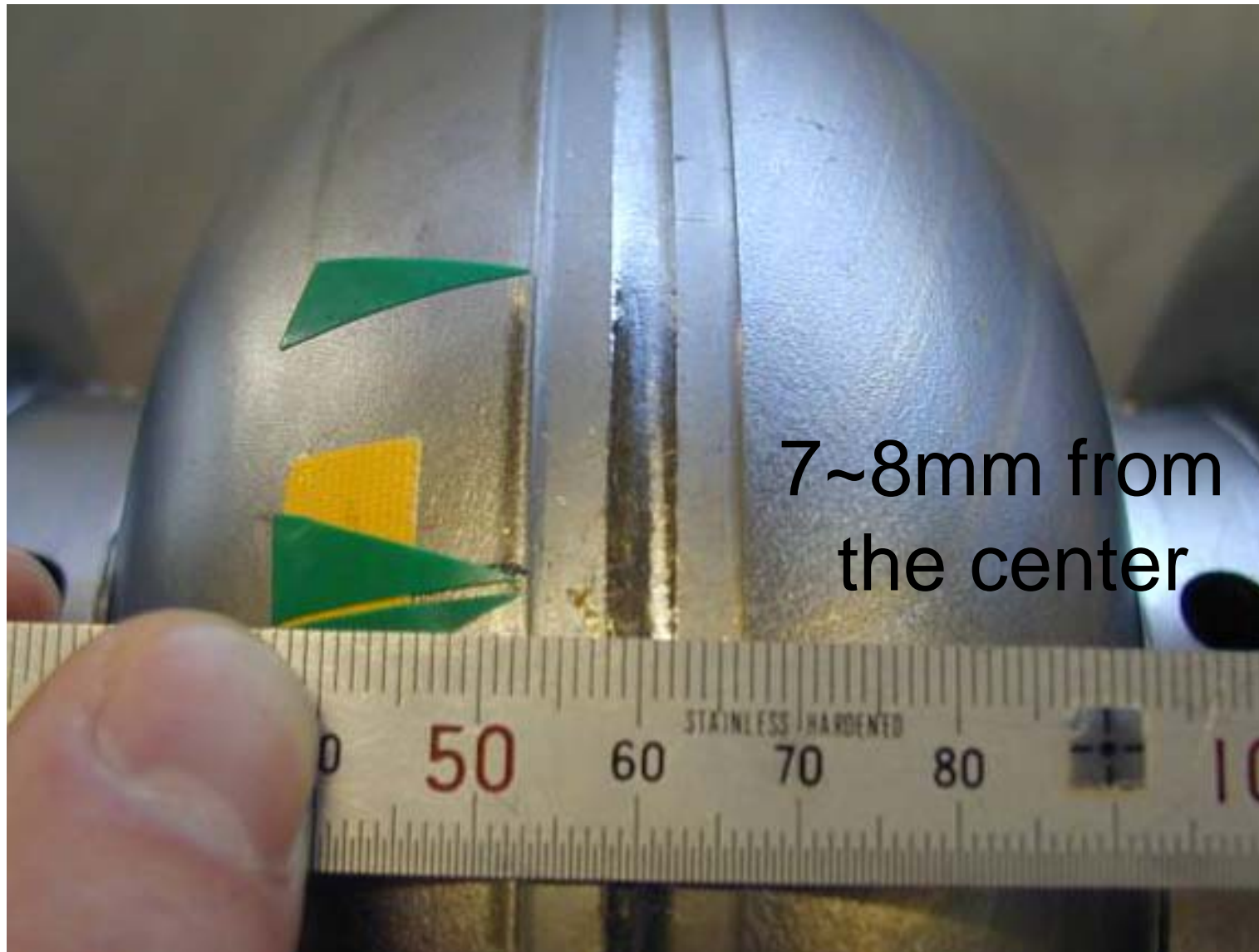


Dmitri A. Sergatskov: Thermometry on AES01 cavity at Fermilab  
©webex20071204

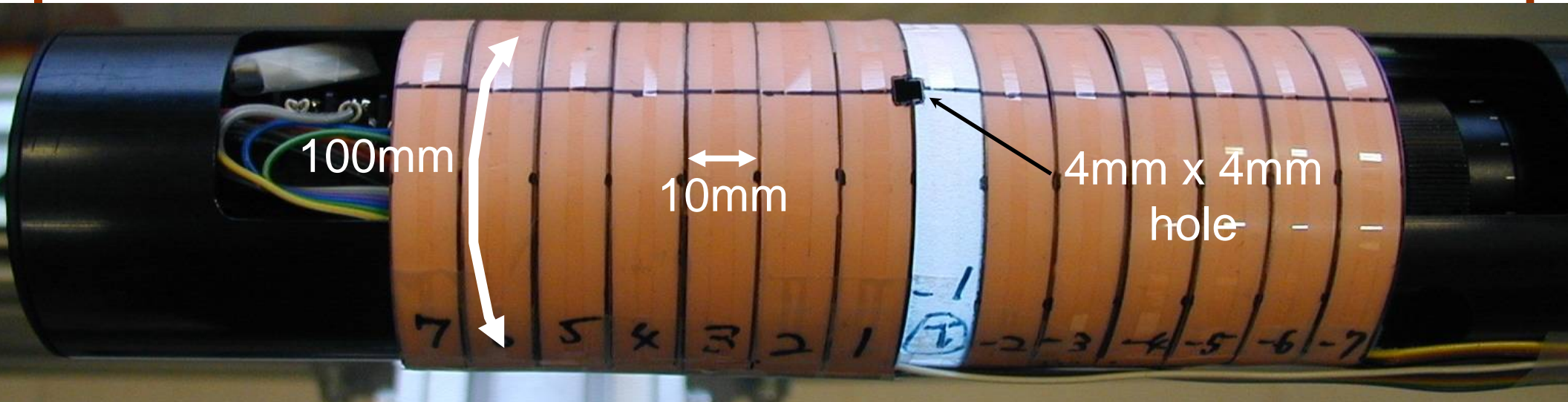
Two hot spots @ FNAL/JLAB

Three spots found @ Kyoto

# The location



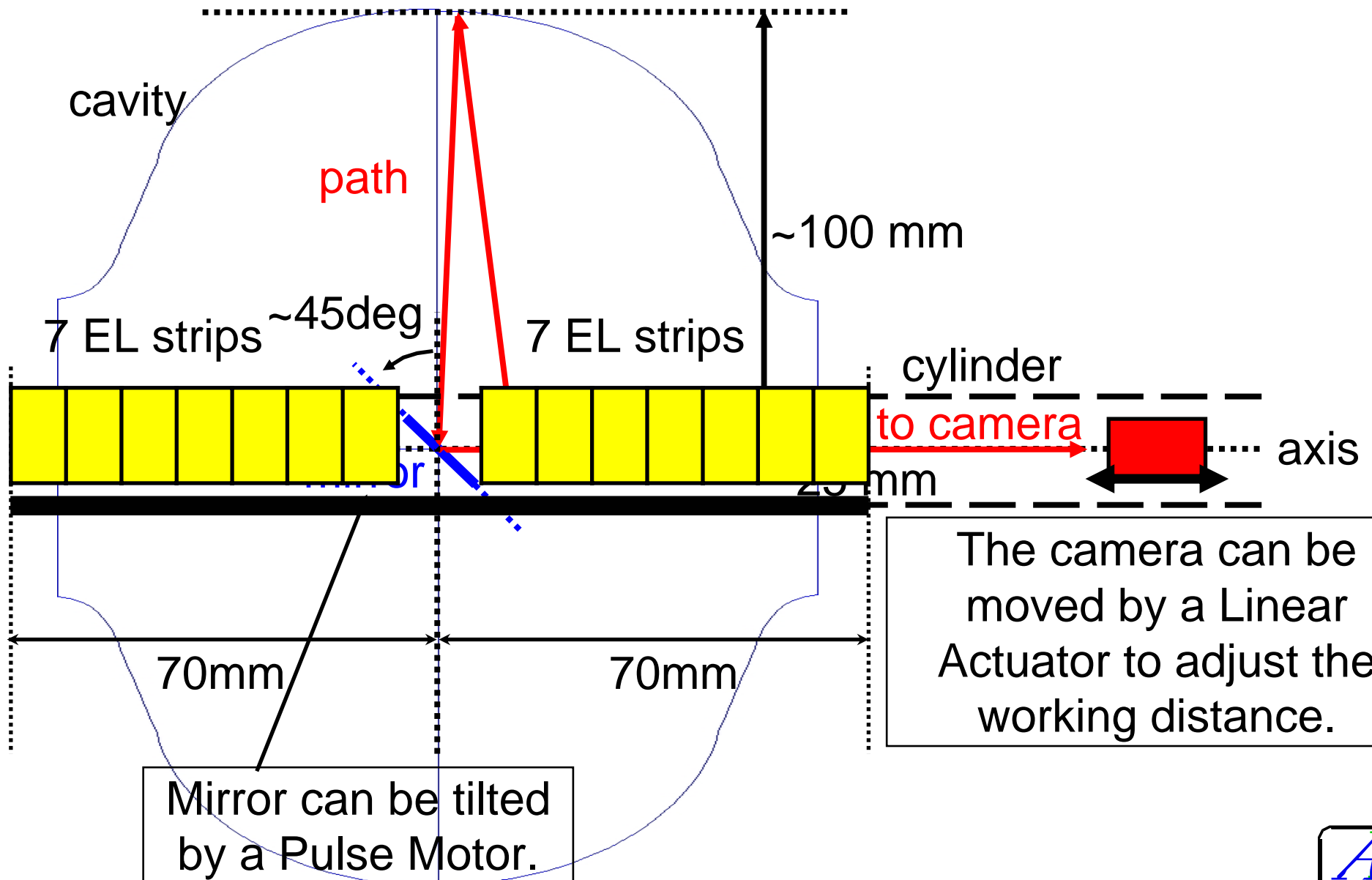
# Stripe Illumination(SI)



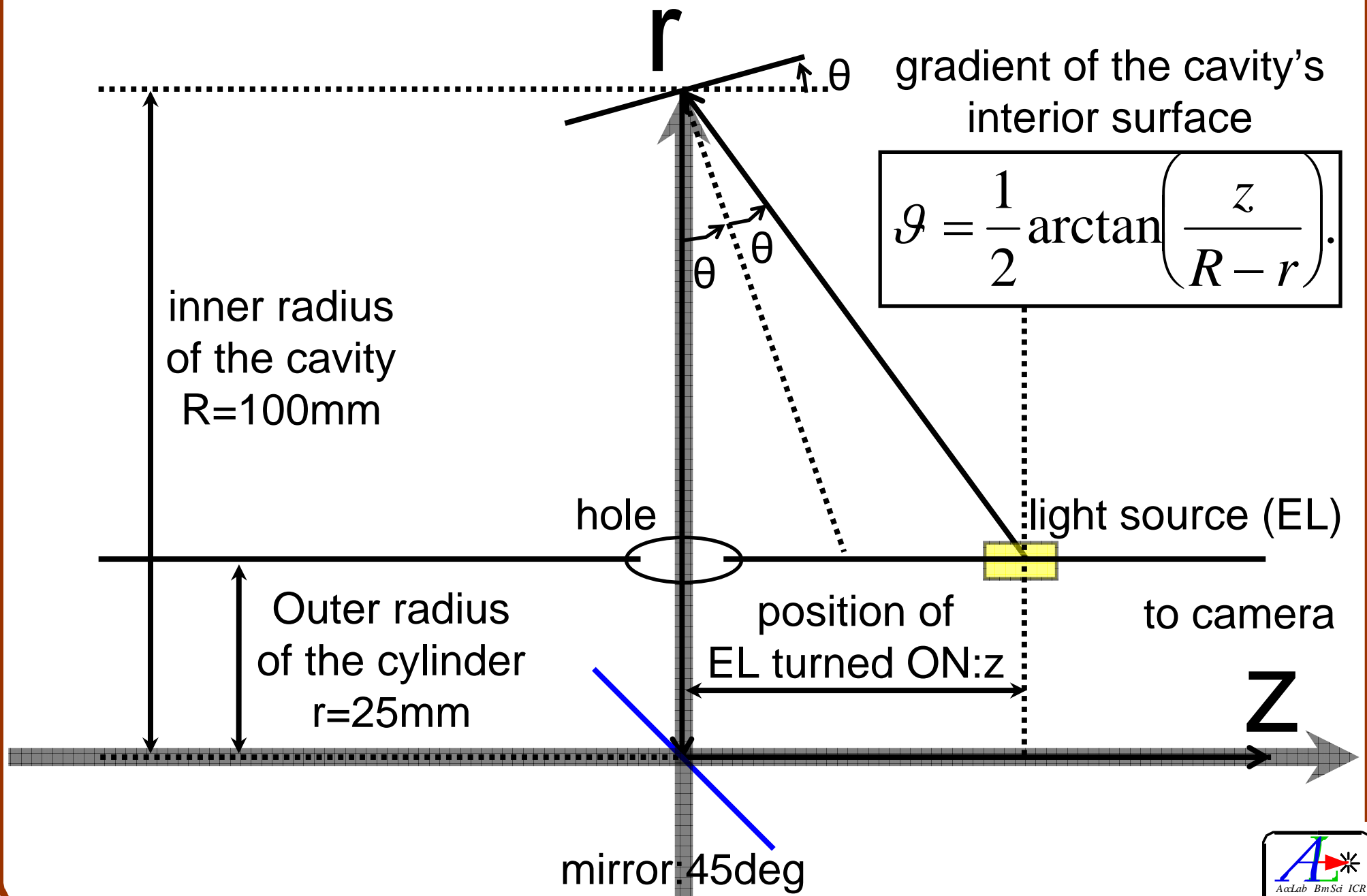
- Fourteen Electro-Luminescence(EL) strip sheets are 10mm in axial direction and cover 100mm in azimuthal direction.
- These fourteen strips can be turned ON/OFF one by one.
- Assuming that cavity's interior surface is a complete mirror, we can measure wall gradients of the cavity's interior surface with these ELs.



# Inside the Cylinder



# Wall Gradient Measurement

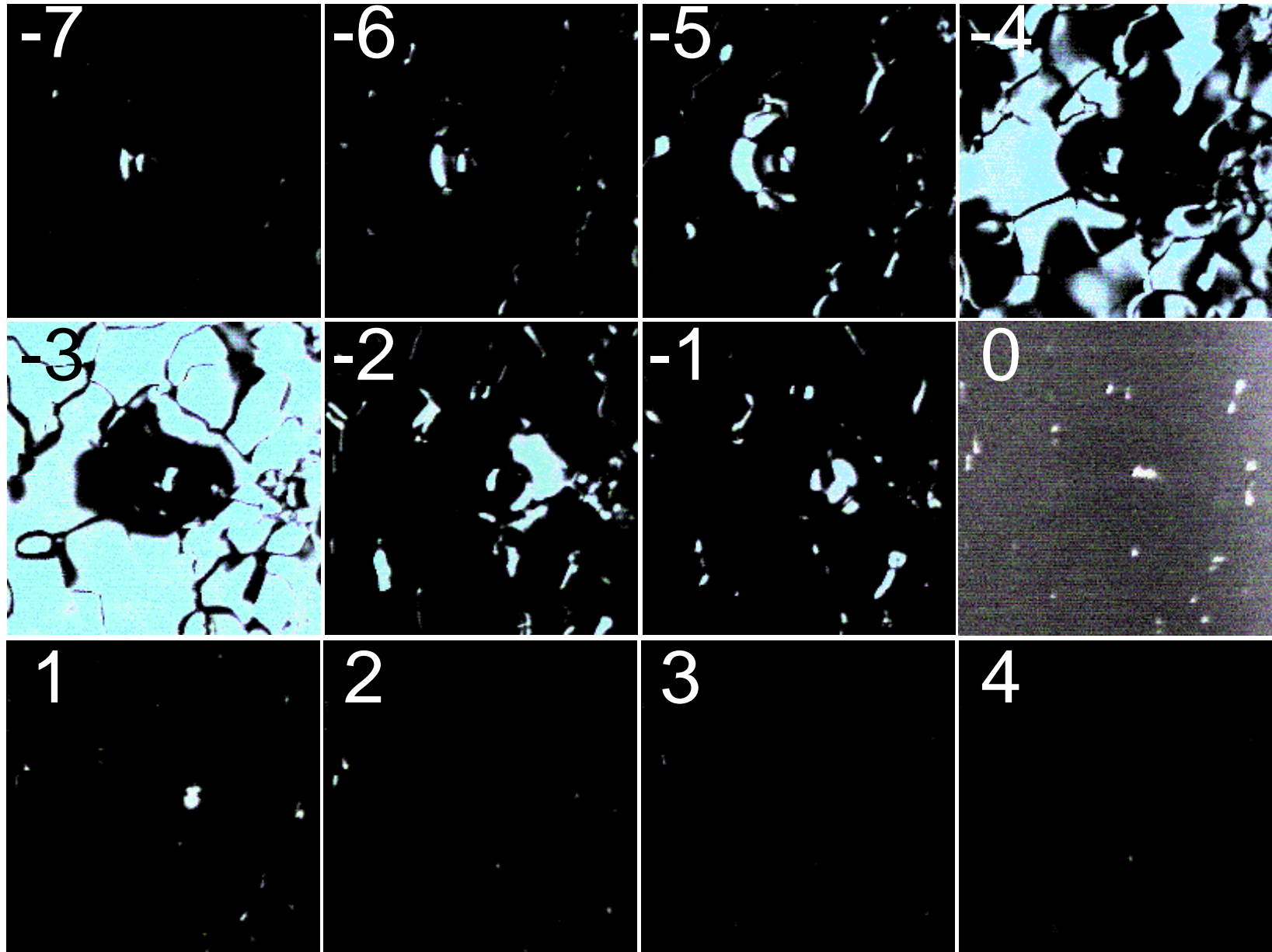


# Wall Gradient Measurement

QuickTimeý C²  
GIF êLí£EvEçÉÖÉâÉÄ  
Ç™Ç±ÇÃÉsÉNE`ÉÉÇ¾å©ÇEÇžÇ½Ç...ÇÖïKóvÇ-Ç ÅE

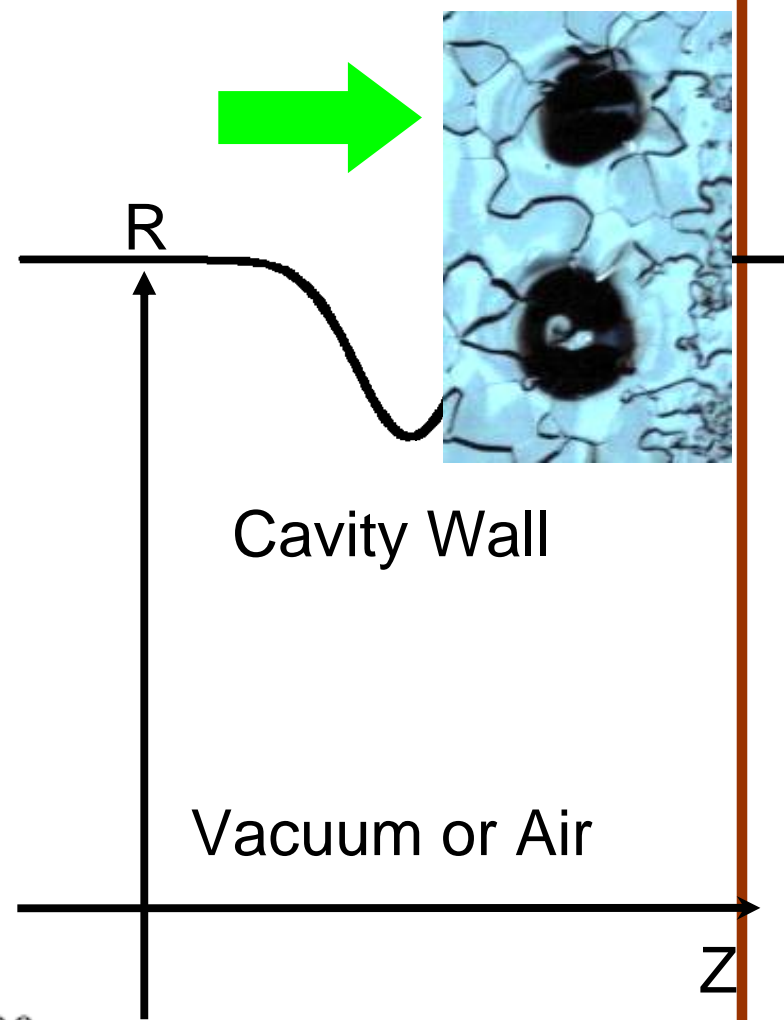
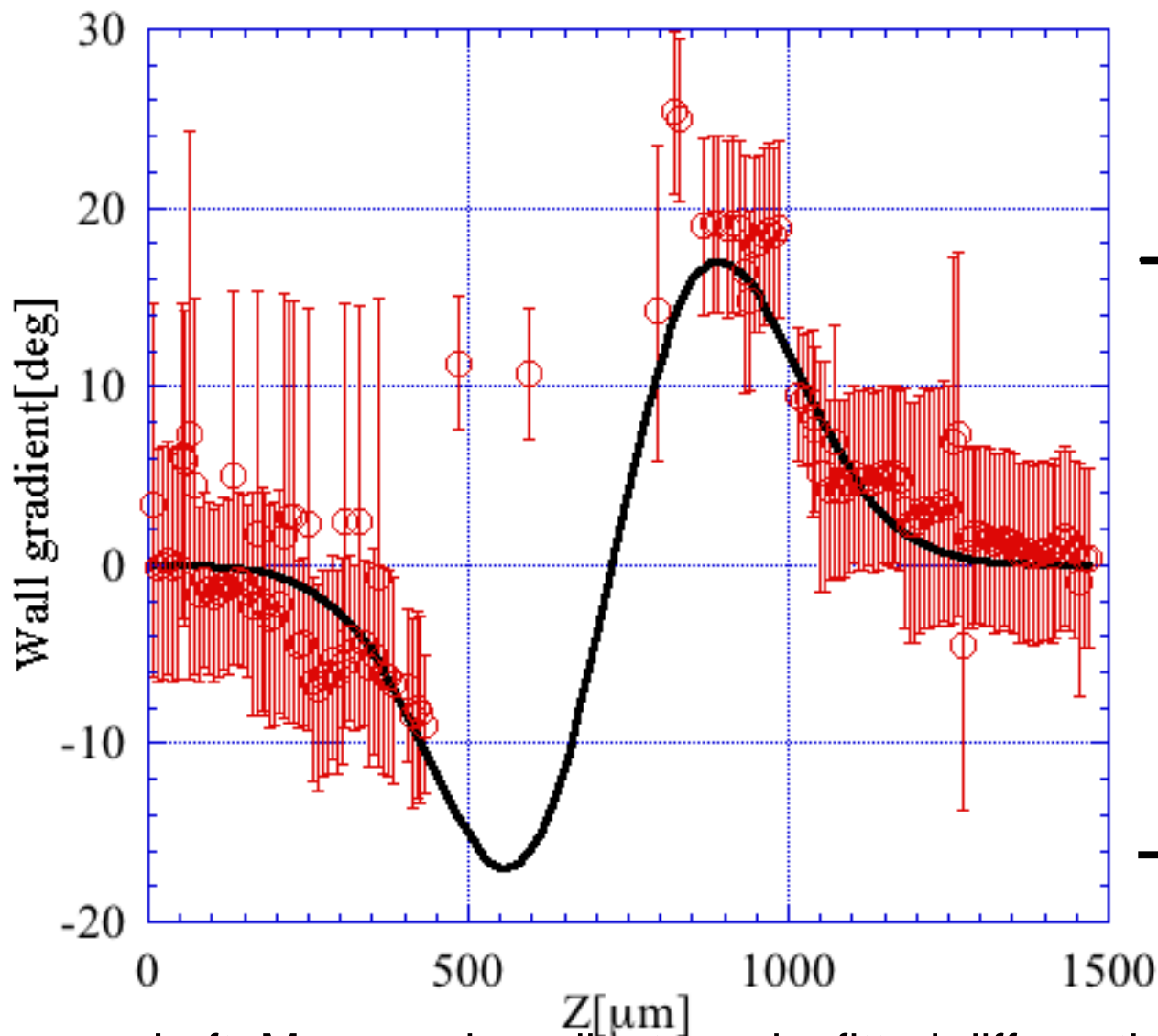
The center spot move left to right

# Wall Gradient Measurement





# Wall Gradient of spot at #3 cell 168°



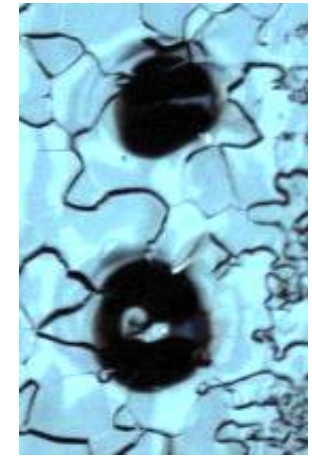
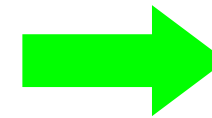
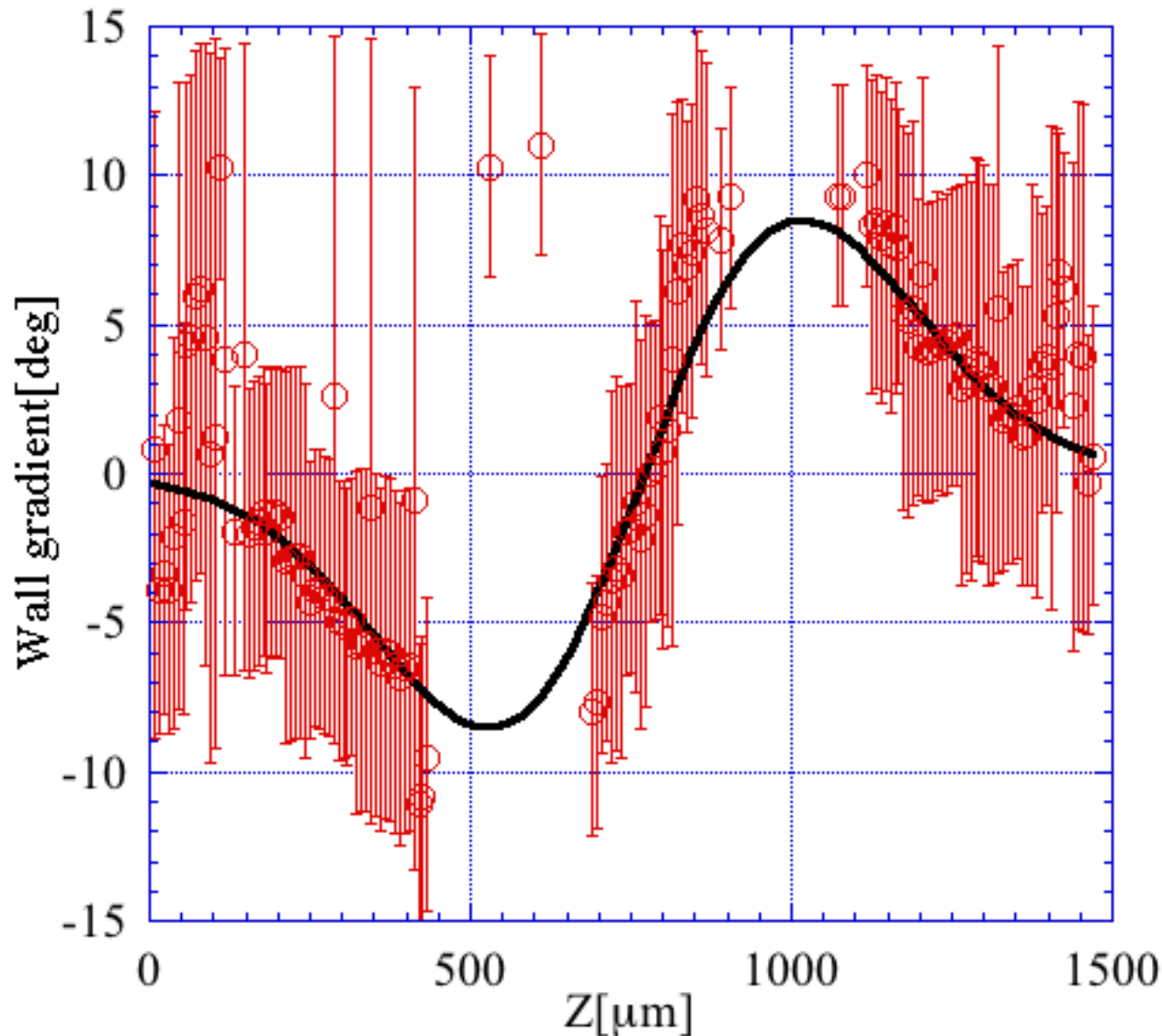
Left: Measured gradients and a fitted differential gaussian.

Right: Schematic drawing of the integral of the fitted curve in the left.

This data shows that the spot is a convex(ball).

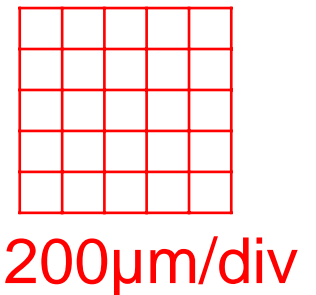
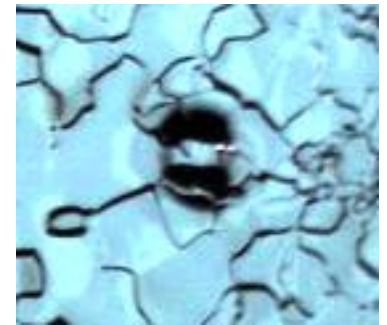
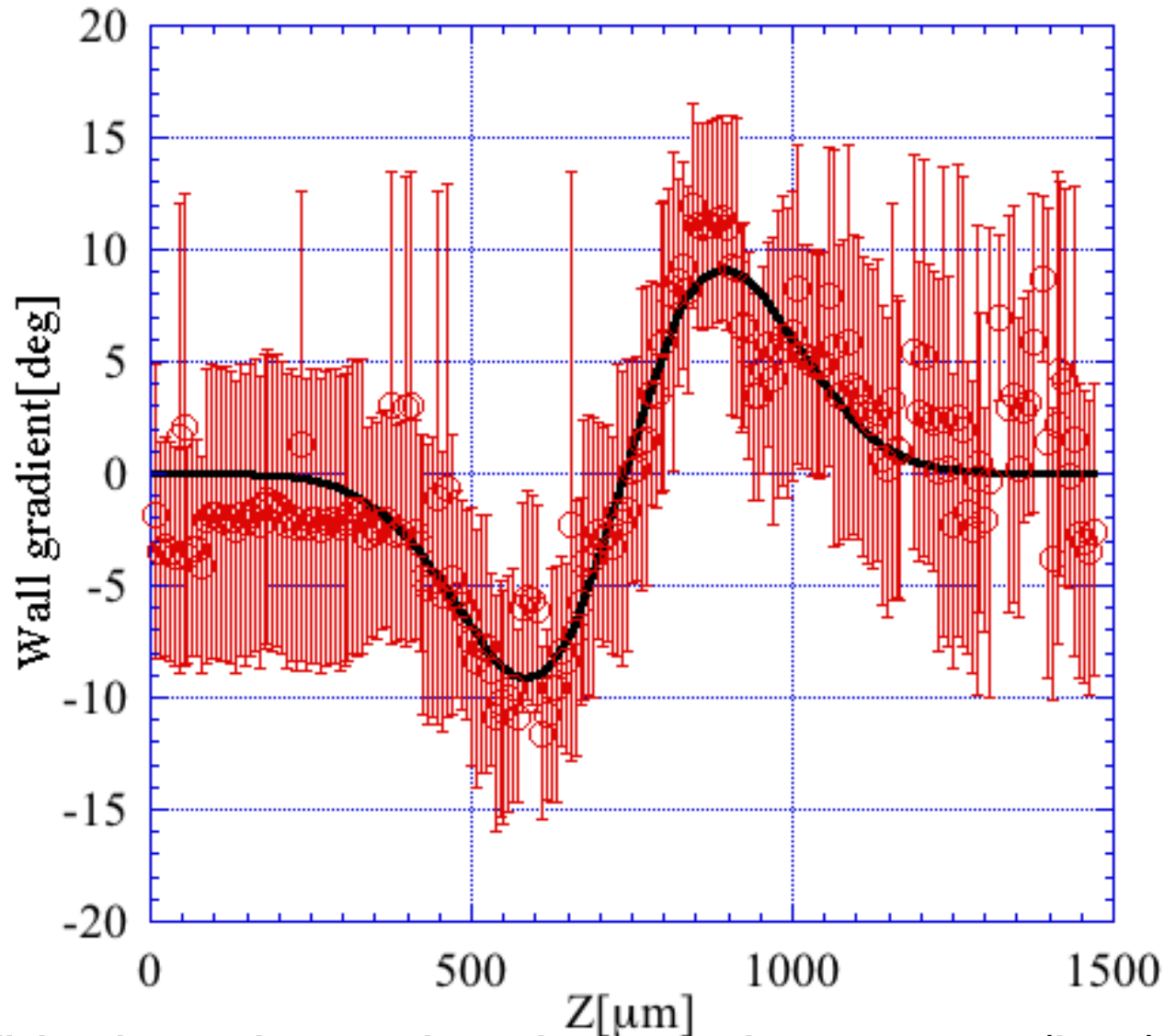
From the fitted differential gaussian, the height is 84 $\mu\text{m}$ .

# Wall Gradient of spot at #3 cell 169°



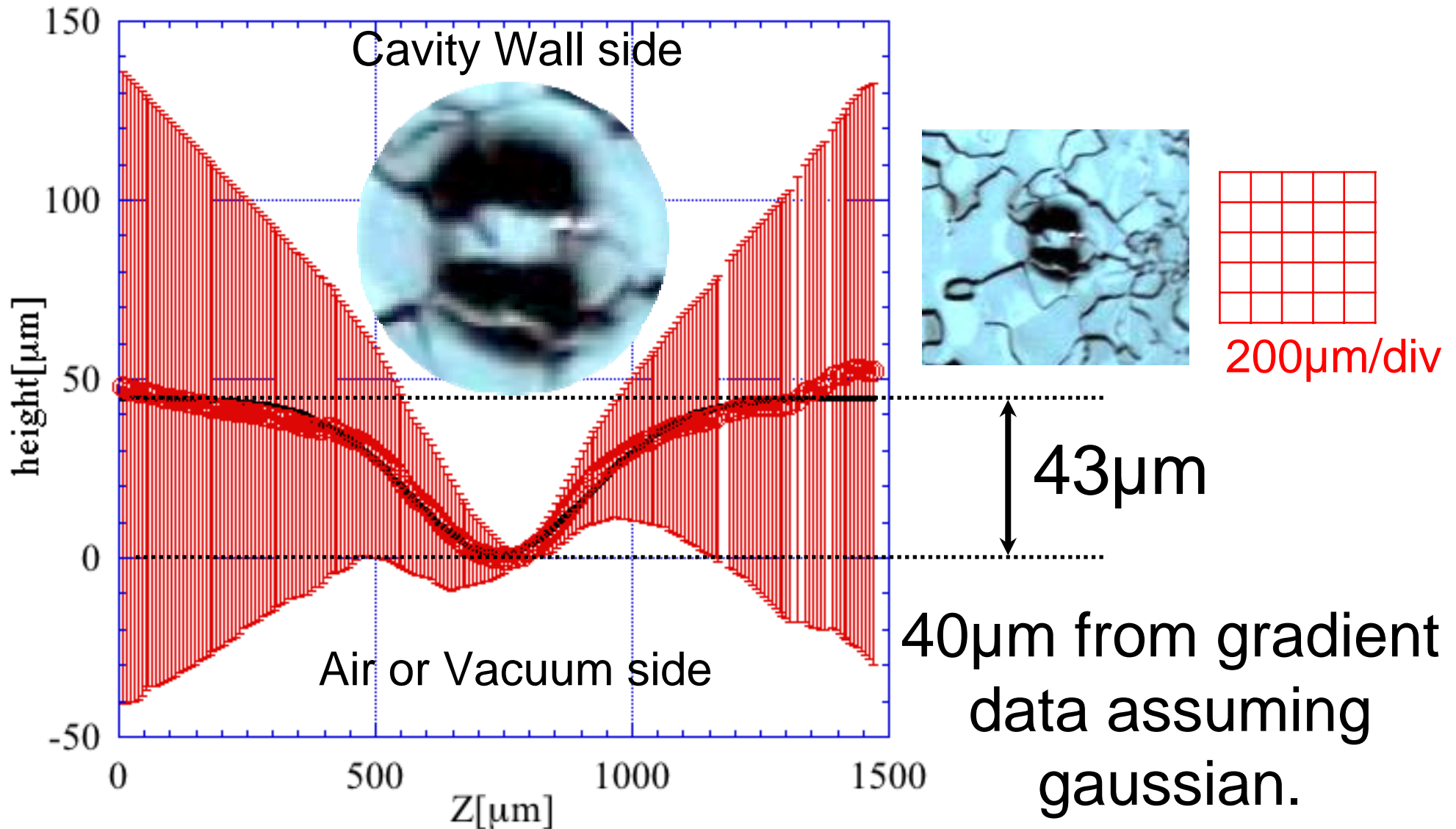
This data shows that the spot is a convex(ball).  
From the fitted differential gaussian, the height is  $60\mu\text{m}$ .

# Wall Gradient of spot at #3 cell 181°



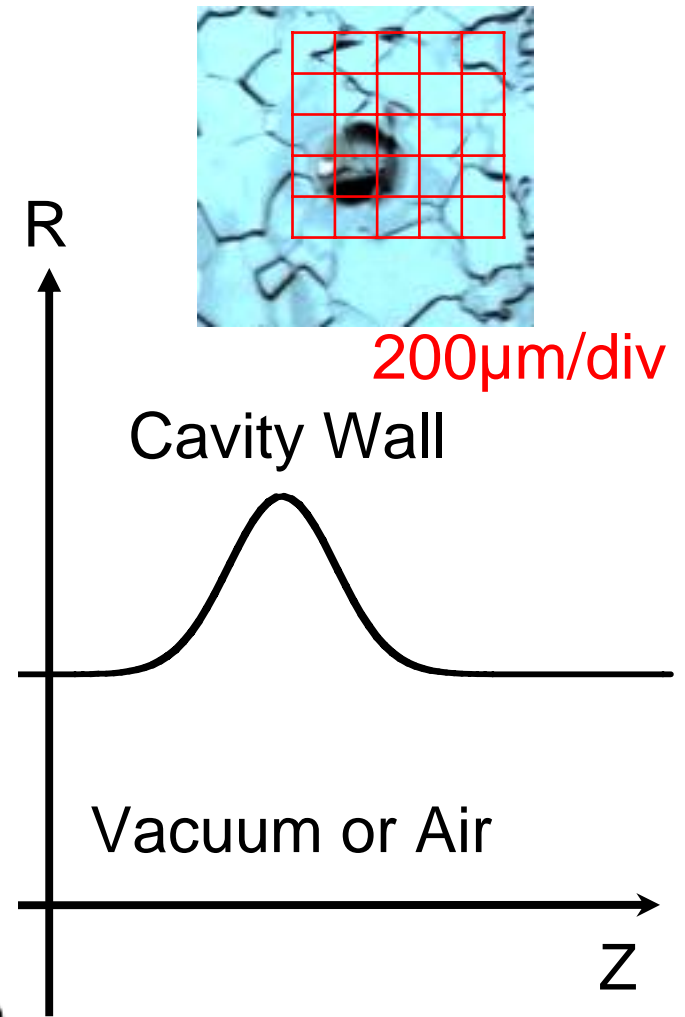
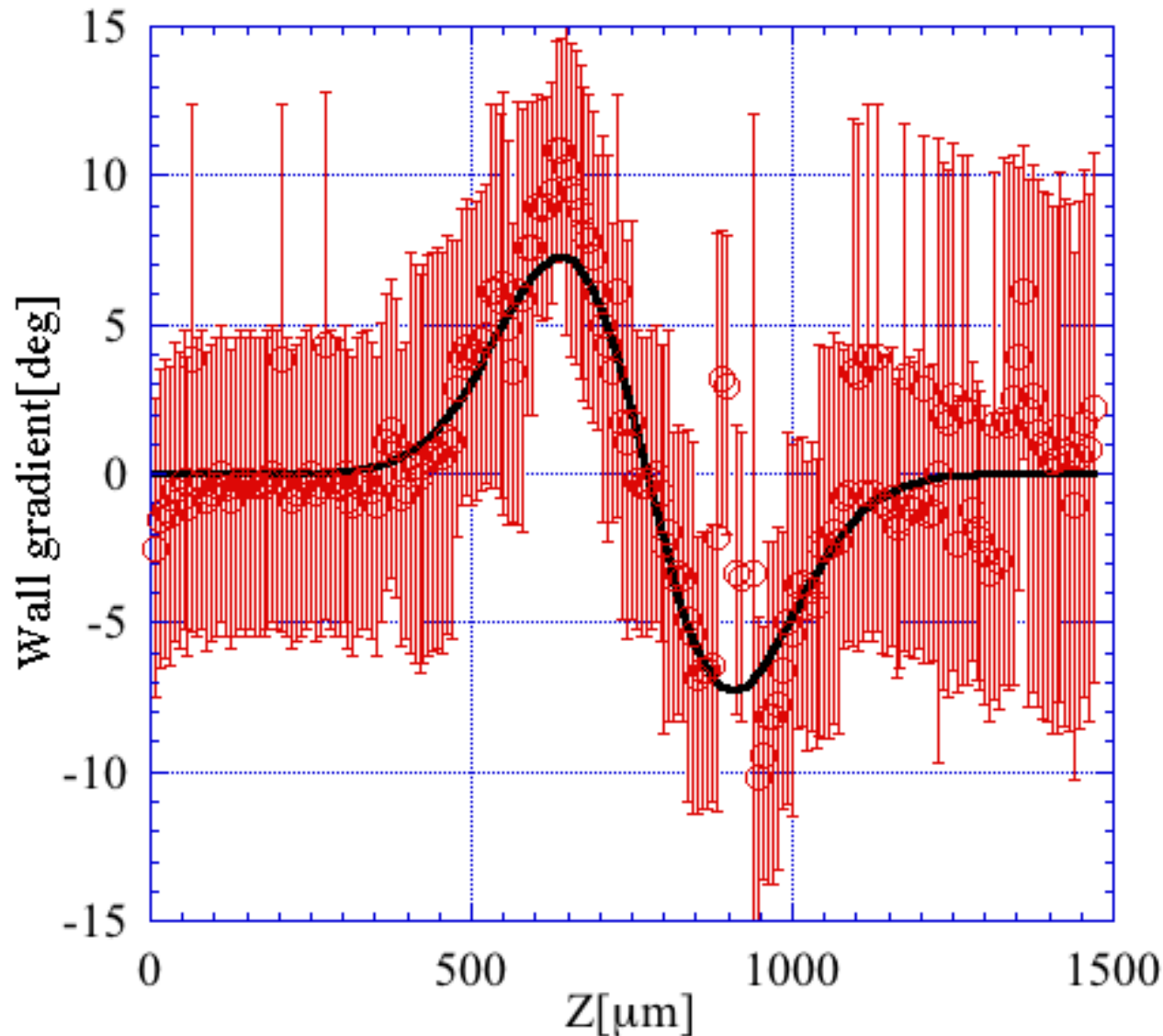
- This data shows that the spot is a convex(ball).
- Because of the continuity of the measured gradient, we can integrate the gradient to estimate the height of the spot.

# Height of spot at #3 cell 181°



Black curve is a fitted gaussian.

# Wall Gradient of spot at #7 cell 325°



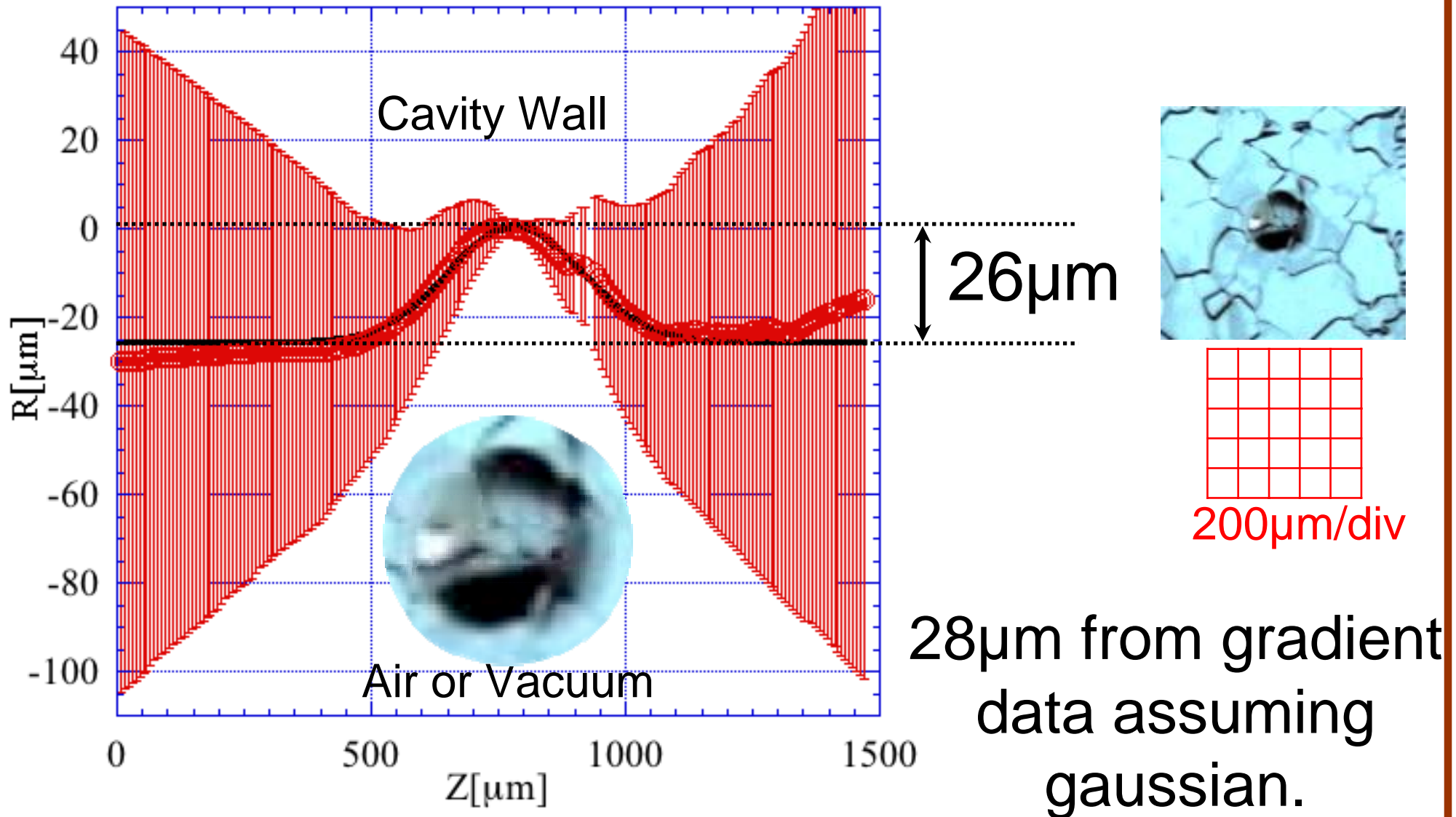
Left: Measured gradients and a fitted differential gaussian.

Right: Schematic drawing of the integral of the fitted curve in the left.

This data shows that the spot is a concave(pit).



# Height of spot at #7 cell 325deg



Black curve is a fitted gaussian.

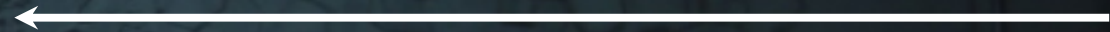
$28\mu\text{m}$  from gradient data assuming gaussian.

# Observation of AES001

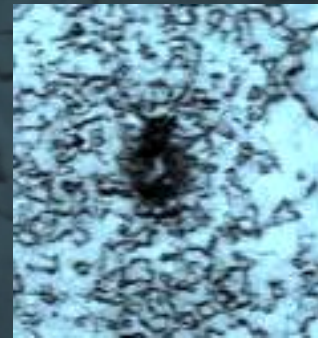
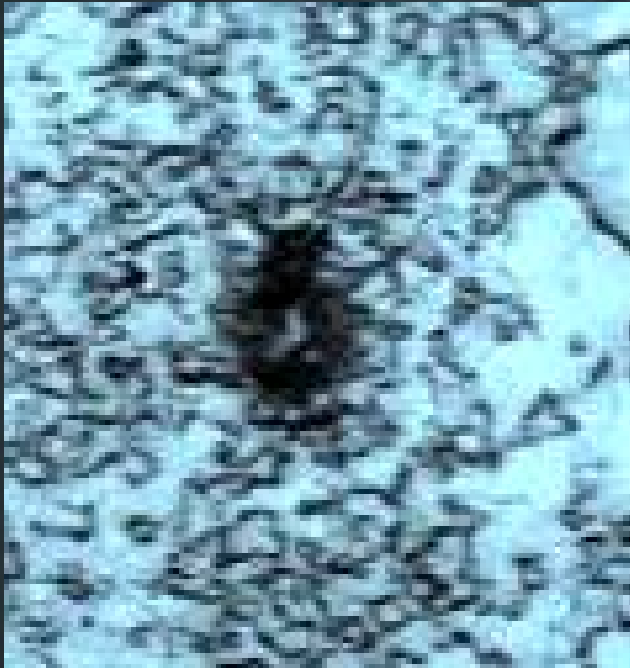
- Mainly the equator and the iris regions of all the cells were observed.(about 30mm width)
- Three spots in the equator region of #3 cell were found.
- One spots in the equator region of #7 cell were found.
- These two results seems to be correlated with the pass-band mode measurements.
- The azimuthal positions of the three spots found in #3 cell were 168, 169 and 181deg:
- This result seems to be correlated with the result of CERNOX measurements. (We think that in the CERNOX measurements, the first two spots were observed as one hot spot, because of the position resolution. )

# Appendix

AES001 #1 cell 252°



EBW seam



↑  
stain?

→  
to Equator  
and #2 cell

The result of SI measurements  
shows that this spot is flat.

1mm



# Appendix

AES001 #2-3 iris 212°

back side of EL  
to Equator  
of #3 cell

← iris →

←  
to Equator  
of #2 cell

↗  
arc scar?

back side of EL



The result of SI measurements shows that this spot is flat.  
This spots looks like a sign of Field Emission or Arcing.  
Many spots like this were observed.

1mm



# Appendix

AES001 #4-5 iris 233°

iris

back side of EL

back side of EL

bright belt

to Equator  
of #4 cell

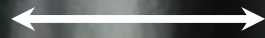
to Equator  
of #5 cell

All the Iris regions are **yellowish**.  
This spot is locally bright.  
It may be caused by EP?

1mm

# Appendix

AES001 #4-5 iris 136°



iris



back side of EL

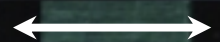
back side of EL

← to Equator  
of #4 cell

to Equator  
of #5 cell →

Dropped coffee  
smear?

1mm



# Appendix

AES001 #7-8 iris 279°



← to Equator  
of #7 cell  
back side of EL

scar?

Dropped  
coffee  
smear?

→ to Equator  
of #8 cell  
back side of EL

iris  
↔

1mm  
↔



# Appendix

AES001 #8-9 iris 9°



back side of EL

← to Equator  
of #8 cell

scars?

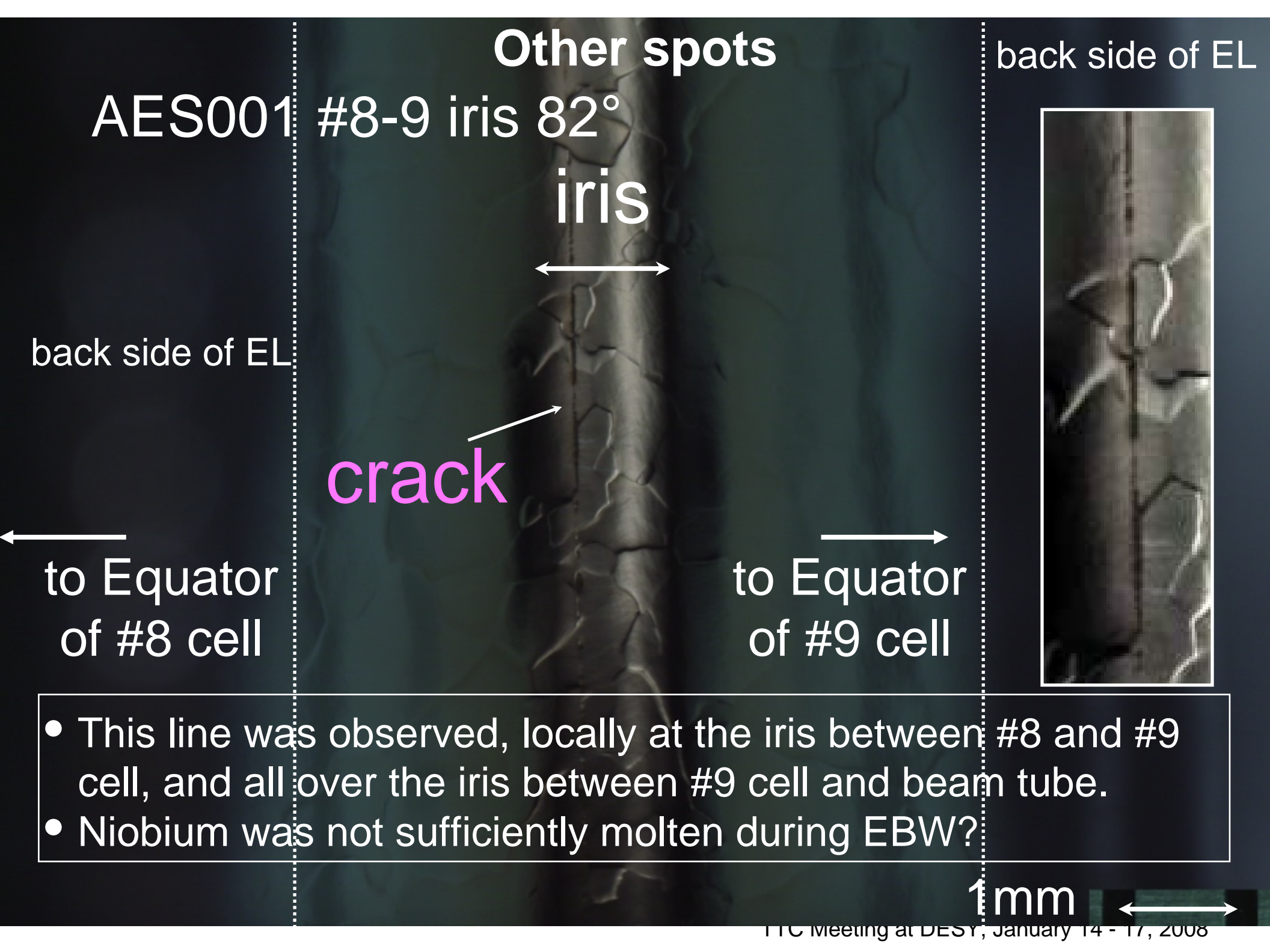
→ to Equator  
of #9 cell

back side of EL

iris

1mm





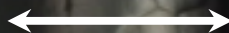
AES001

#8-9 iris 82°

Other spots

back side of EL

iris



back side of EL

crack



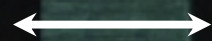
to Equator of #8 cell

to Equator of #9 cell



- This line was observed, locally at the iris between #8 and #9 cell, and all over the iris between #9 cell and beam tube.
- Niobium was not sufficiently molten during EBW?

1mm



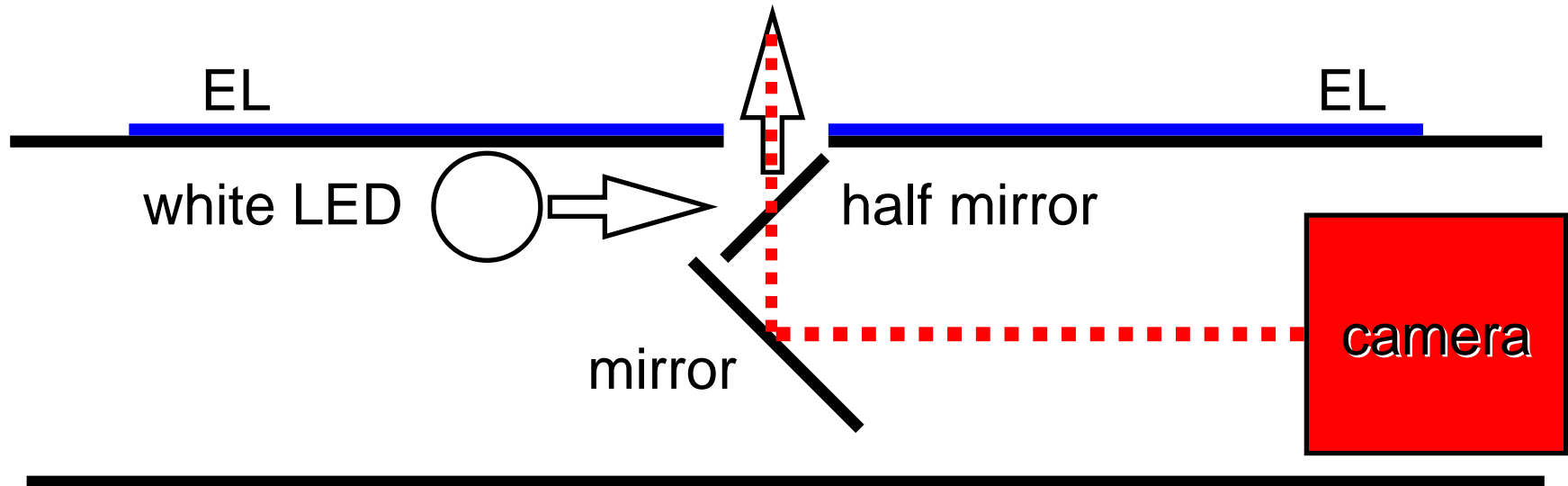
# Summary

- ◆ Z84 had 28 spots with more than  $100\mu\text{m}$  radii; they were all input coupler side.
- ◆ The resolution of  $7.4\mu\text{m}$  is achieved; limited by the working distance of the lens.
- ◆ AES1 had four spots; their locations agree with the results from passband mode and thermometry measurements.
- ◆ The wall height/depth can be estimated by integrating the measured gradient.
- ◆ Waiting for DESY cavities...

# Appendix



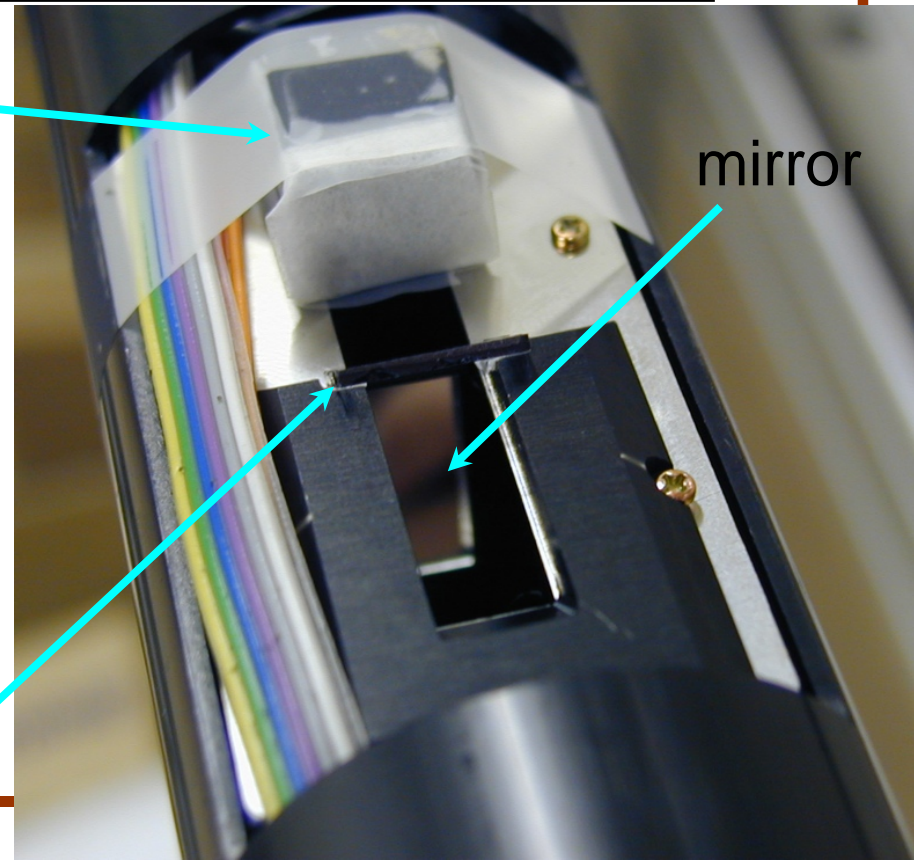
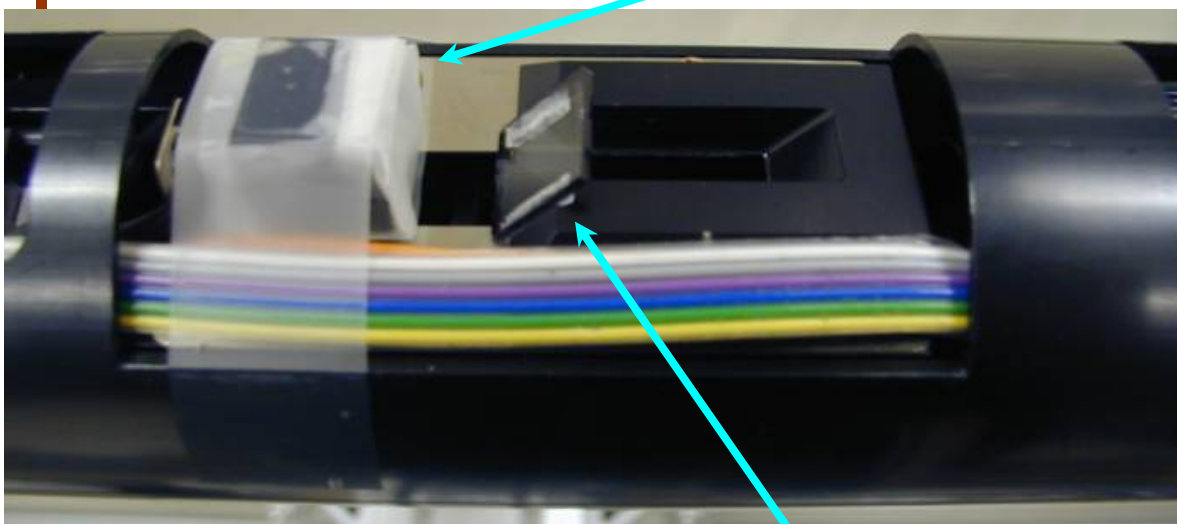
# Illuminating in front of mirror



white LED

mirror

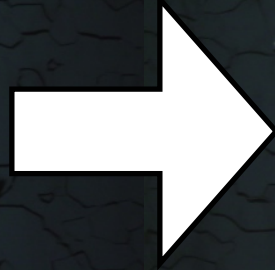
half mirror



# Illuminating ahead of the mirror

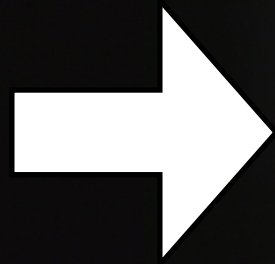
without LED

with LED

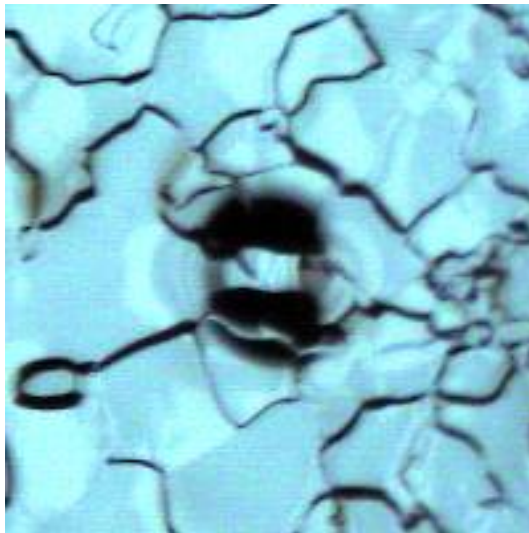


without LED

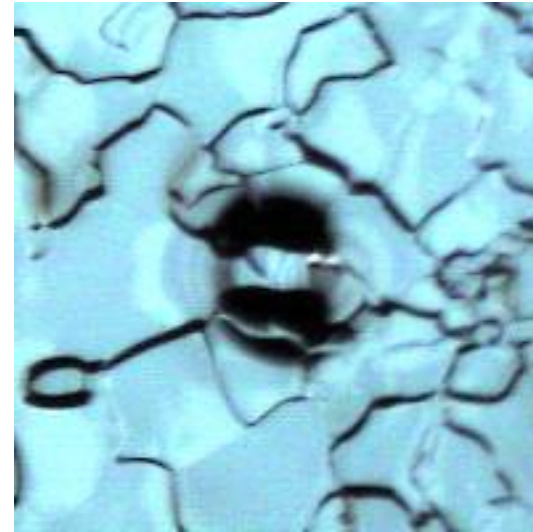
with LED



# Center Light



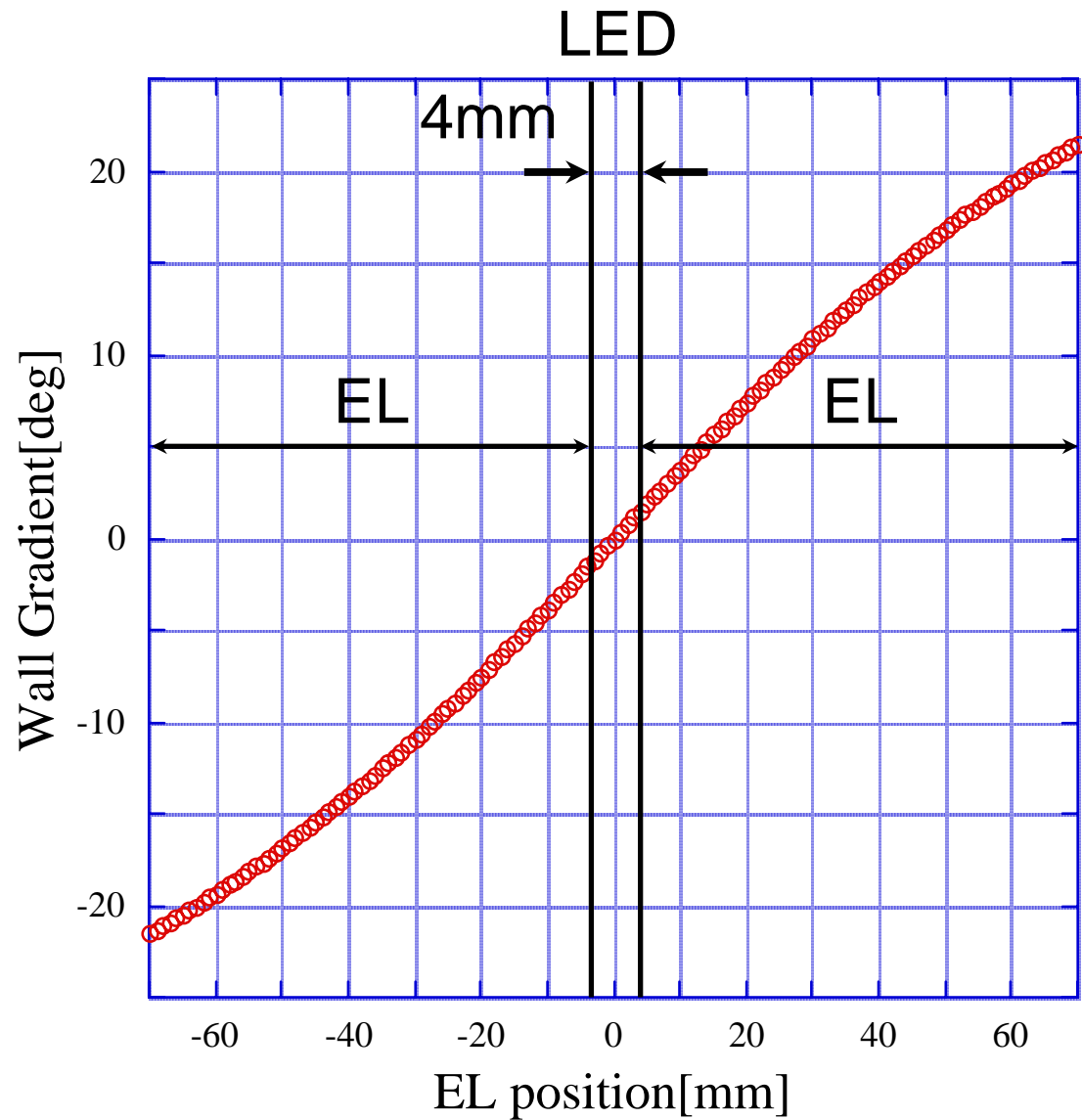
All stripe on  
except center



All stripe on



# Illumination of the mirror front



# Damper

$\alpha$ GEL

Shock Absorber & Vibration Damper

**Under Development!**

The End of Camera Cylinder:  
opposite side of the camera

SUS plate  
for Counter Balance(4kg)