

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



DEVELOPMENT OF A HIGH RESOLUTION CAMERA AND OBSERVATIONS OF SUPERCONDUCTING CAVITIES

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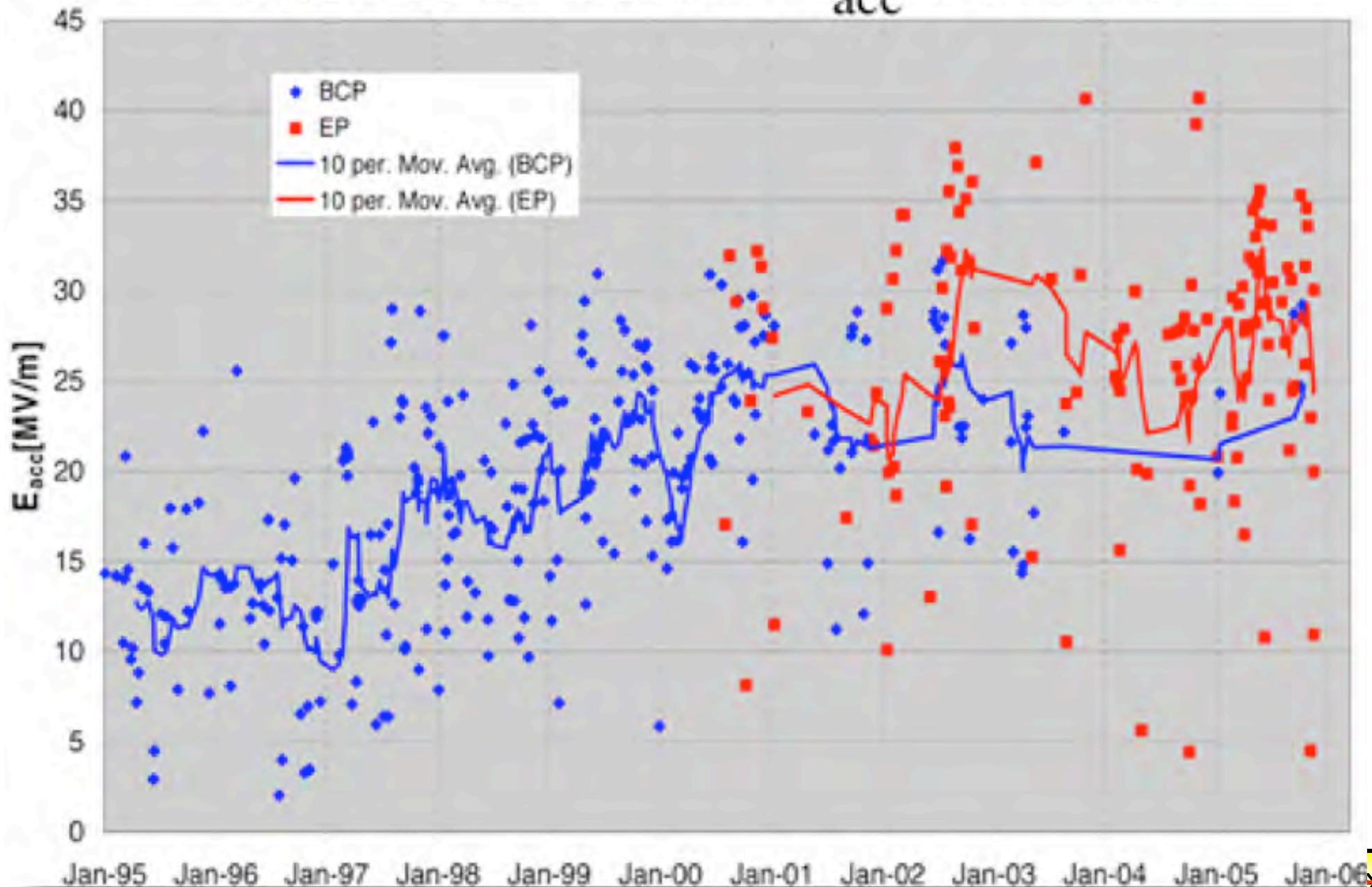
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(on leave from Kyoto Univ.)

H. Hayano, KEK, Ibaraki, JAPAN



Scatter at DESY E_{acc} vs. time



Field Limits

1) Global Heating

Ultimate limit of SRF cavities' gradient,
 $E_{acc} \sim 45 \text{ MV/m} @ \text{TESLA}$ shape cavity.

2) Multipacting

Understood enough to be controlled (shape or material of RF components).

3) Thermal Breakdown (about $100 \mu\text{m}$)

Local heating by surface irregularities
(defect: bumps or foreign materials).

4) Field Emission (about $1 \mu\text{m}$)

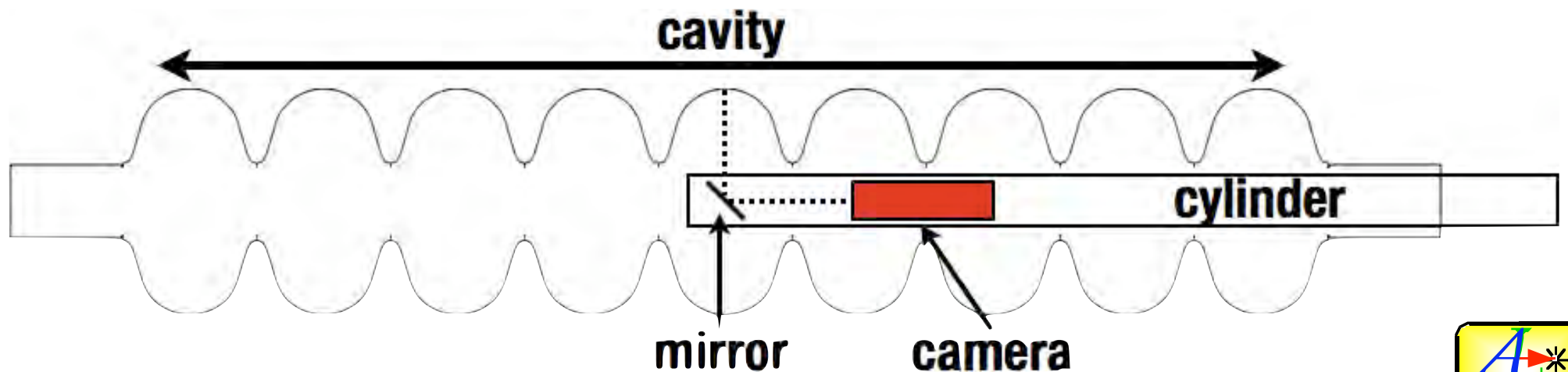
Field emitted electrons are accelerated by RF field
and hit the cavity wall.



Targets

We developed an optical inspection system...

- 1) To study the relation between the surface condition and the accelerating gradient (**thermal breakdown**).
- 2) To compare with the existing test data (thermometry, passband mode measurement).
- 3) To enable screening “bad” cavities at the final stage of the preparation (early stage in the fabrication).



Inspection System

camera cylinder

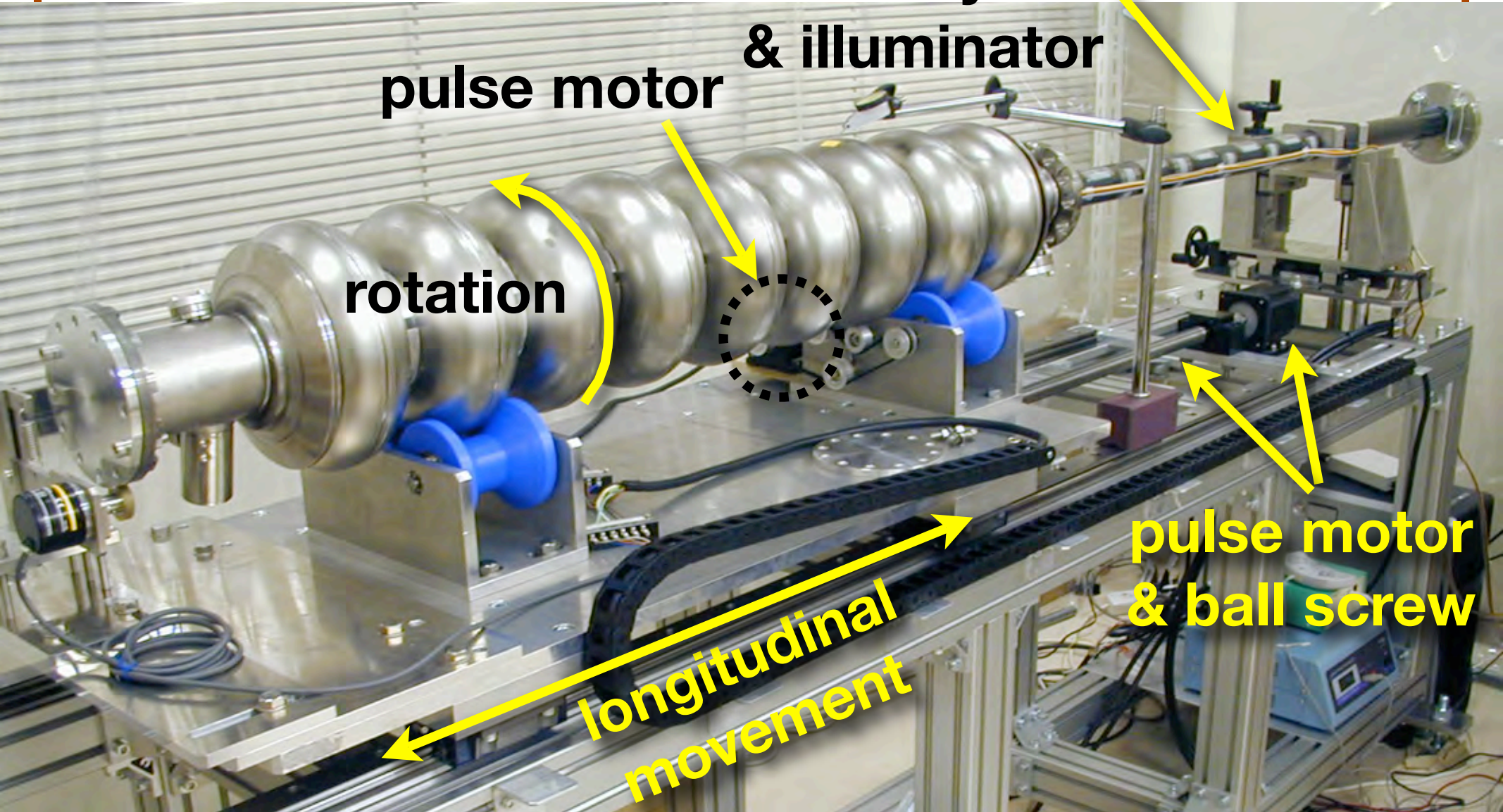
& illuminator

pulse motor

rotation

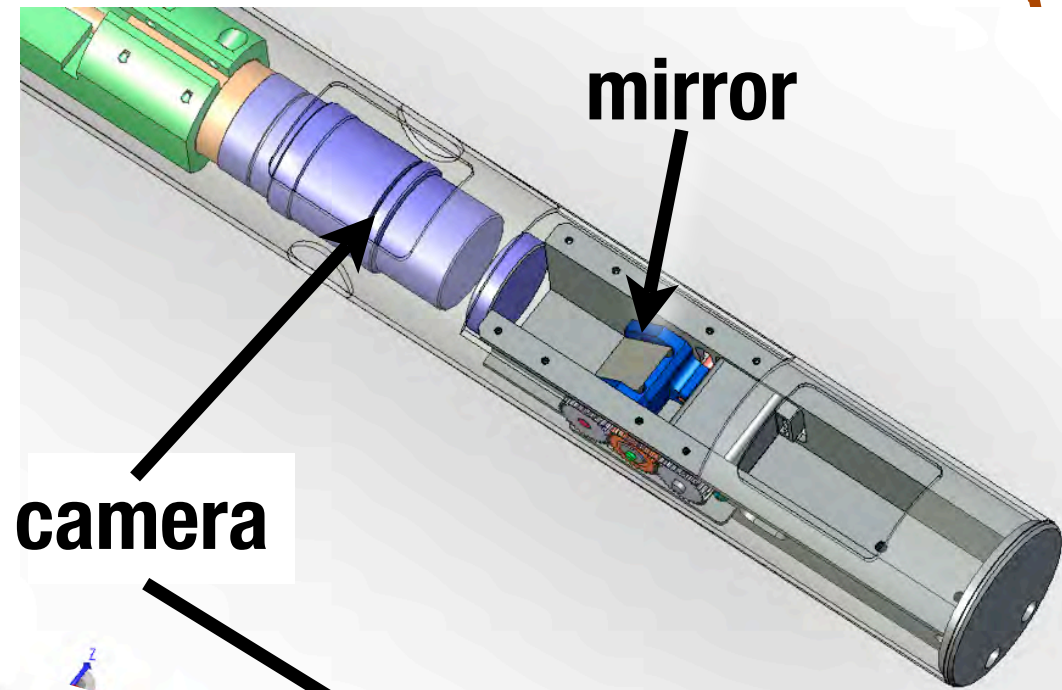
pulse motor
& ball screw

longitudinal
movement



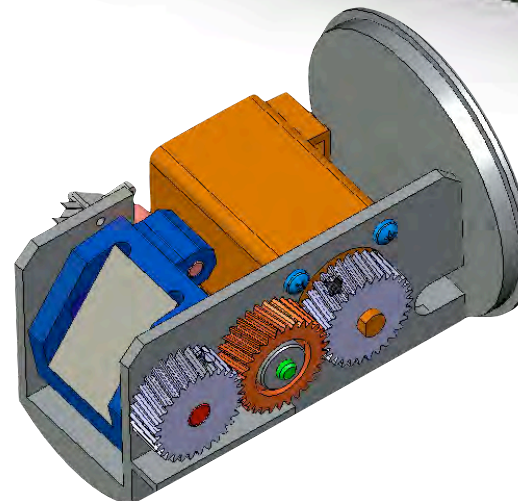
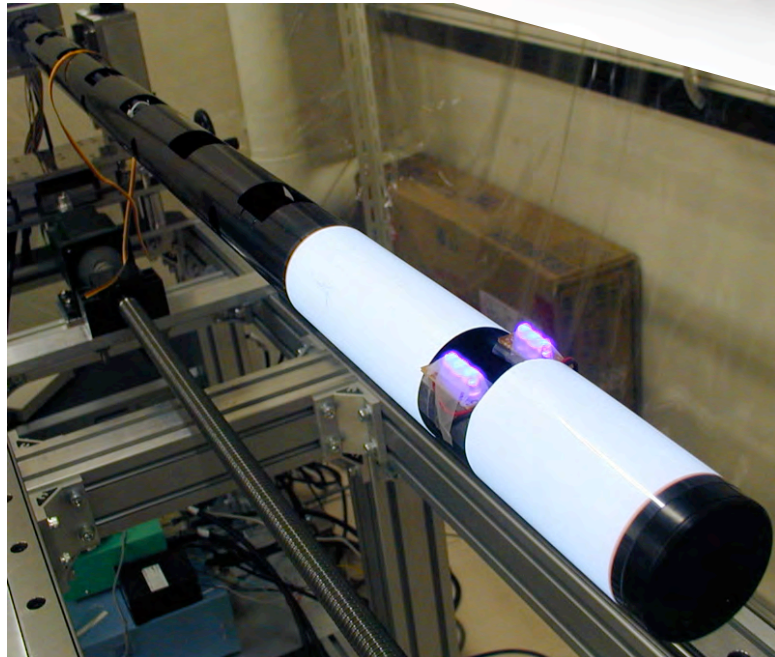
Camera Head

resolution: $7.4\mu\text{m} / \text{pixel}$



camera

mirror



Zanon #84 cavity

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

Interior Surface of Zanon #84

- 28 spots with cat's-eye shape were found at the equators of the cells.
(only the spots with diameters larger than $100\mu\text{m}$ were counted.)
- No other kind of spot was found.
- All the spots were found at the input coupler side of the EBW seam.

EBW seam



spot

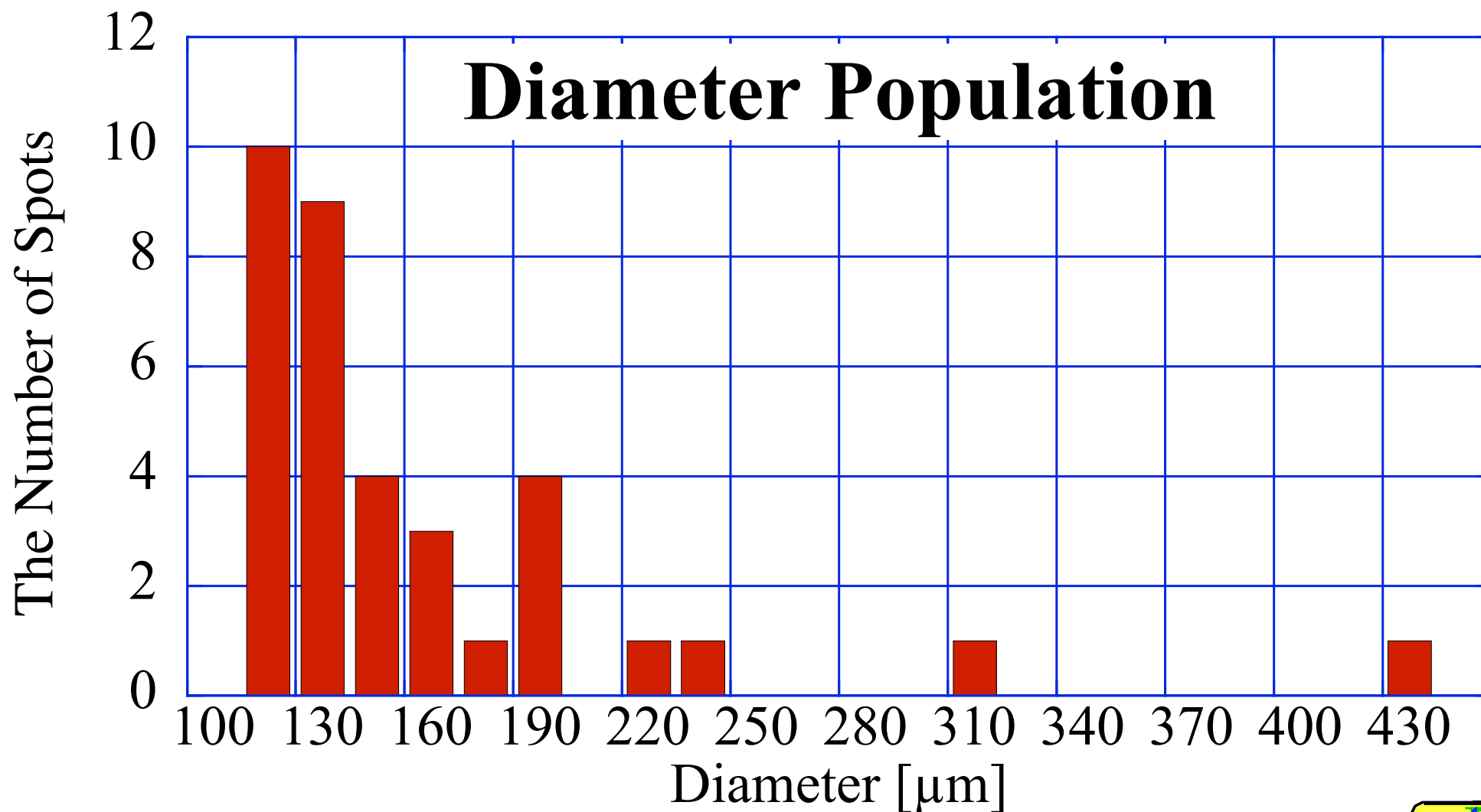


1 mm

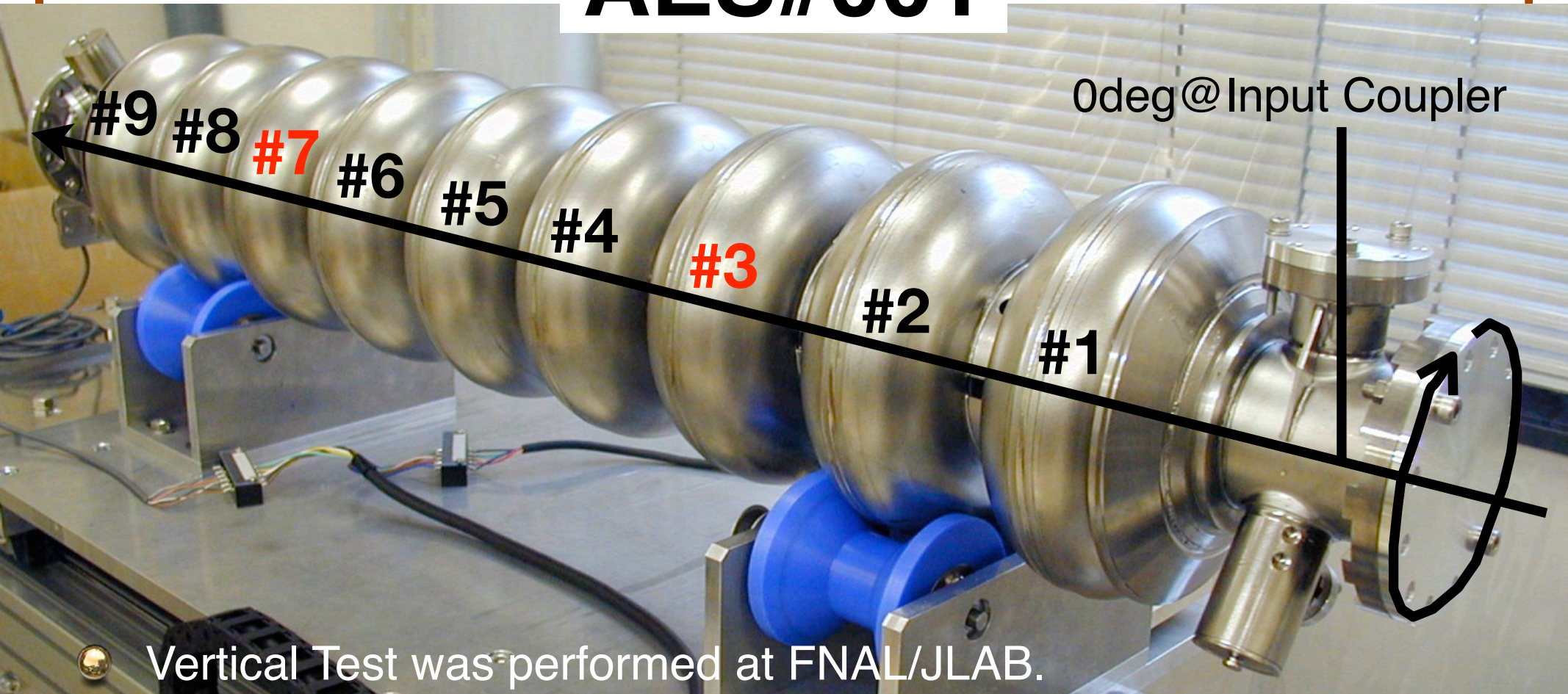


AccLab BmSci ICR
KyotoUniversity

Statistics of spots(>100 μm) in Z84



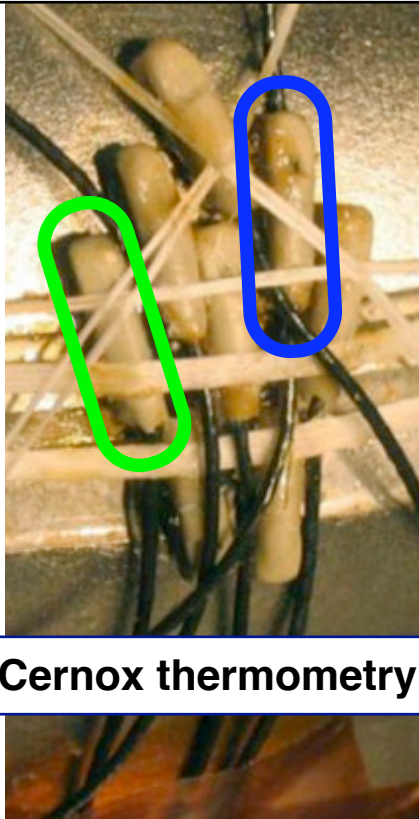
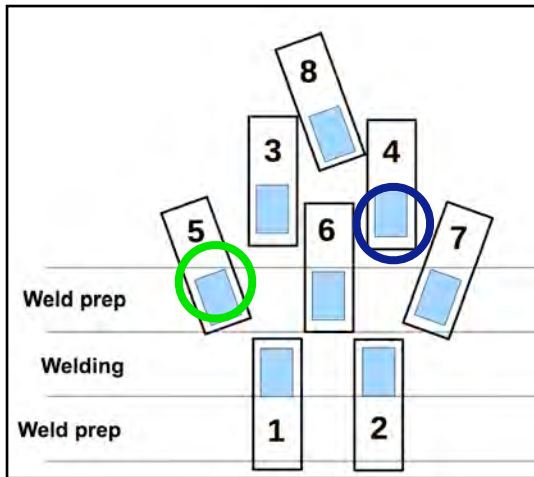
AES#001



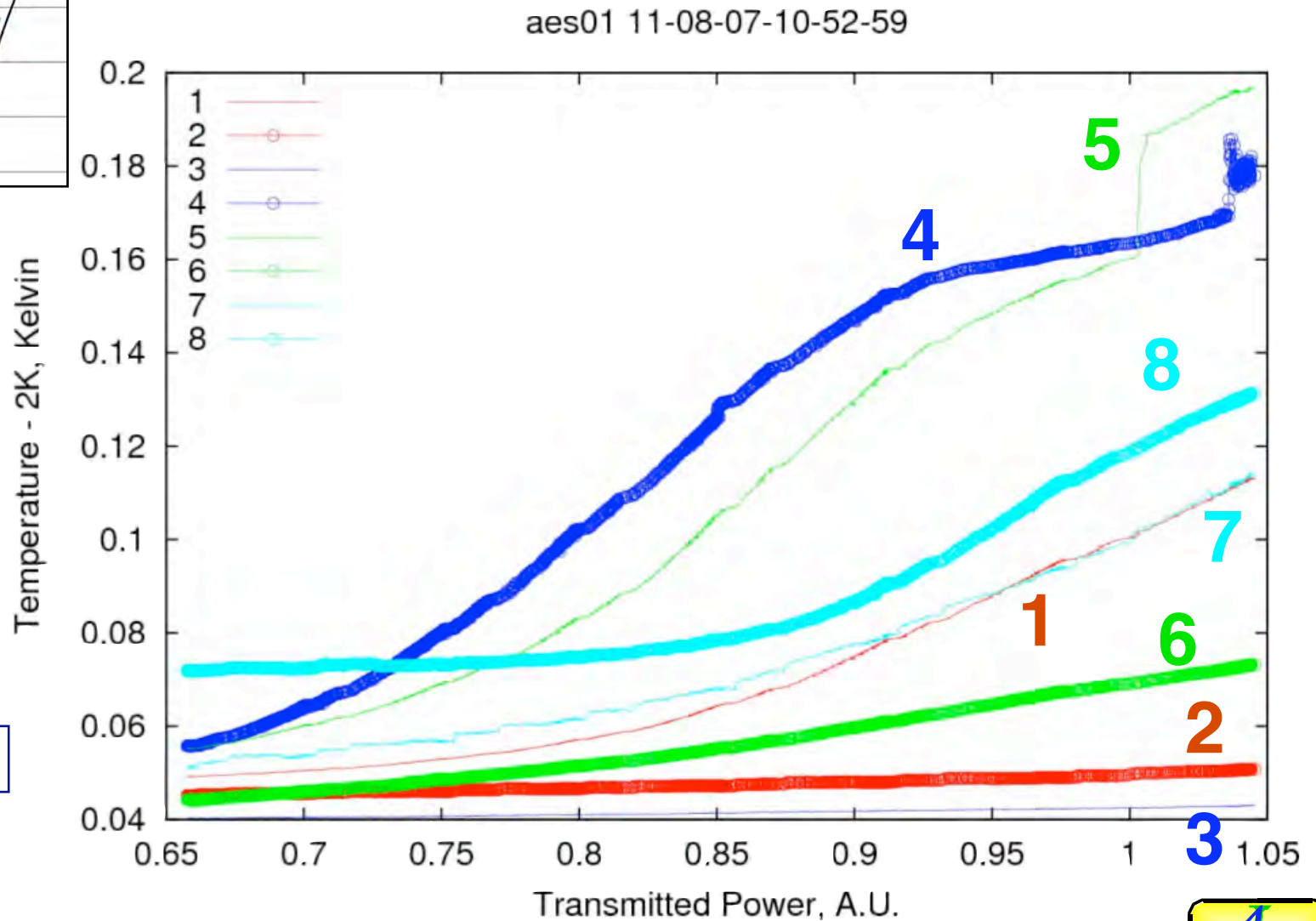
0deg@Input Coupler

- 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 thermometry 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.



Cernox thermometry

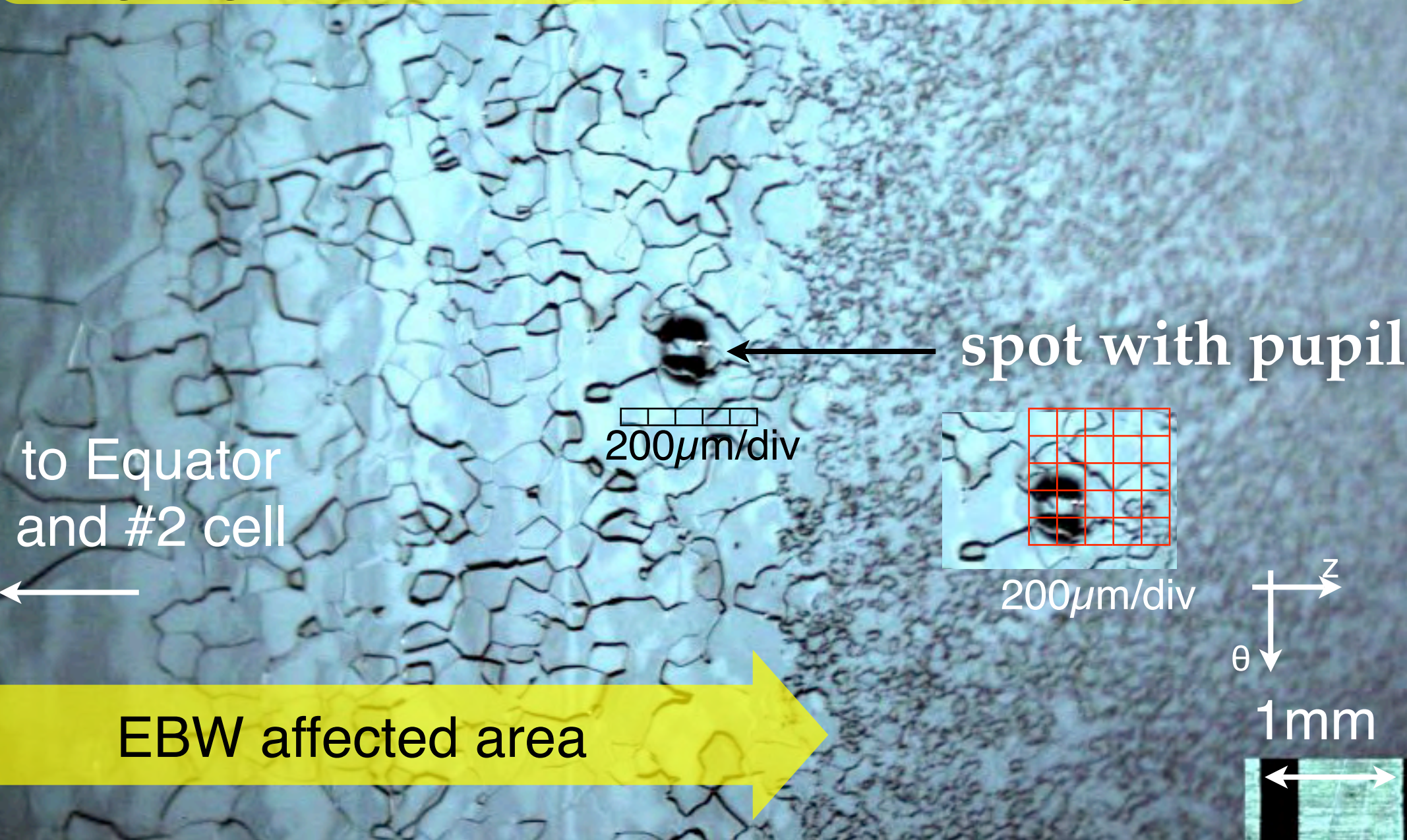


Dmitri A. Sergatskov: Thermometry on AES01 cavity at Fermilab @webex20071204



AES001 #3 cell 181°

Larger grains Transition? Fine grains



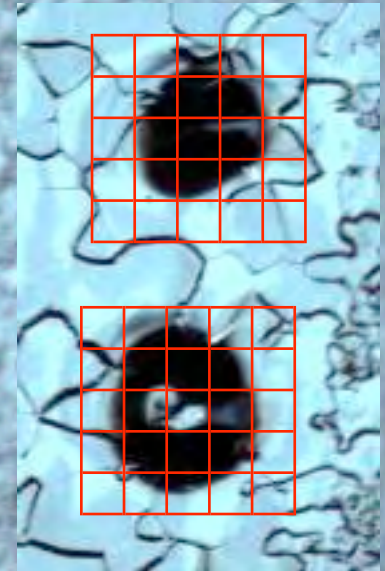
AES001 #3 cell 169°

Larger grains Transition? Fine grains

Twins

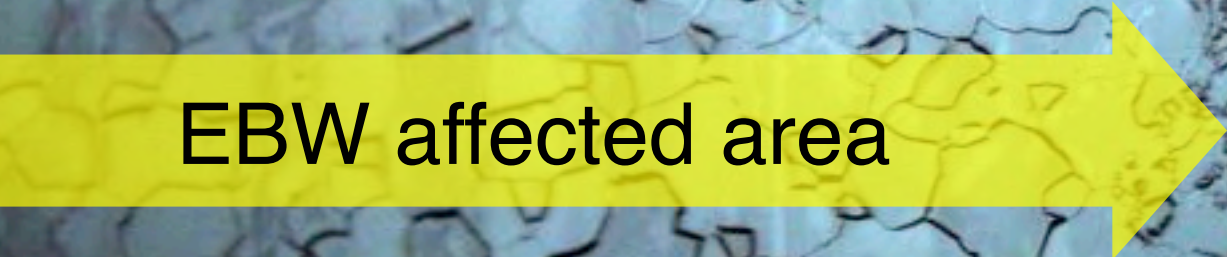
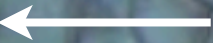
← spot(a) @ 168°

← spot(b) @ 169°



200μm/div

to Equator
and #2 cell



EBW affected area



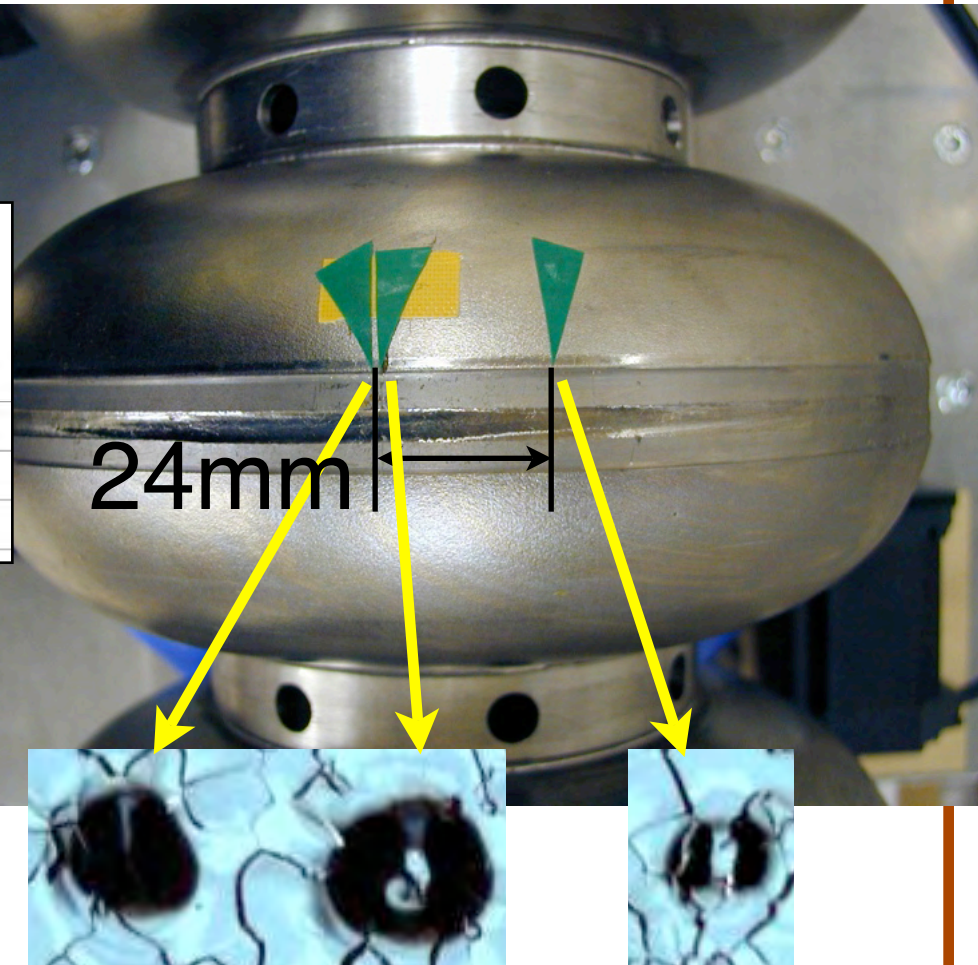
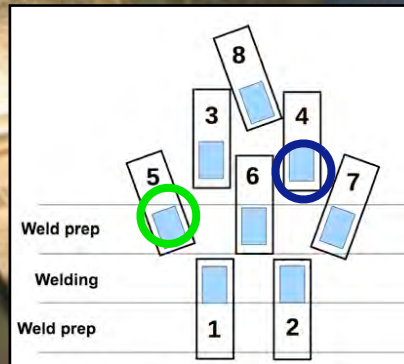
1mm



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

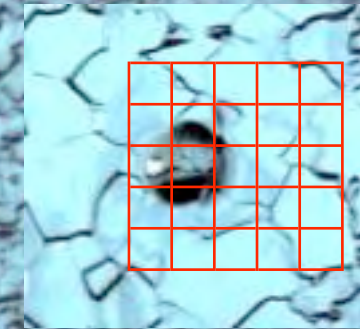
Three spots found@Kyoto



AES001 #7 cell 325°

Larger grains Transition? Fine grains

to Equator
and #6 cell



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

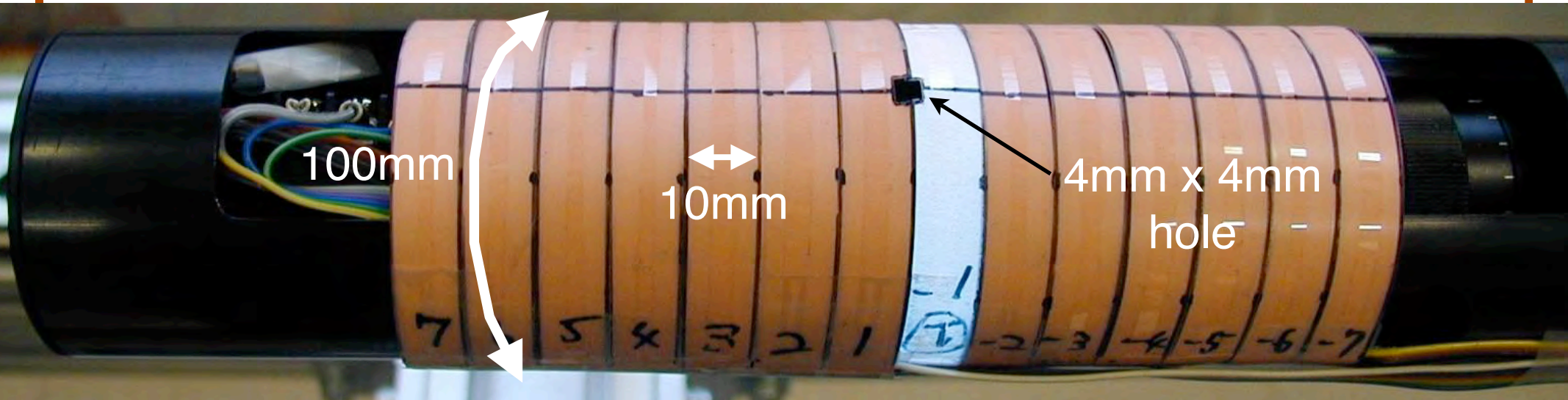
spot with pupil



EBW affected area

1mm

Stripe Illumination(SI)



- Fourteen Electro-Luminescence(EL) stripe sheets are 10mm in axial direction and cover 100mm in azimuthal direction.
- These fourteen stripes 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.

Wall Gradient Measurement

**cavity surface
(mirror)**

$$\vartheta = \frac{1}{2} \arctan\left(\frac{z}{R-r}\right).$$

inner radius
of the cavity
 $R=100\text{mm}$

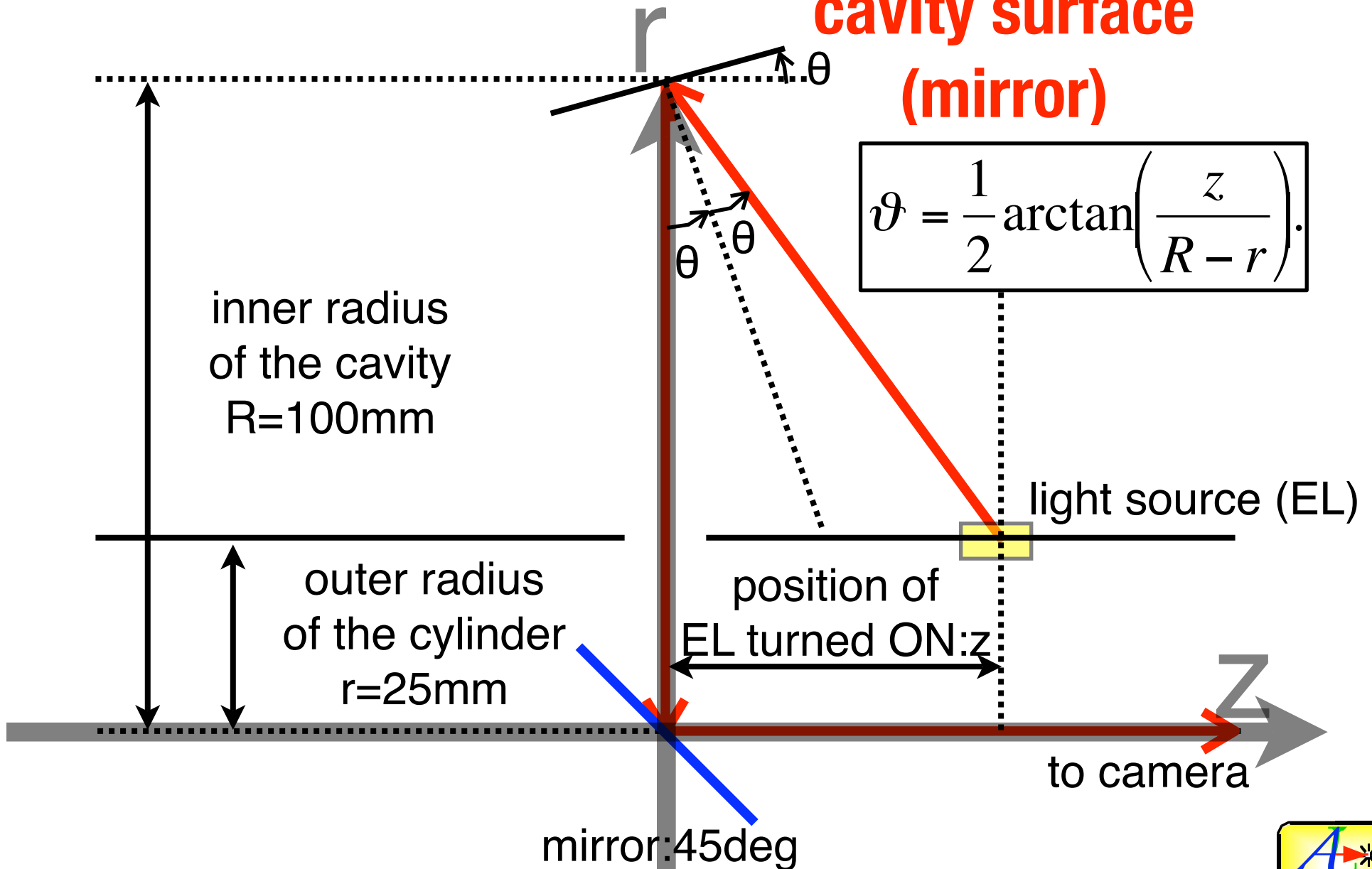
outer radius
of the cylinder
 $r=25\text{mm}$

light source (EL)

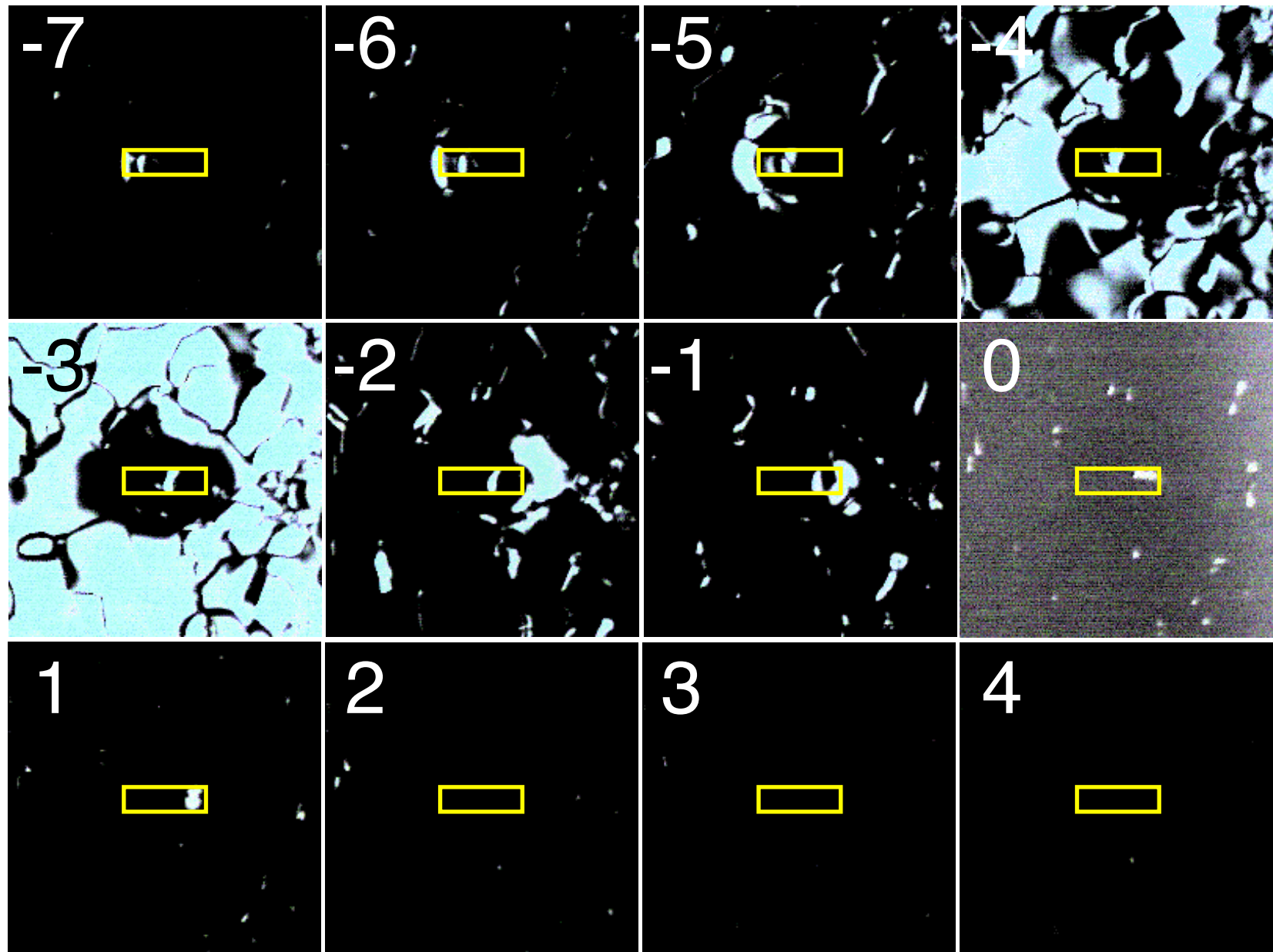
position of
EL turned ON: z

to camera

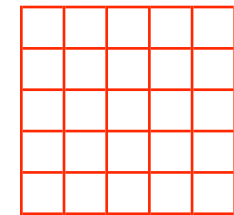
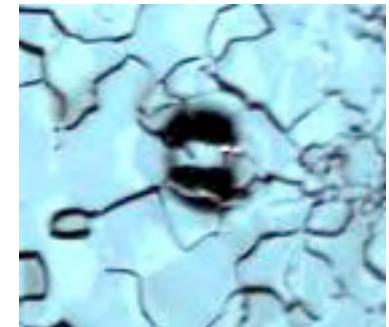
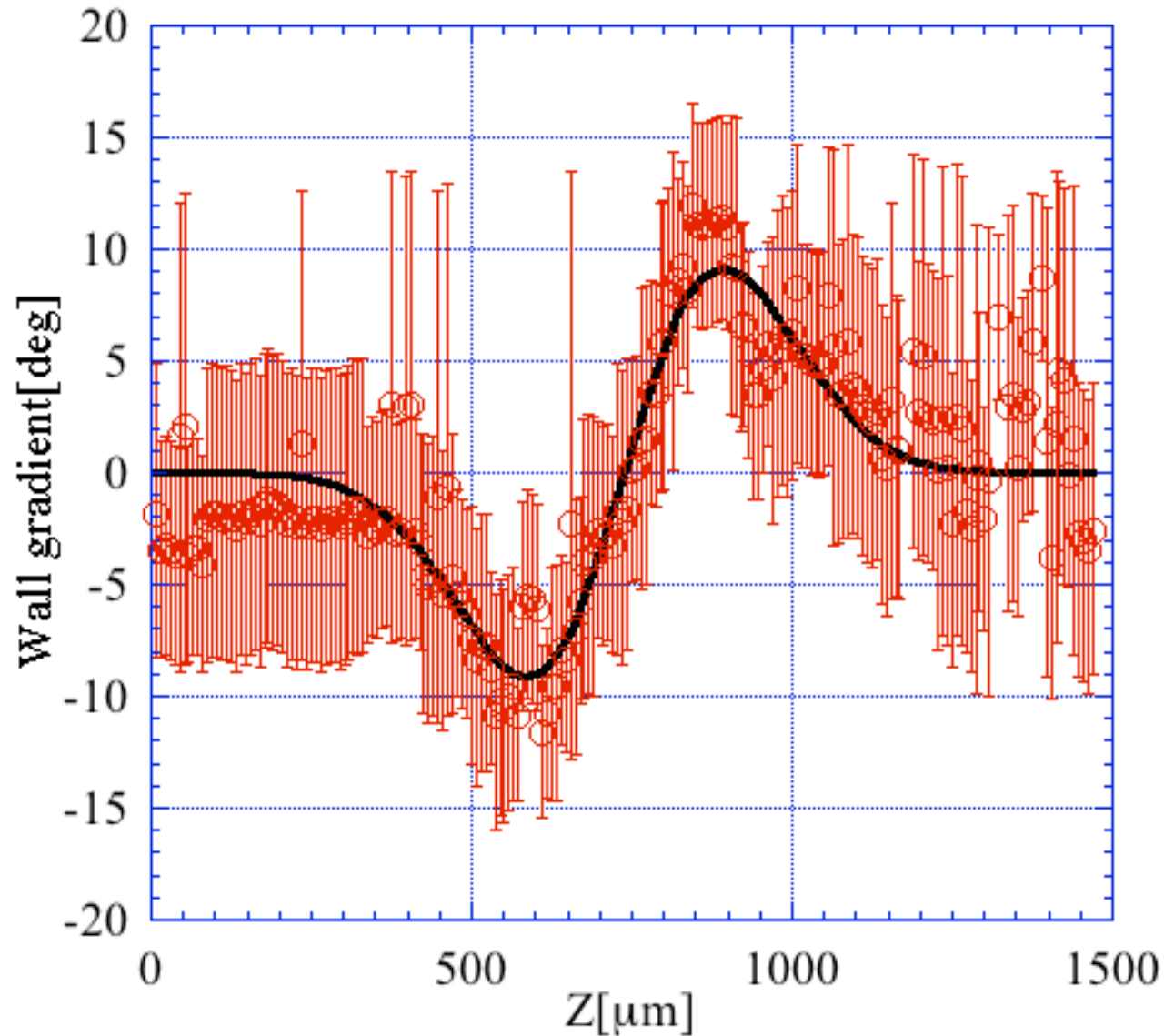
mirror: 45deg



Wall Gradient Measurement



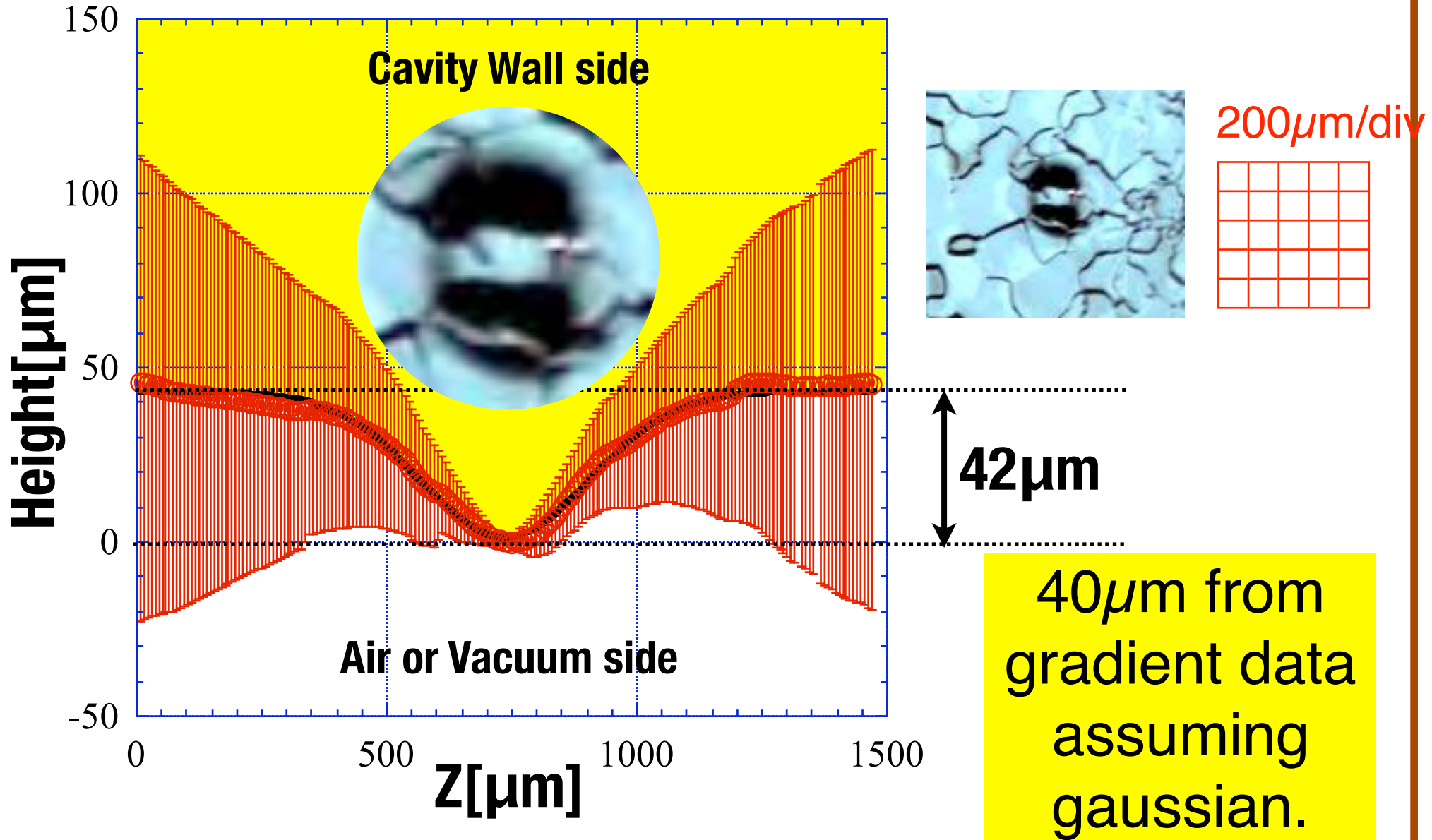
Wall Gradient of spot at #3 cell 181°



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

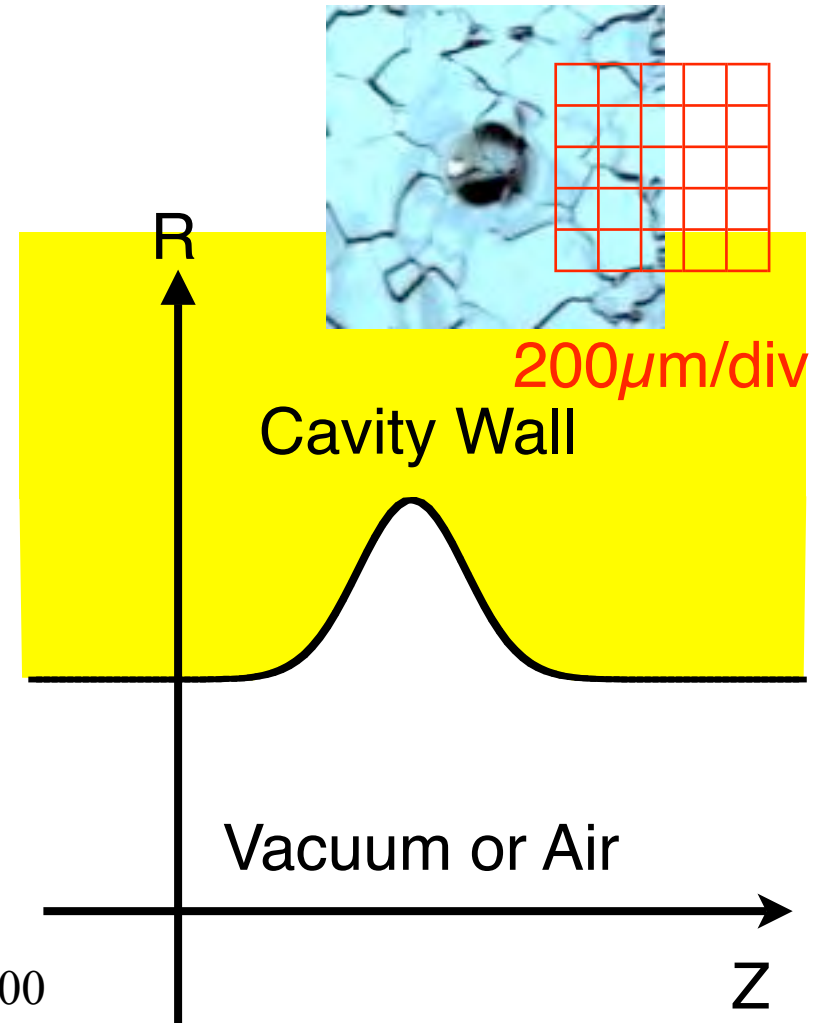
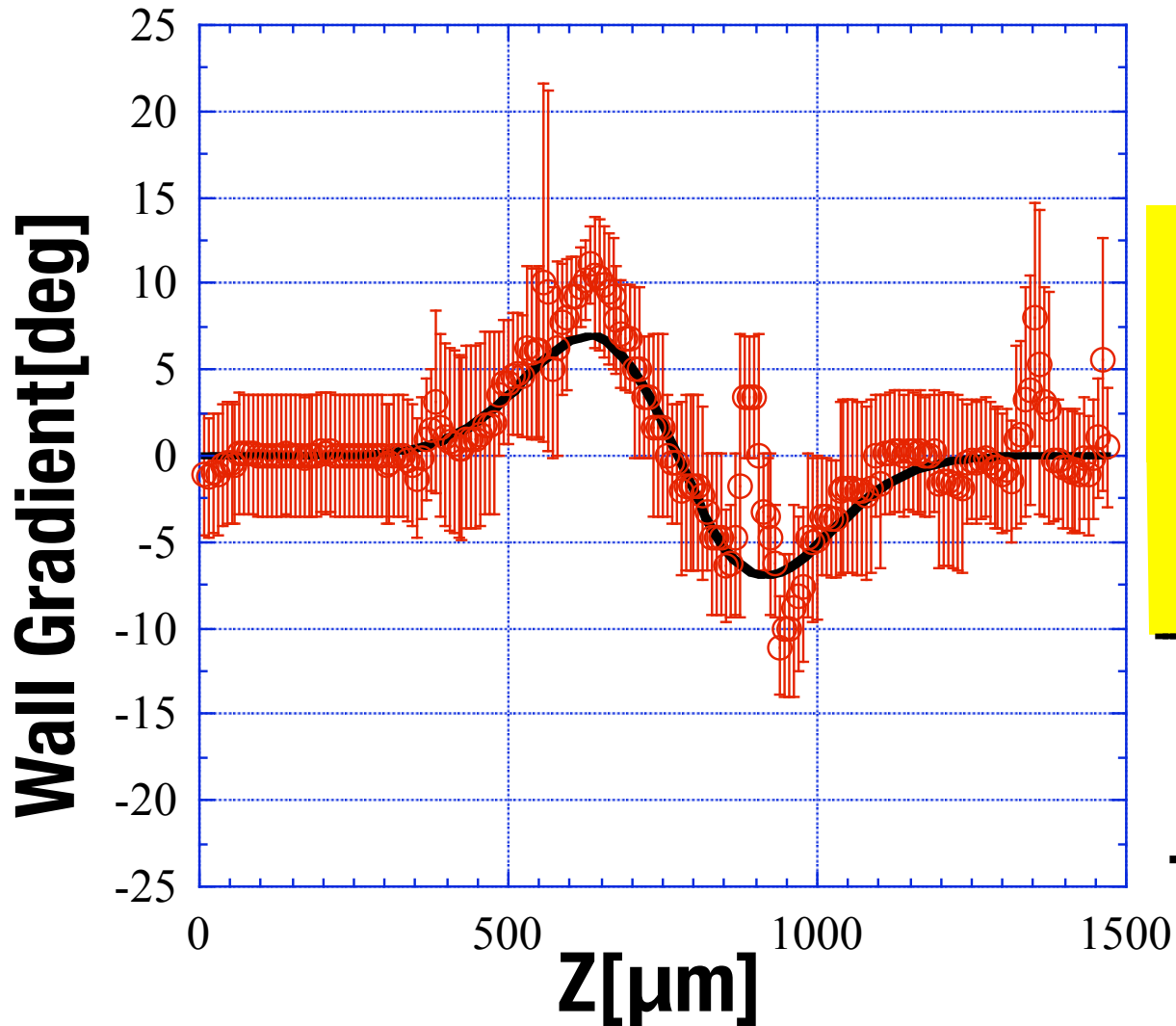
- This data shows that the spot is a convex(ball).
- Because of the continuity of the measured gradient, we can integrate the gradient to estimate the height of the spot.

Height of spot at #3 cell 181°



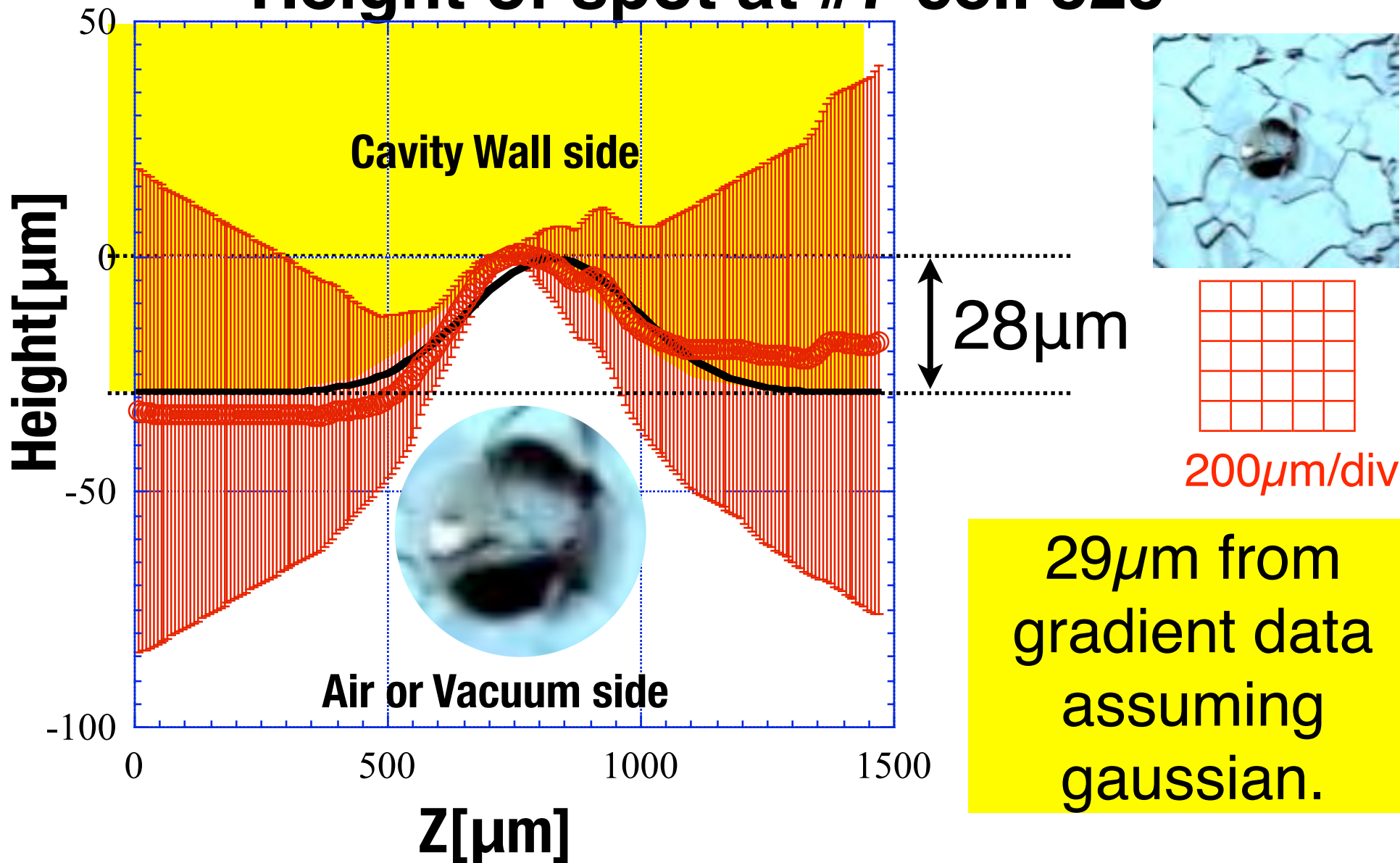
Black curve is a fitted gaussian.

Wall Gradient of spot at #7 cell 325°



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

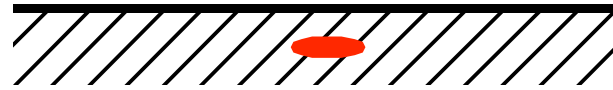
Height of spot at #7 cell 325°



Black curve is a fitted gaussian.

A Speculation

Impurity inside?



Eruption!

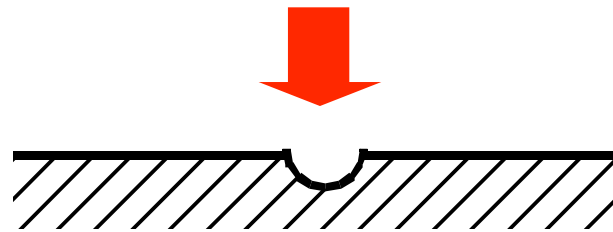


or

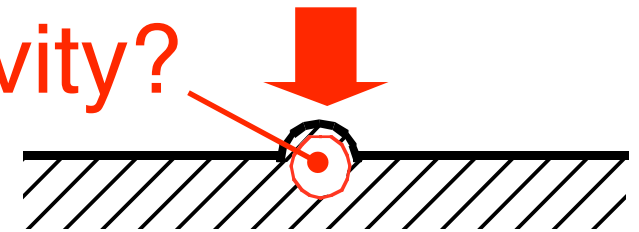
Bulge



Transition region?

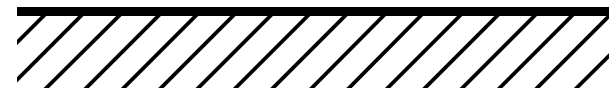


cavity?



Seam center?

Hot enough to melt over



Nothing left if temperature is high enough

Spot location

AC74

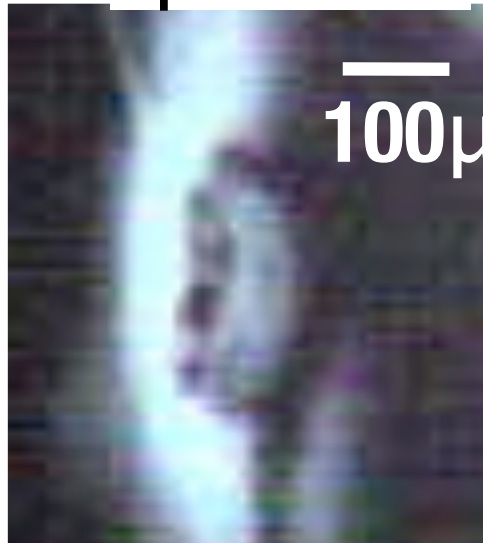
#3 ←

Cell #4

→ #5

Stiffener out side? 95°, 141°

AC74:
spot1 95°



AC74:
spot2 141°



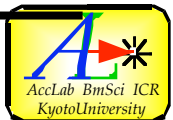
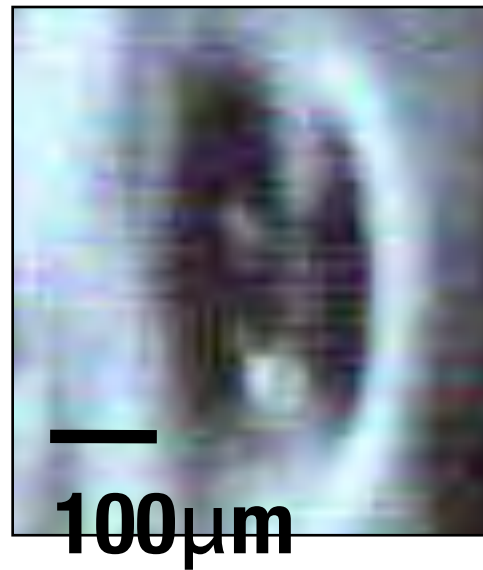
Spot location

AC80

#4 ←

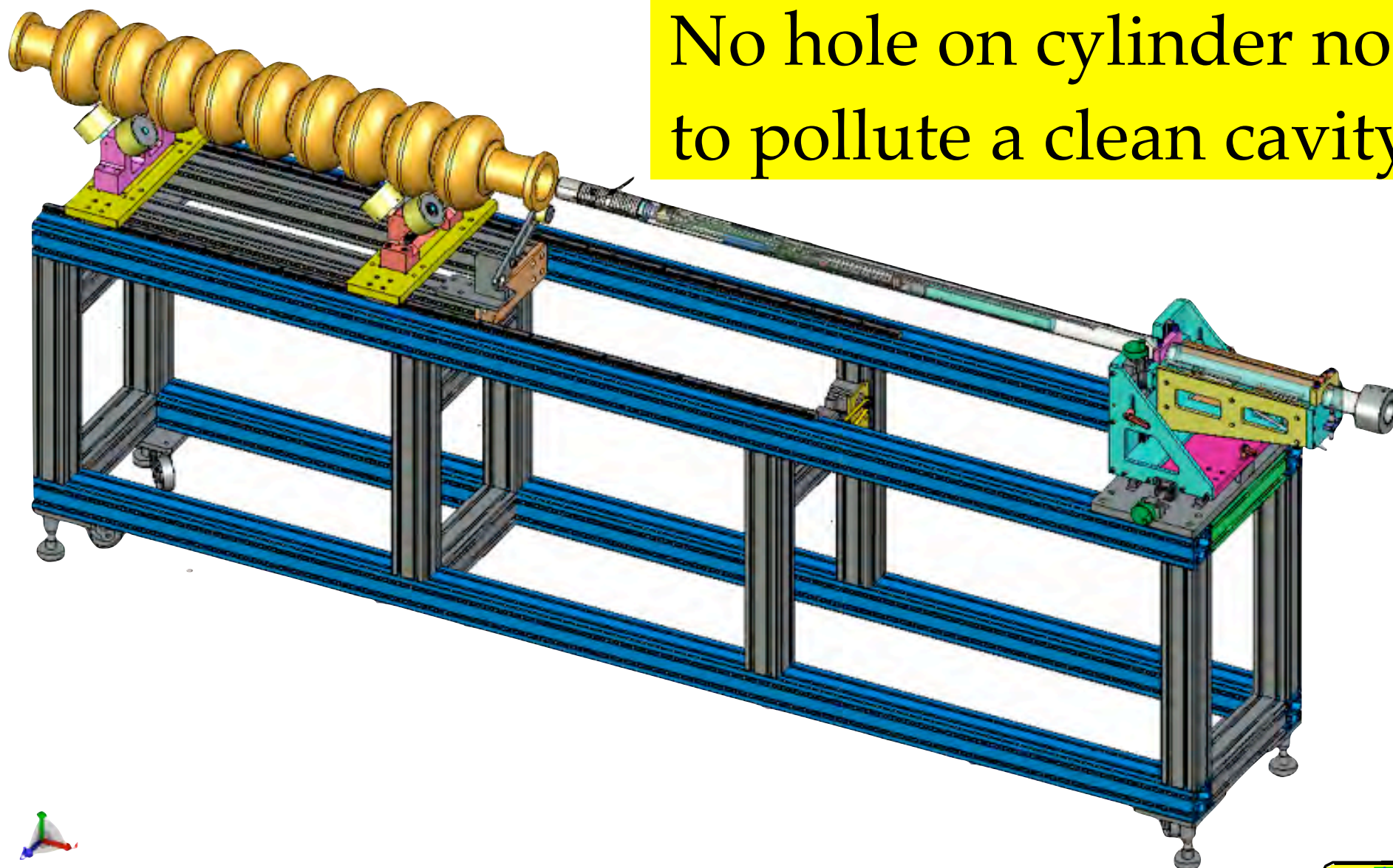
Cell #5

→ #6



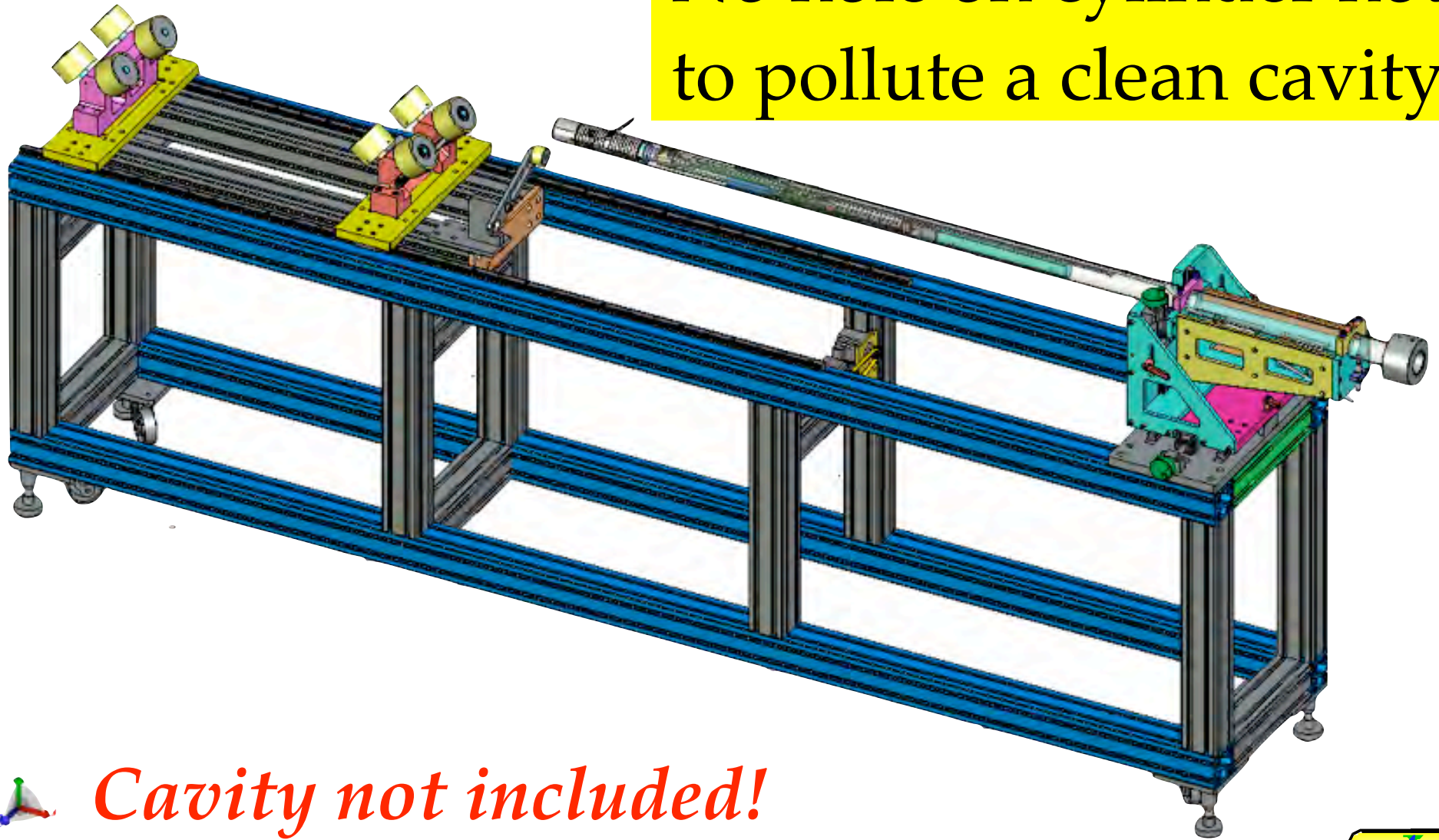
Prototype design for production series

No hole on cylinder not to pollute a clean cavity



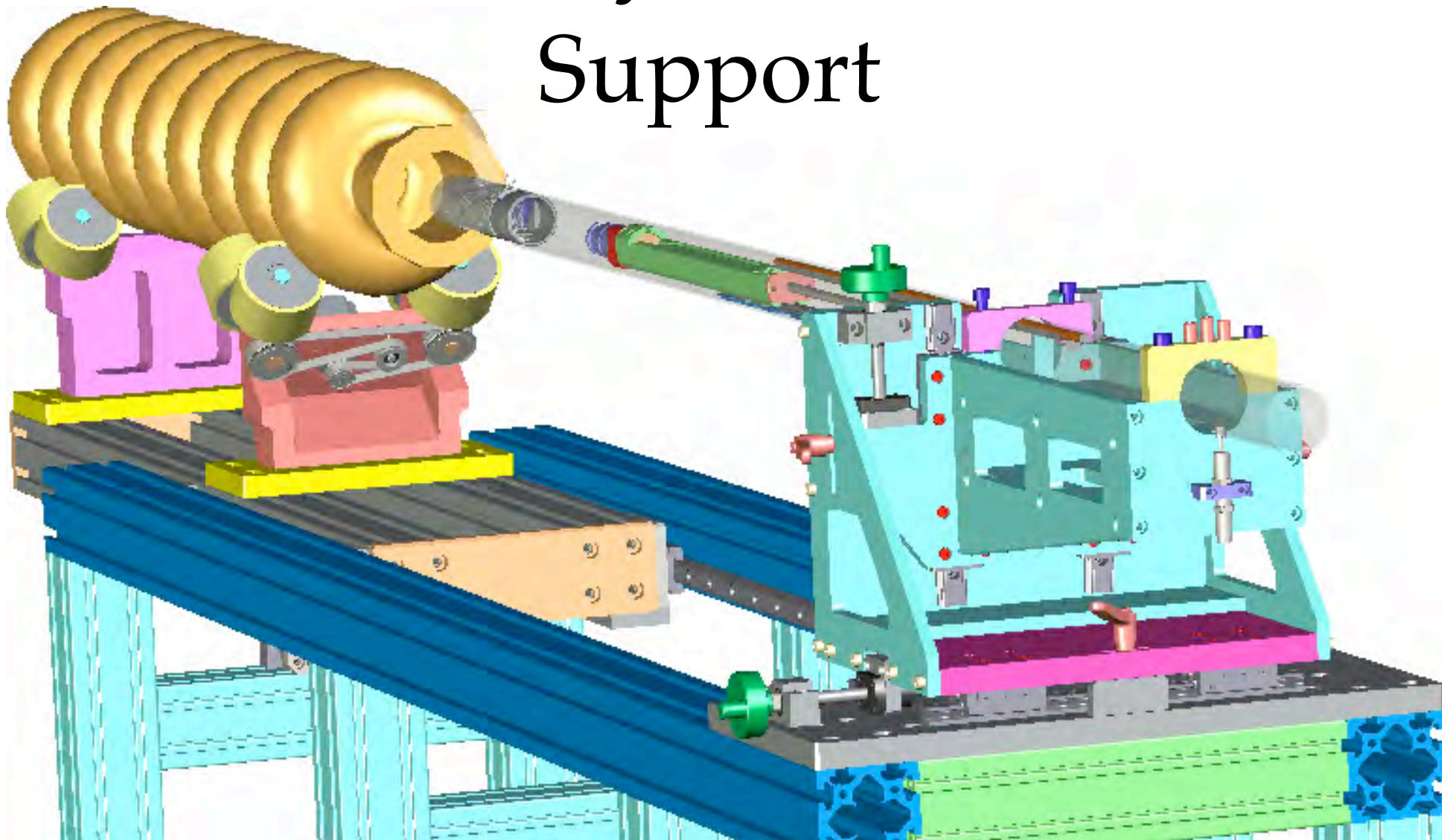
Prototype design for production series

No hole on cylinder not to pollute a clean cavity

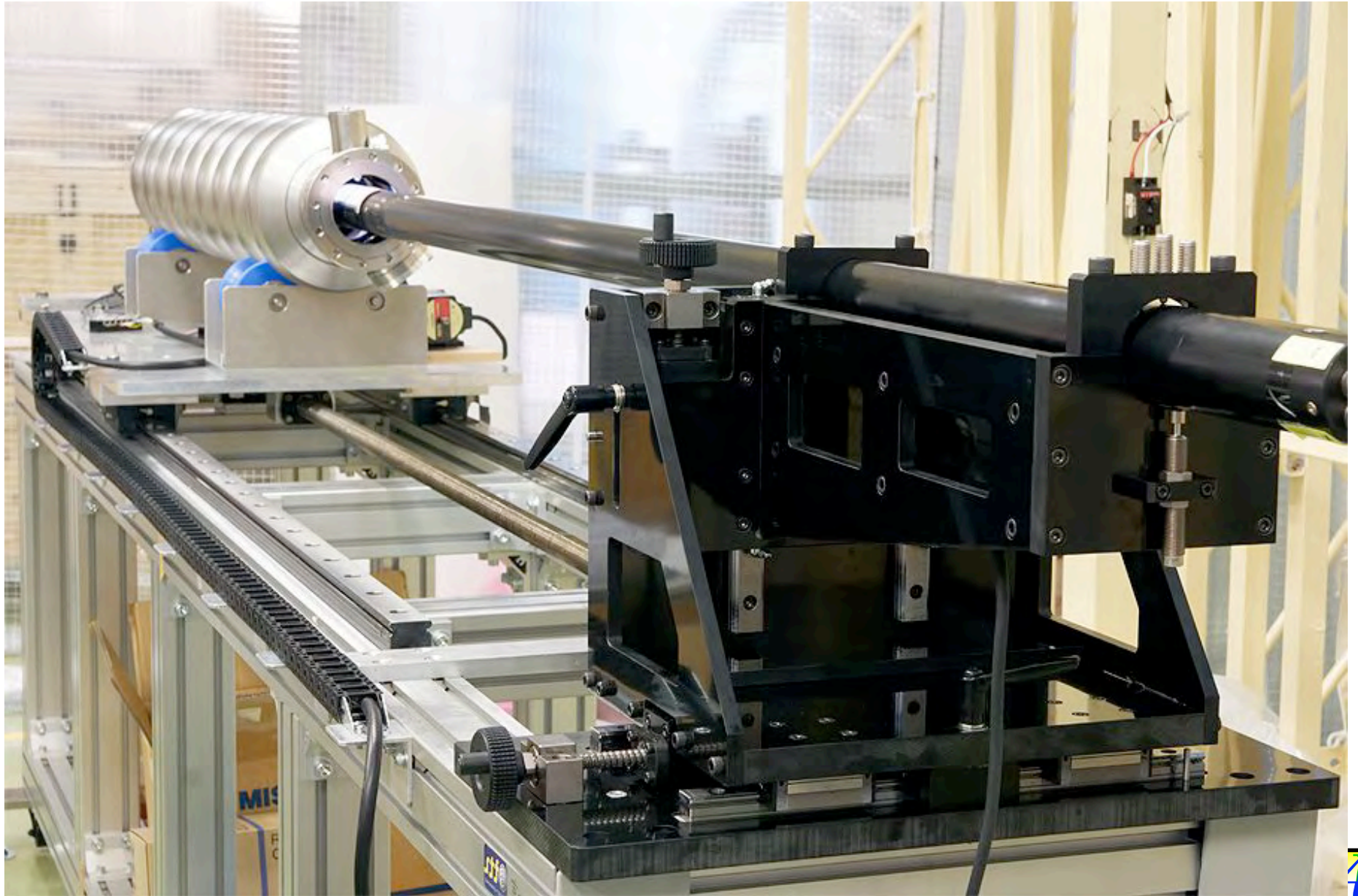


 *Cavity not included!*

Camera Cylinder and its Support



System Delivered to KEK



Summary

- I. The resolution of $7.4\mu\text{m}$ is achieved.
- II. AES1 spot locations agree with the results from passband mode and thermometry.
- III. The wall height/depth can be estimated by integrating the measured gradient.
- IV. It may improve the yield of the cavity fabrication.
- V. It is ready to be delivered to worldwide; the first product was just delivered to KEK.

