IHEP Large Grain Low Loss 9-cell Cavity R&D

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IHEP

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Content

- *IHEP 1.3 GHz Low Loss 9-cell cavity and SRF facilities R&D Progress*
- *IHEP 1.3 GHz input coupler, tuner, LLRF & cryomodule R&D*
- *Summary*

Low Loss 9-cell Cavity IHEP-01

- *Fabricated in Beijing with Ningxia large grain Nb*
- *February 2009 ~ April 2010*

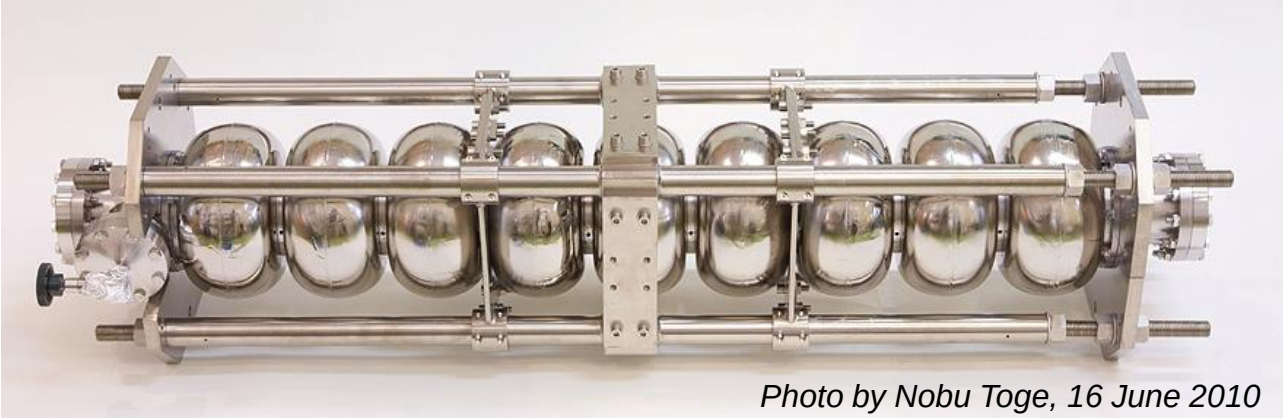
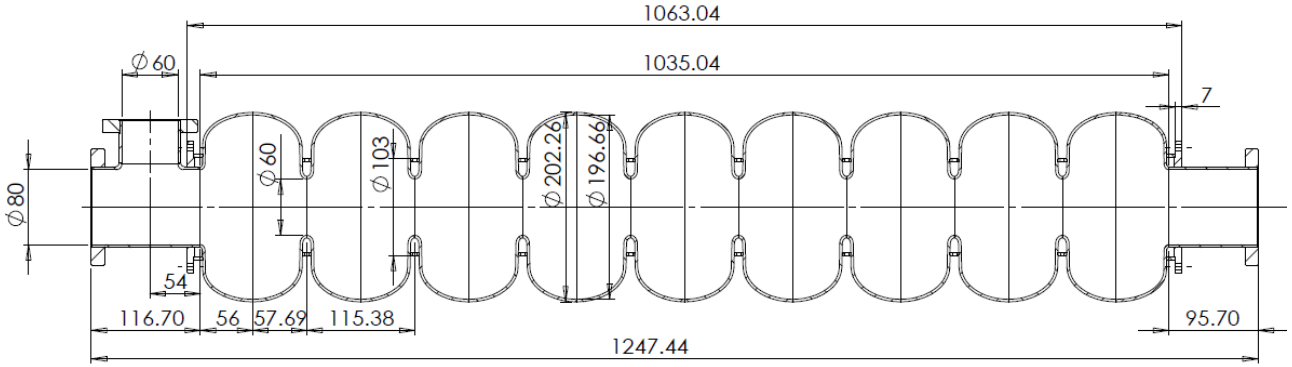
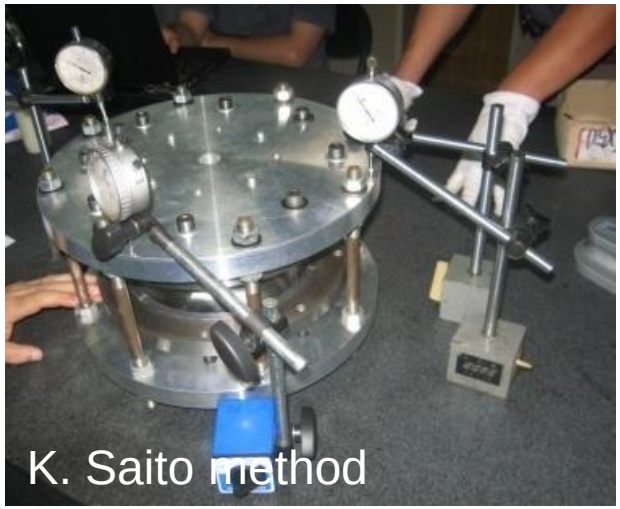


Photo by Nobu Toge, 16 June 2010



Dumbbell Reshaping and Freq. Control



Low Loss shape special issue

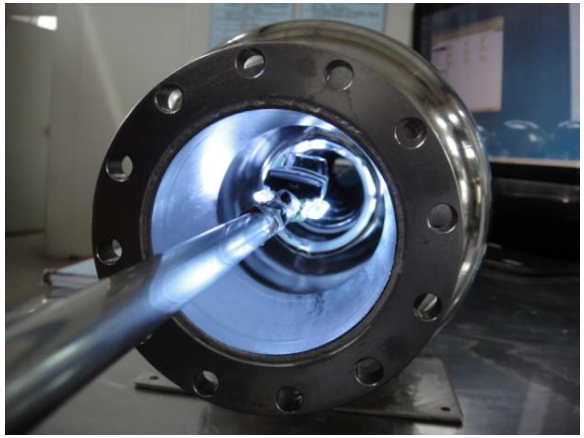
Precise Freq. and Length control

As Received Check

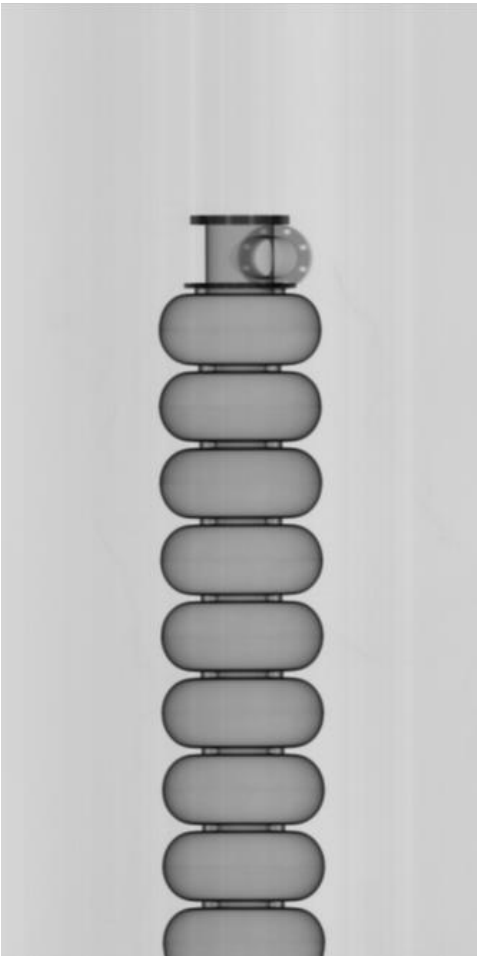
Vacuum

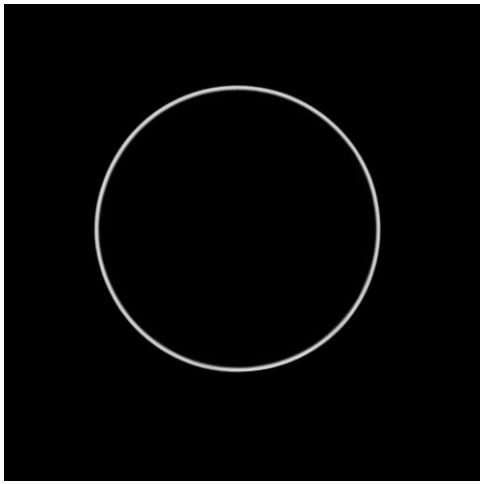
Dimension

Inner Surface



Industrial CT Inspection





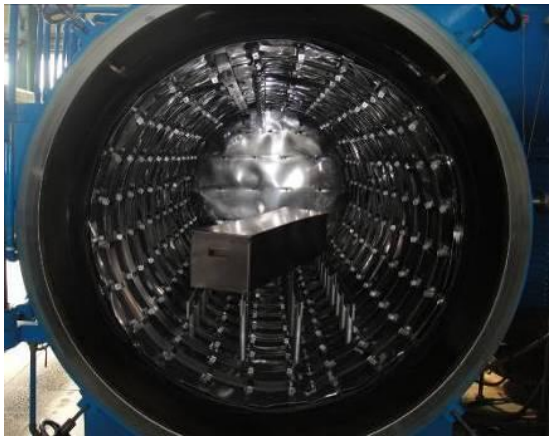
- *IHEP CT Facility*
- *Equator tomography*
- *Resolution too low to find surface defects*

Surface Treatment at IHEP (1)

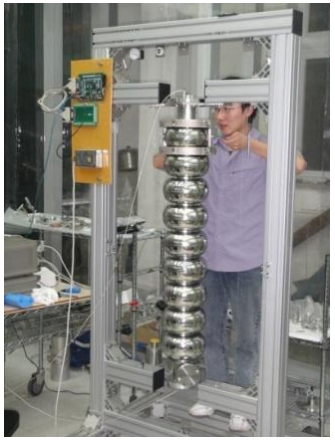
CBP 190 μm, 62 h

1st CP, 110 μm, 15 °C

Pretuning Test



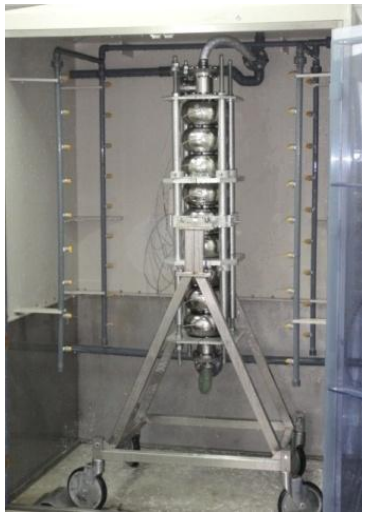
Annealing, 3 h
1.5E-3 Pa, 750 °C



Pretuning 97.6%
94 % with jig

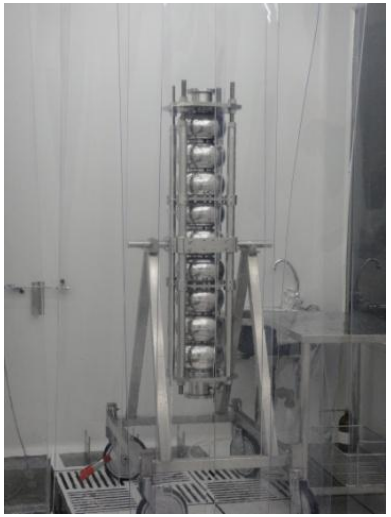
Ultrasonic Cleaning
2 % Micro-90, 50 °C, 3 h

Surface Treatment at IHEP (2)



2nd CP, 20 μm, 22°C

Low Pressure Rinsing
2 MPa, 2 mm nozzle



Dry in Class 10
Clean Room

Fill in Pure Ar Gas

Ship to KEK

2010,June 04 @ KEK

Surface Treatment at KEK STF

Flange Grind and CP

Ultrasonic Cleaning
2 % Liquinox, 43 ^{o}C, 3 h

HPR, 8.5 h,8 MPa

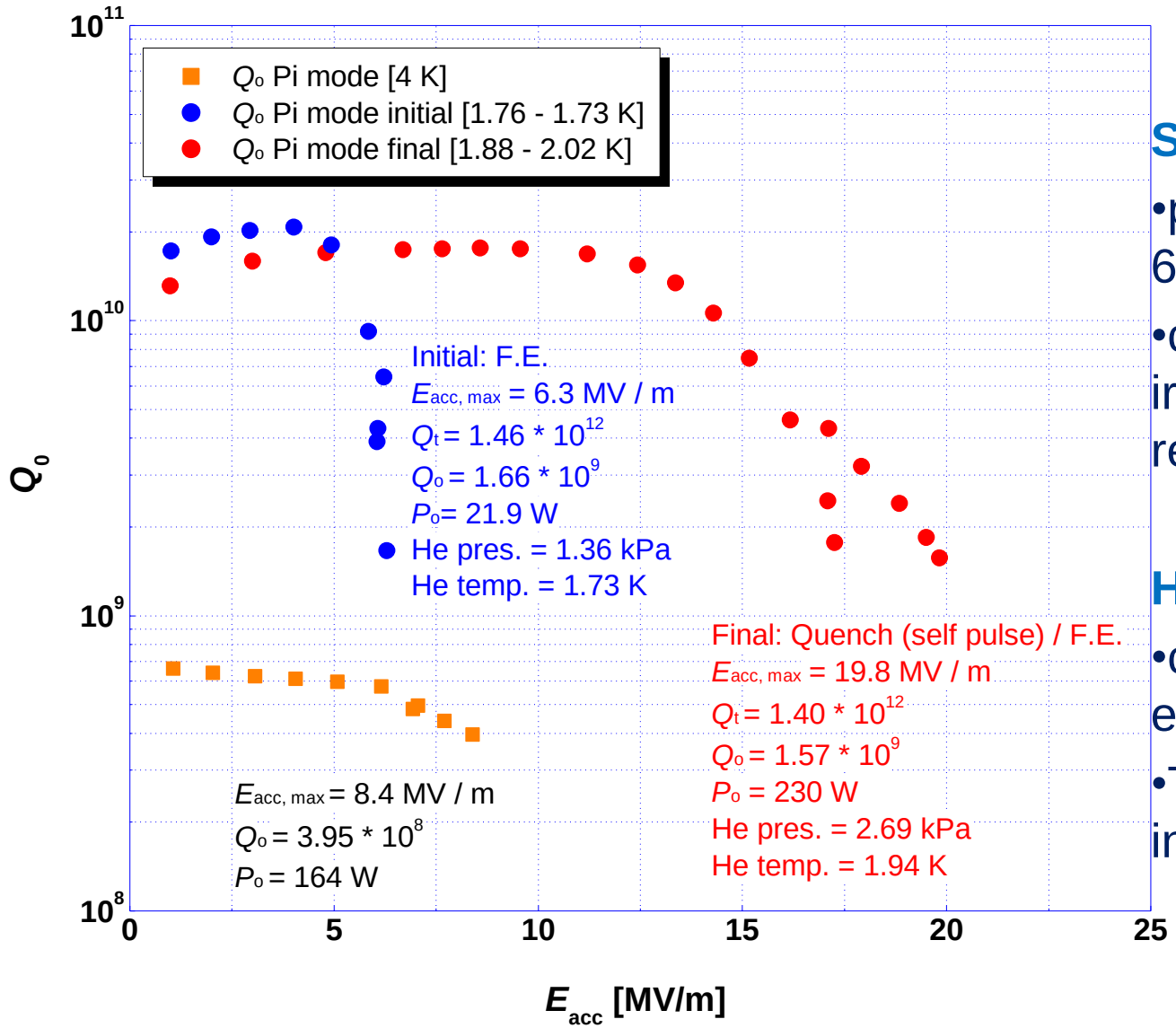
Assemble with KEK Helicoflex,
input coupler & e^{-} pickup

Pumping & Baking,
105 ^{o}C, 48 h

Vertical Test on July 1st 2010

STF T-mapping system

First Vertical Test Result



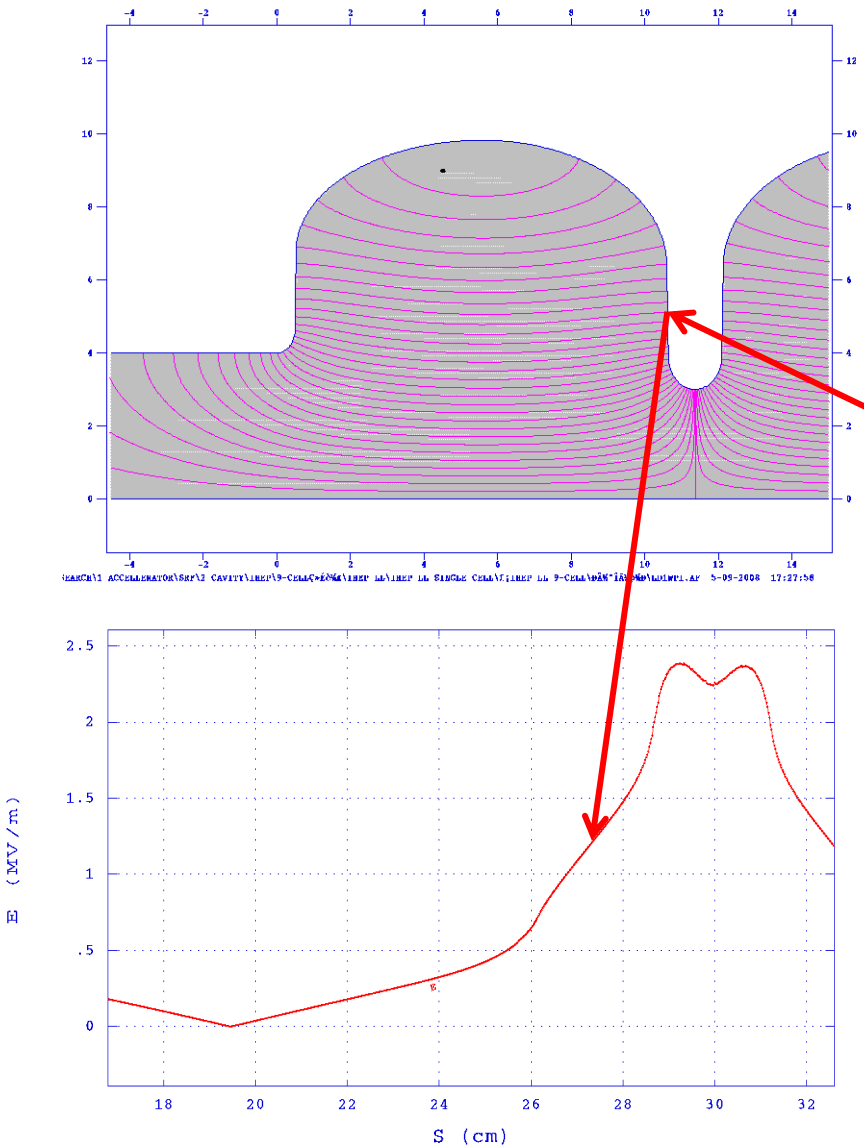
Strong Field Emission

- processed from 6 MV/m to 20 MV/m
- caused by CP stains or iris defects or other reasons?

Hard Quench

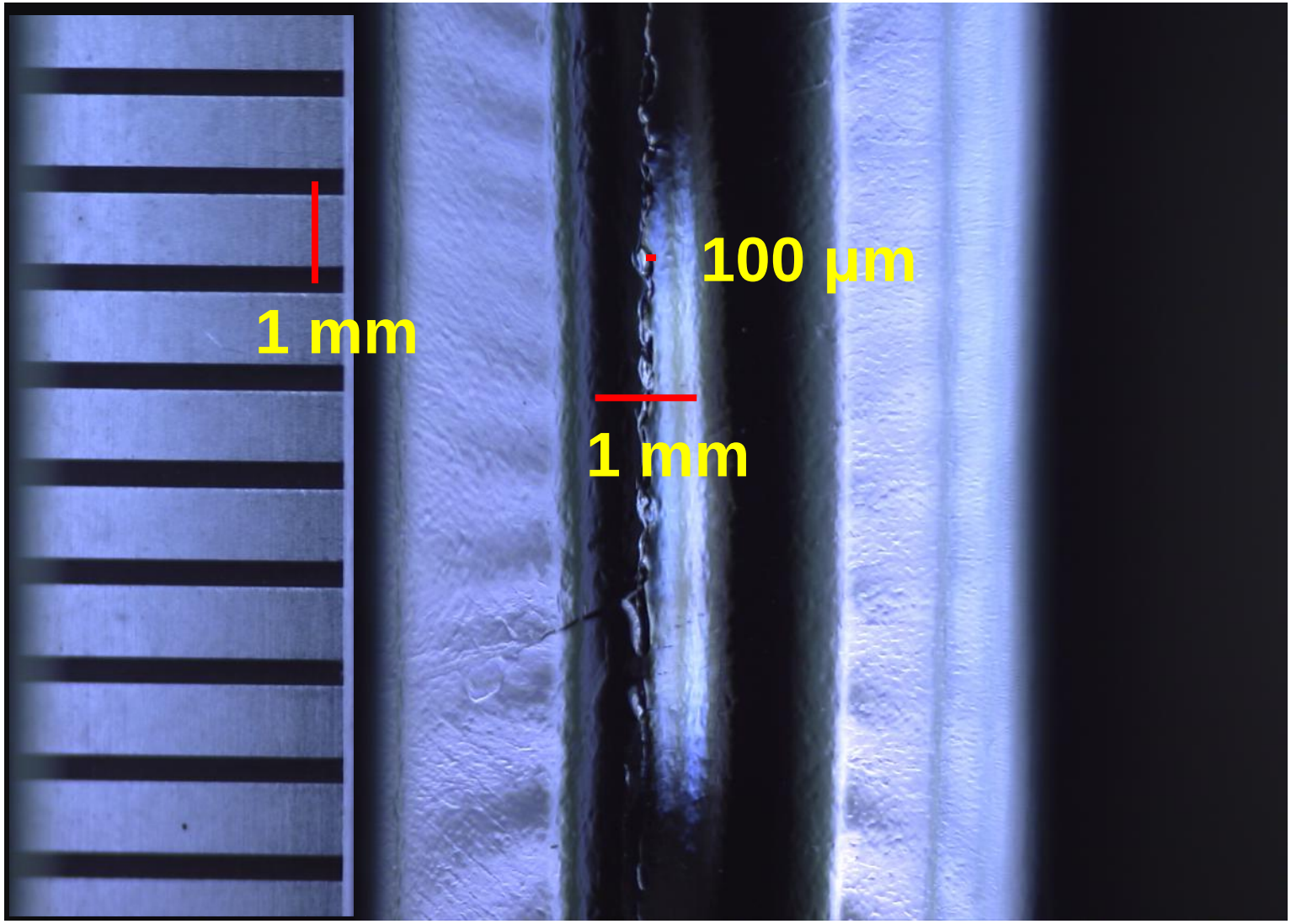
- cell # 9, 270-300° equator at 20 MV/m
- T-mapping and optical inspection diagnostics

CP Stains

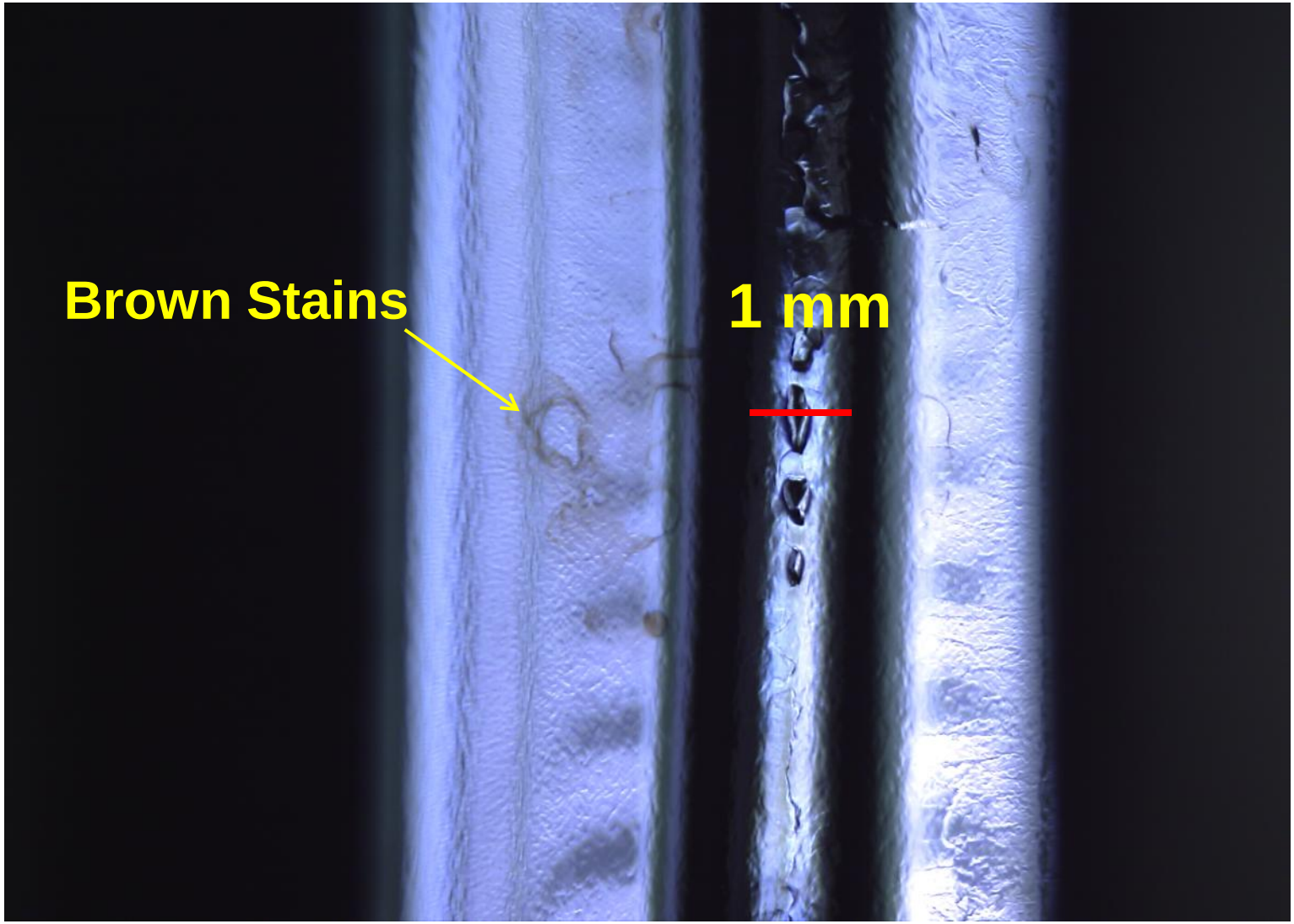


Still existed after HPR

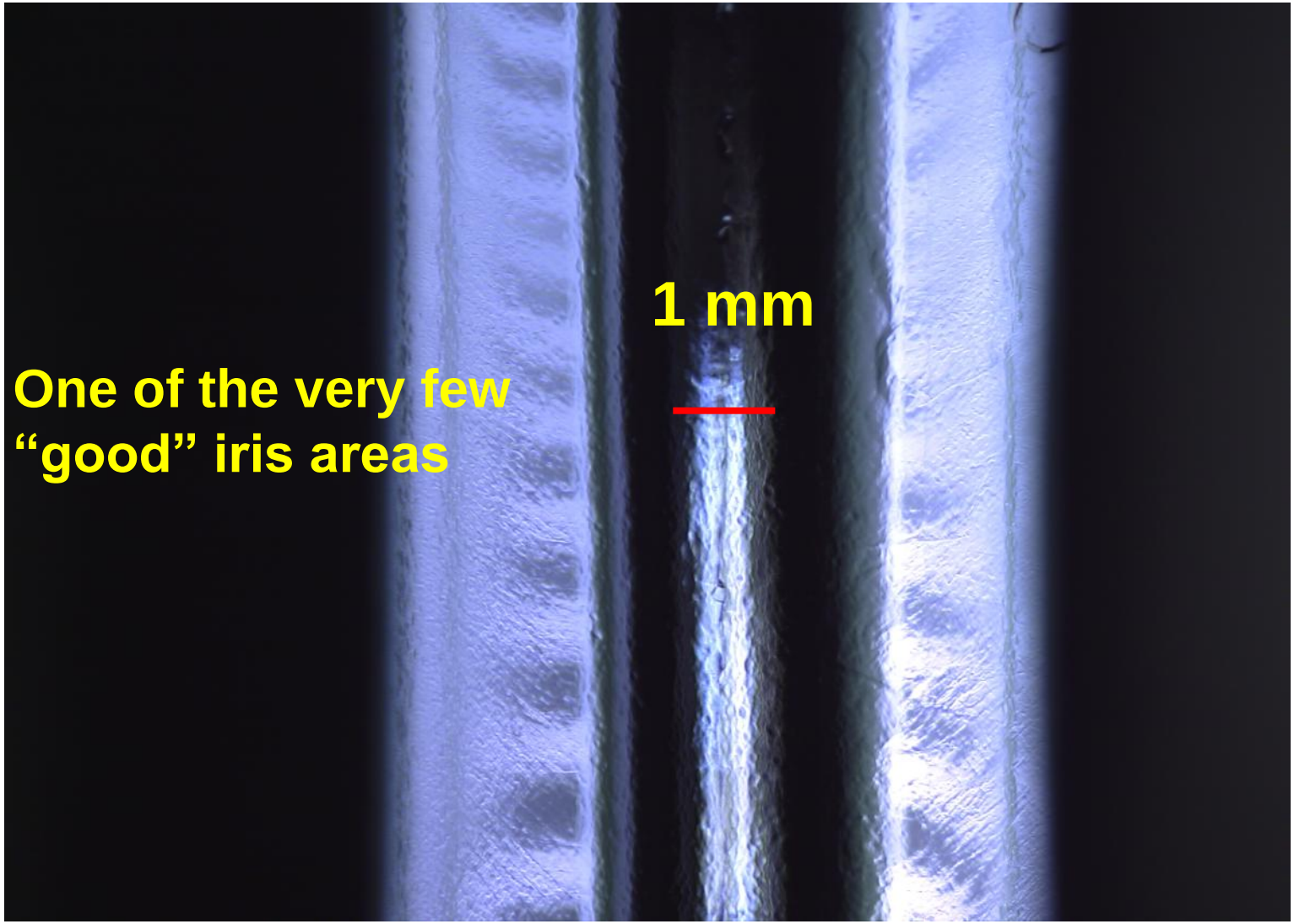
Iris Defects: Cell # 8-9 iris



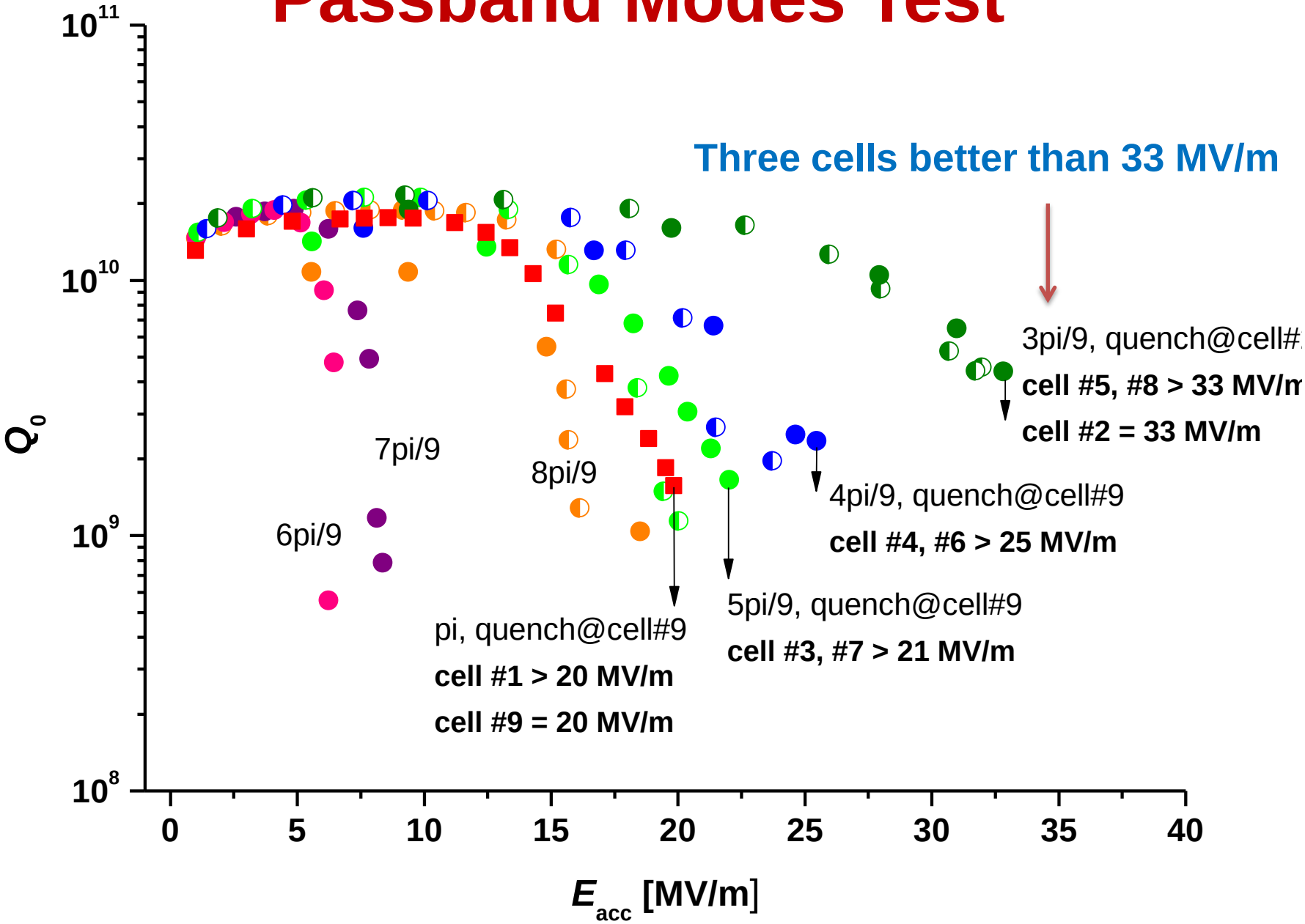
Cell # 6-7 iris 342 deg



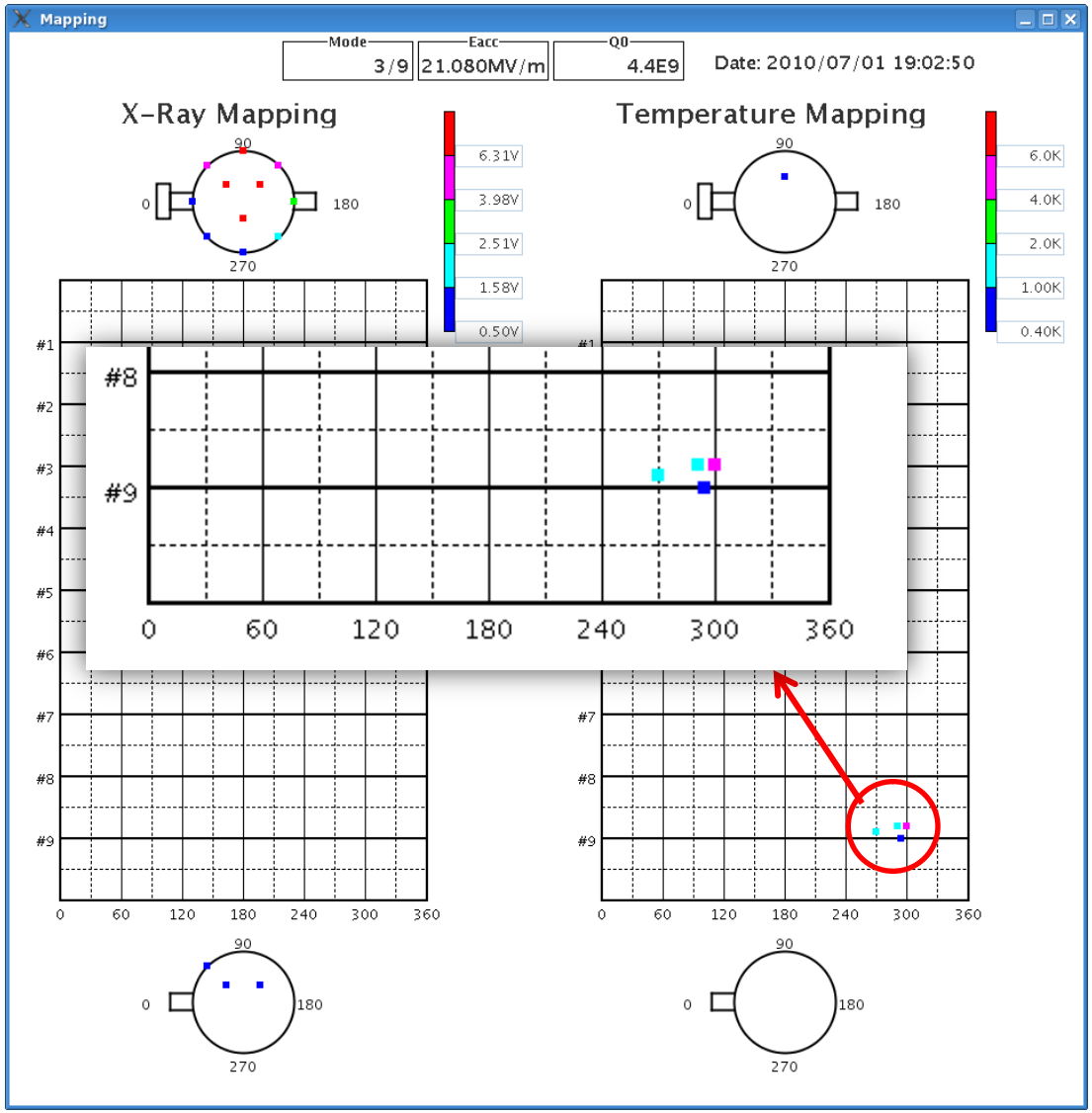
Cell # 4-5 iris 200 deg

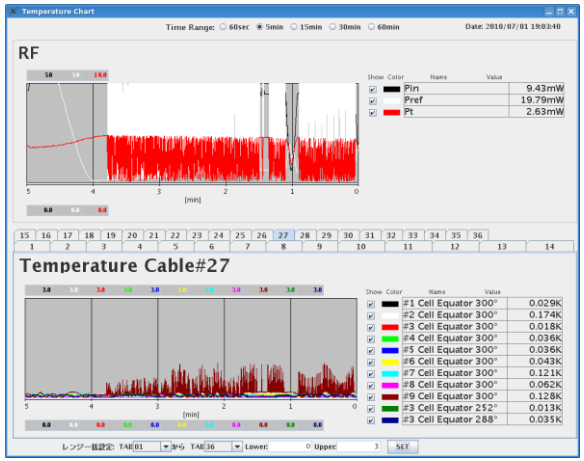


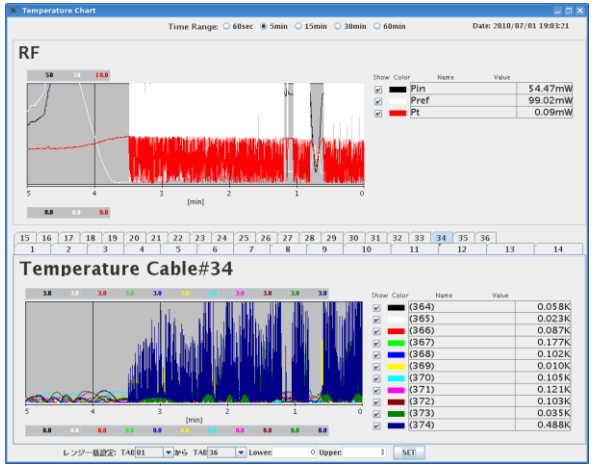
Passband Modes Test

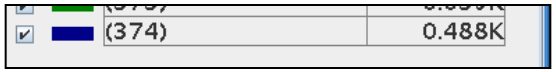


Cell # 9, 270-300º Equator Heating

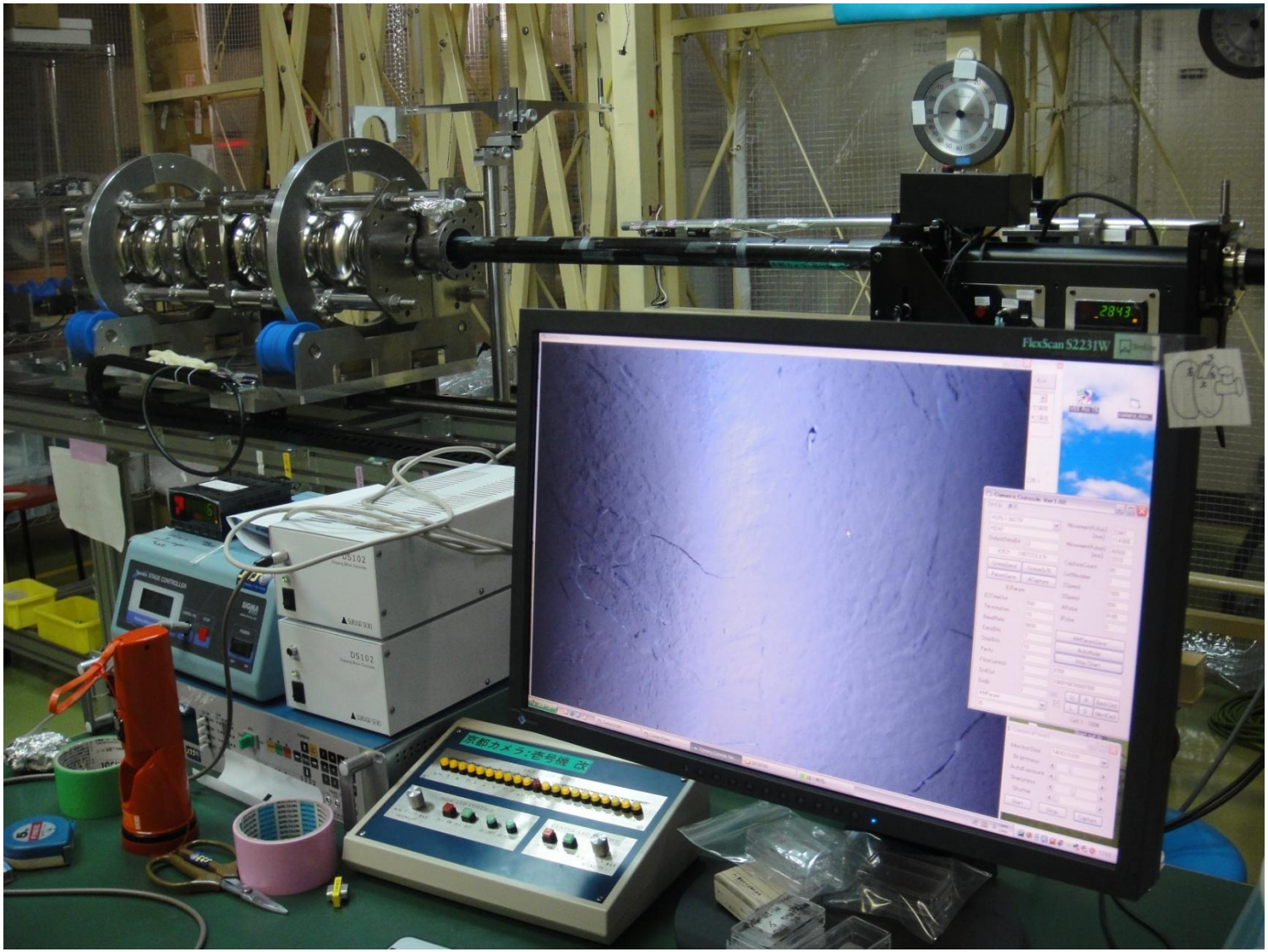




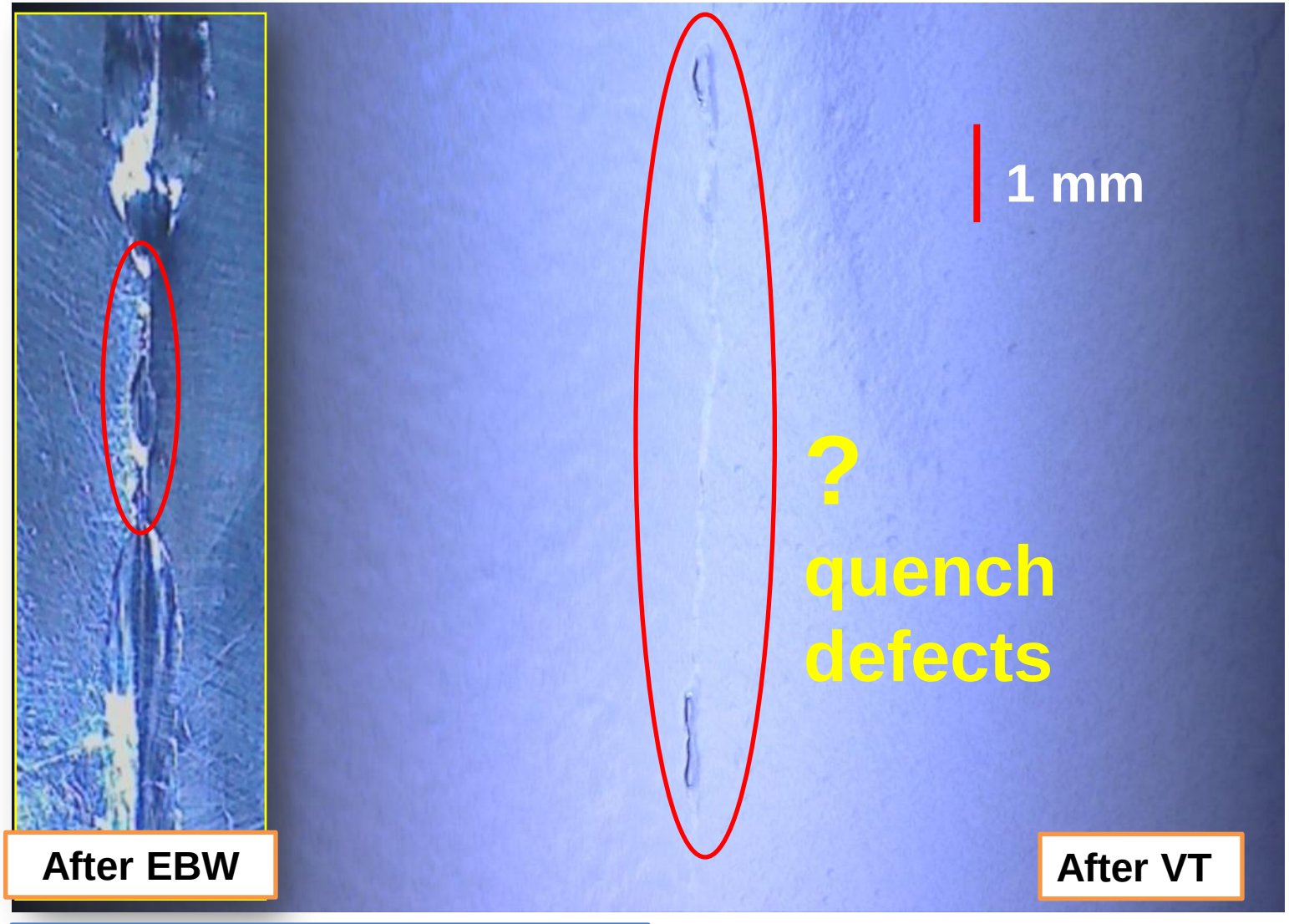




Inspect with Kyoto Camera

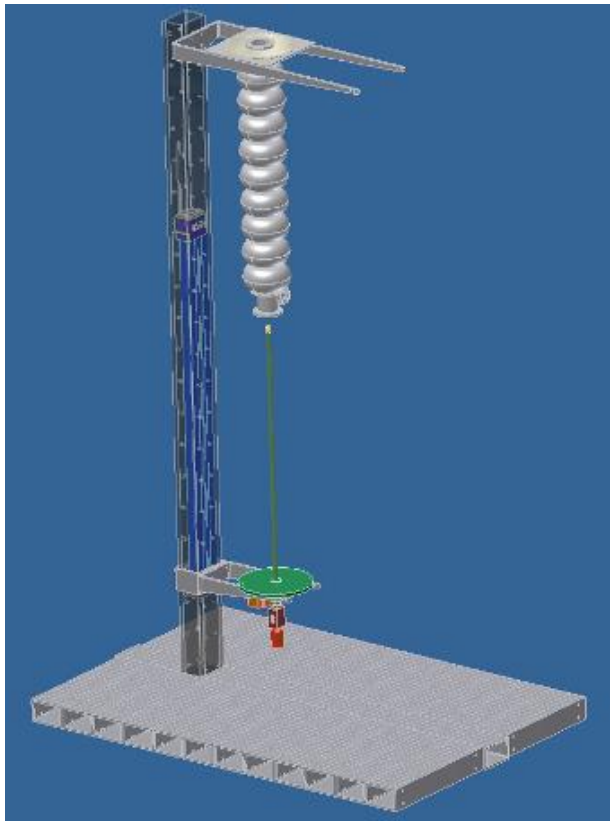


Cell #9 Equator 290°



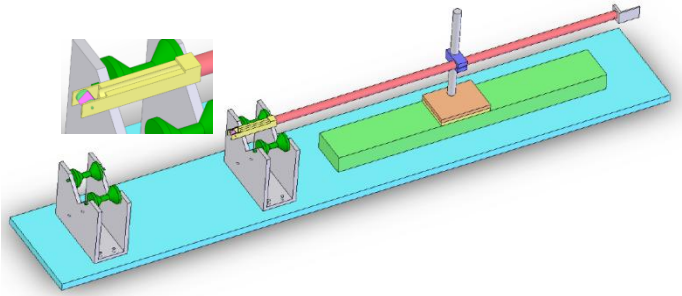
EBW seam ending problem

New Facilities Under Construction



HPR system

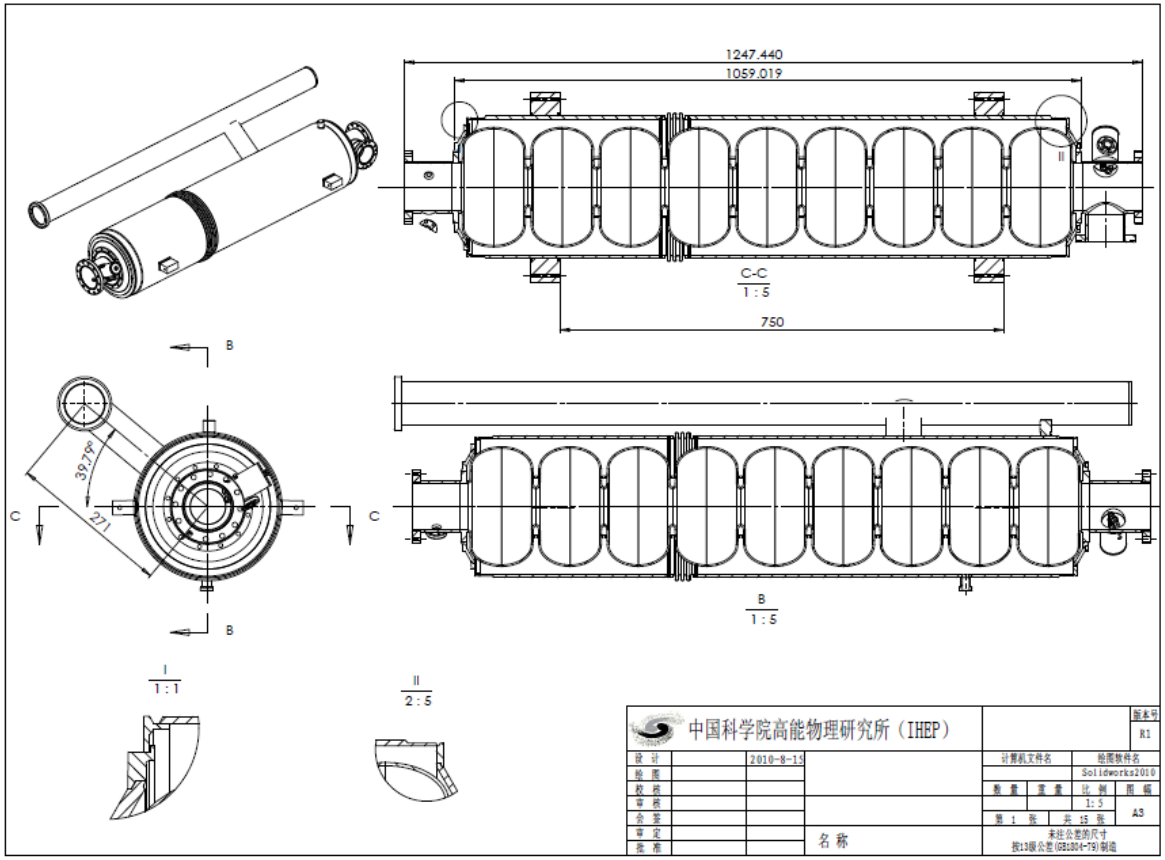
for 9-cell cavities



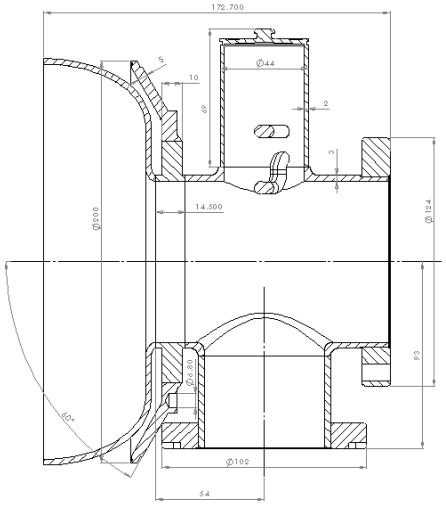
Optical inspection system

Mirror+QM1+Camera

IHEP-02 9-cell Cavity (1)



- *Low Loss shape*
- *Large Grain*
- *With full end groups*
- *Under fabrication*

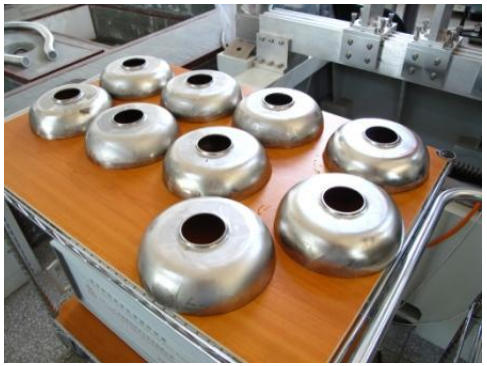


IHEP-02 9-cell Cavity（2）

冲压

切削

切削后



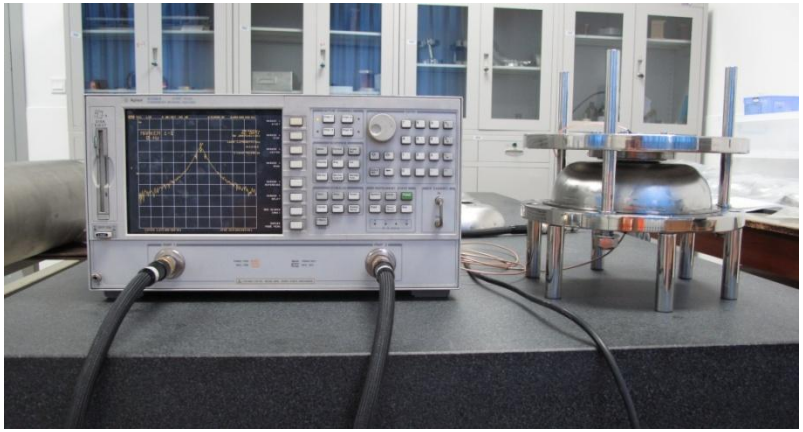
清洗

退火

与IHEP-01比较：
增加半腔退火工艺
升温降温速度：300摄氏度/小时
900摄氏度退火时间3小时

IHEP-02 9-cell Cavity（3）

铌半腔处理

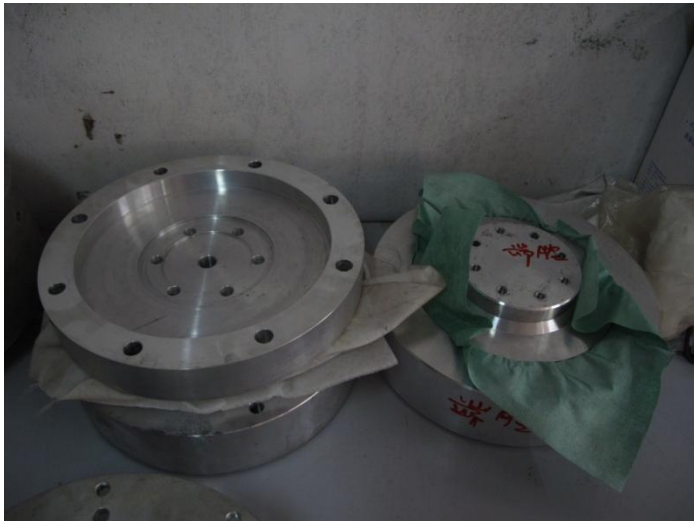


铌半腔频率测量

铌半腔机械尺寸测量

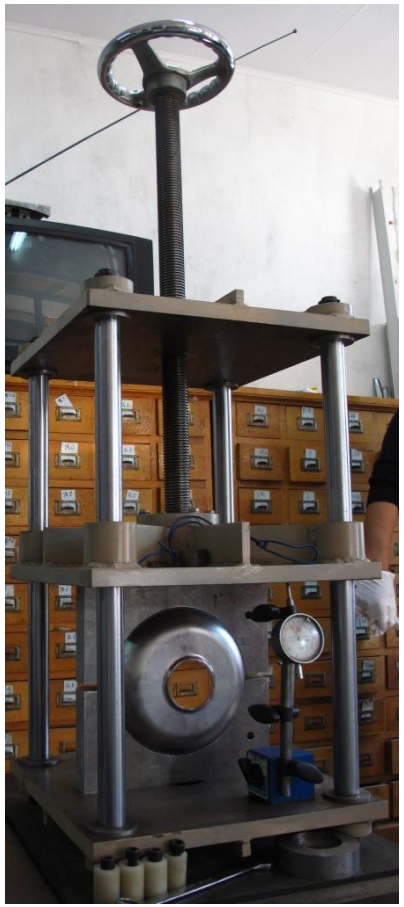
IHEP-02 9-cell Cavity（4）

- 退火之后进行二次切削
- 所有半腔的尺寸与频率测量已经完成
- 正在进行所有半腔的整圆



新增加2套滚圆工装

整圆工艺

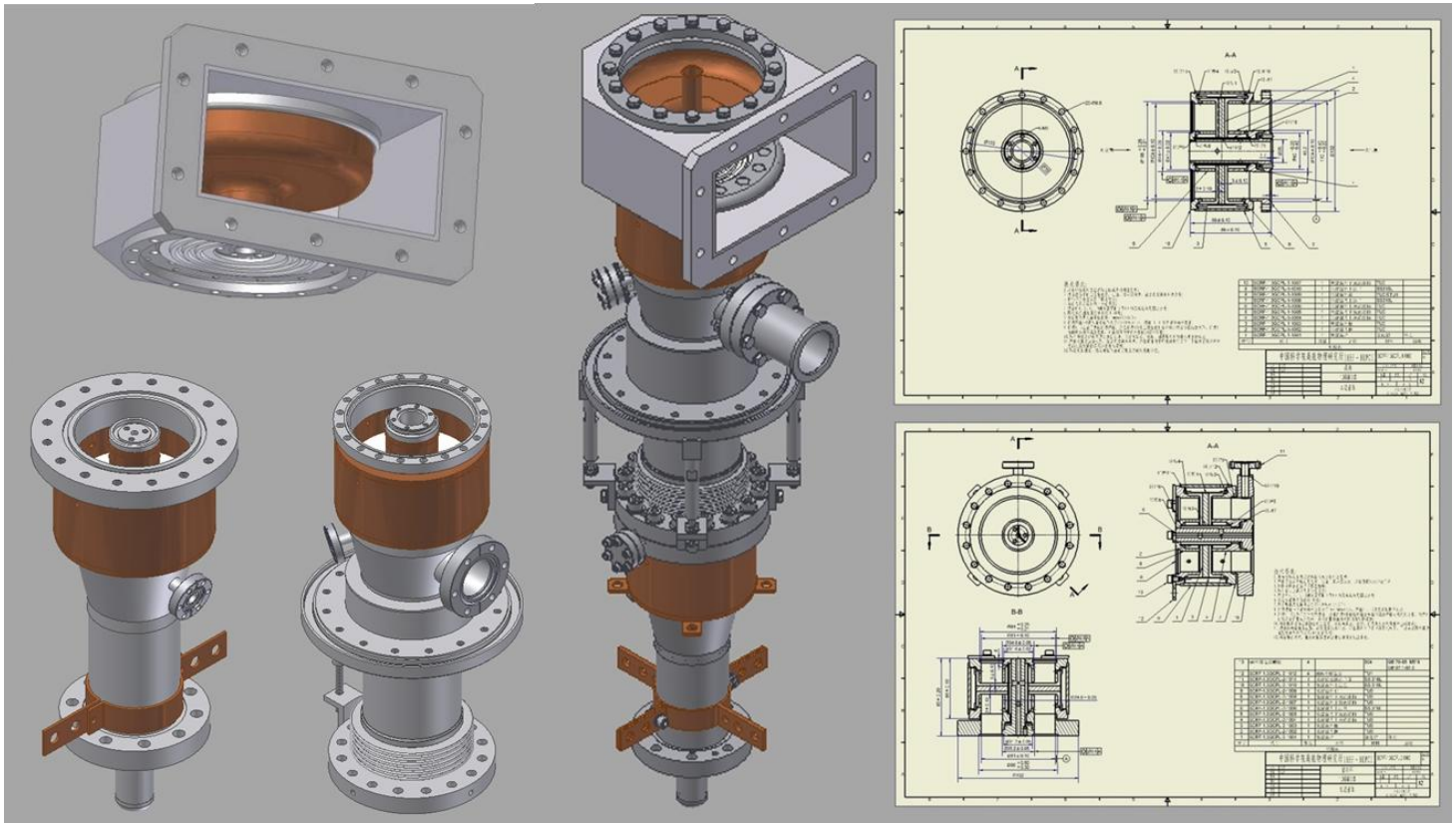


整圆工装

IHEP-02 9-cell Cavity（5）

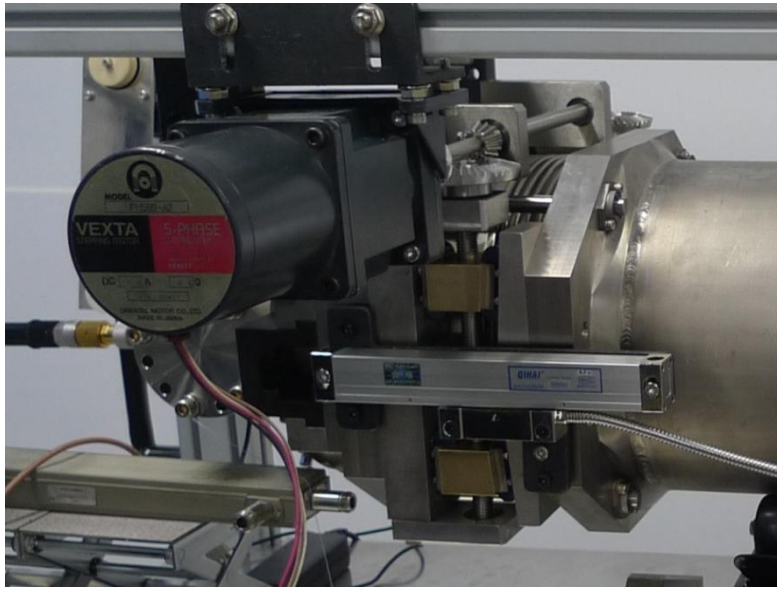
- At the beginning of Feb. 2011IHEP02 should be fabricated.
- Before the end of Feb. 2011,IHEP-02 should be surface treated.

1.3 GHz Input Coupler



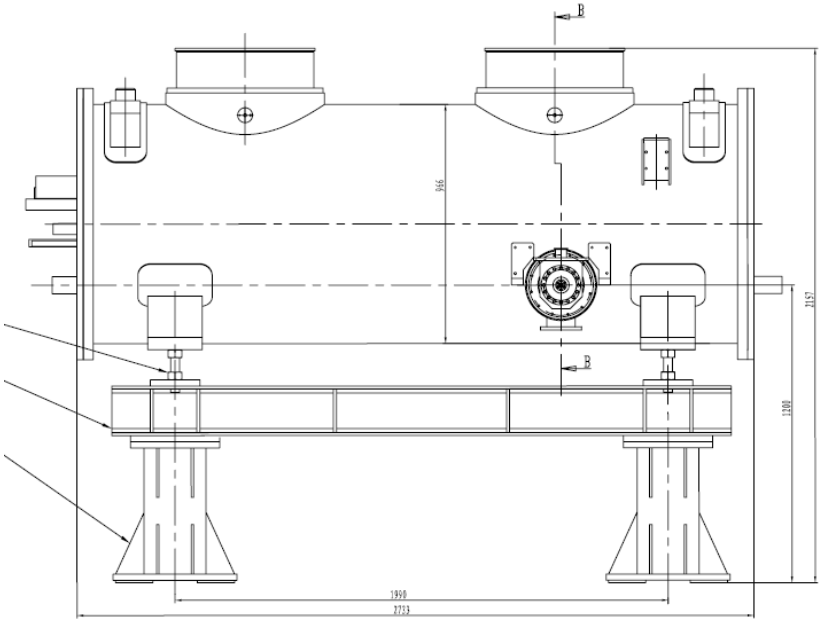
- Two couplers will be available at the end of this year
- High power test in early 2011

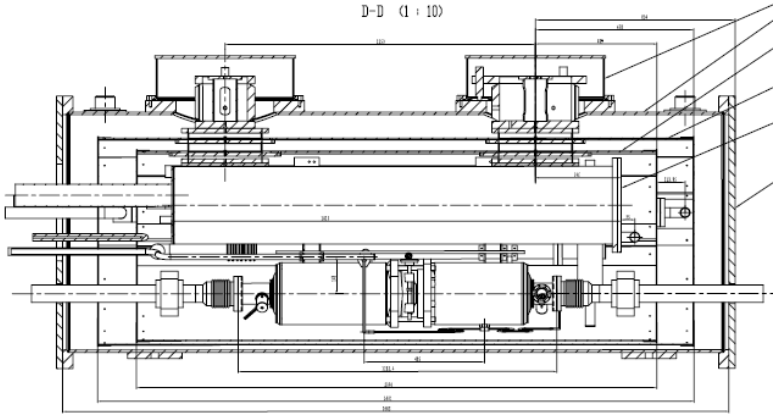
Tuner and LLRF

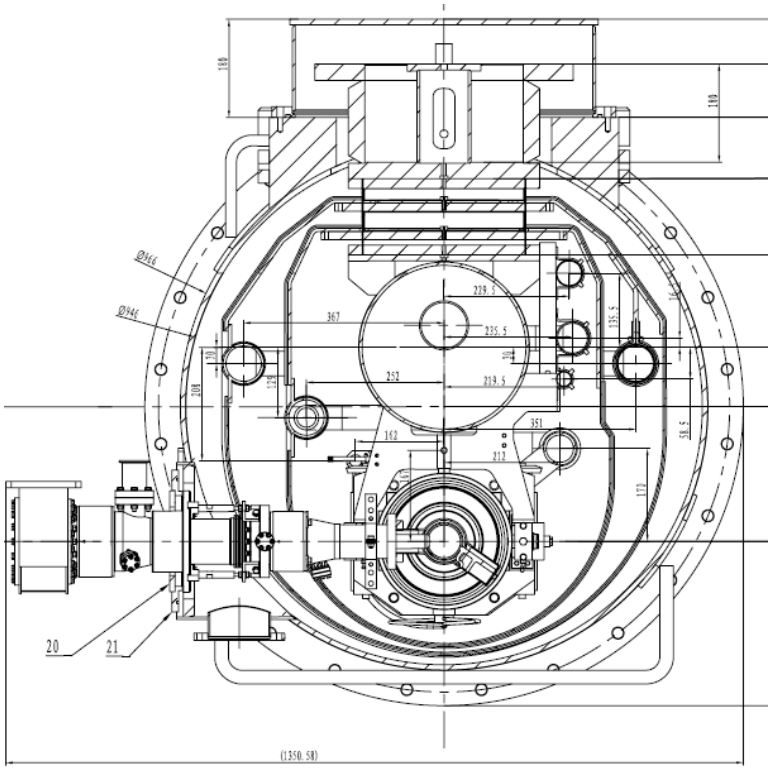


- Home-made slide jack tuner prototype installed to MHI-04
- Digital LLRF system finished
- Room temperature test underway
- 80 K tuner test planned

Cryomodule







- Fabricate and assemble in 2011
- Horizontal test with IHEP's new cryogenic system in Bldg#1

Summary and Outlook

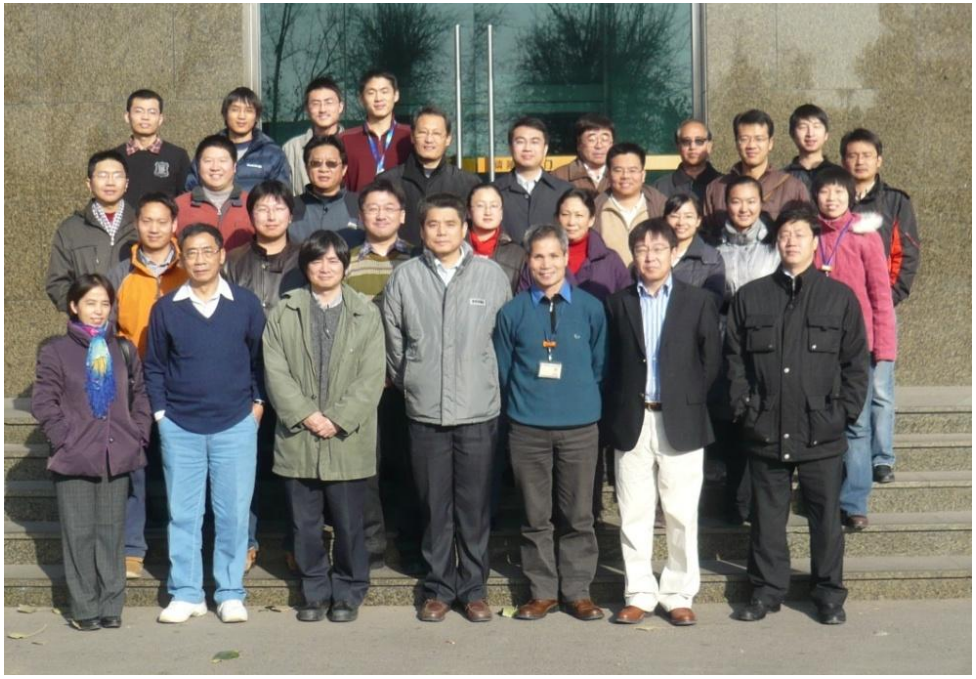
- IHEP started R&D on the Low Loss Large Grain cavity since 2006 and made big progress
- IHEP-01 9-cell cavity got 20 MV/m in the 1st vertical test, will be processed again (CBP+CP) in IHEP and make 2nd test
- IHEP-02 9-cell cavity with HOM couplers will finish fabrication, vertical test, helium vessel welding and install into the cryomodule in 2011. System integration, vertical and horizontal test are foreseen in IHEP
- ILC international collaboration ....

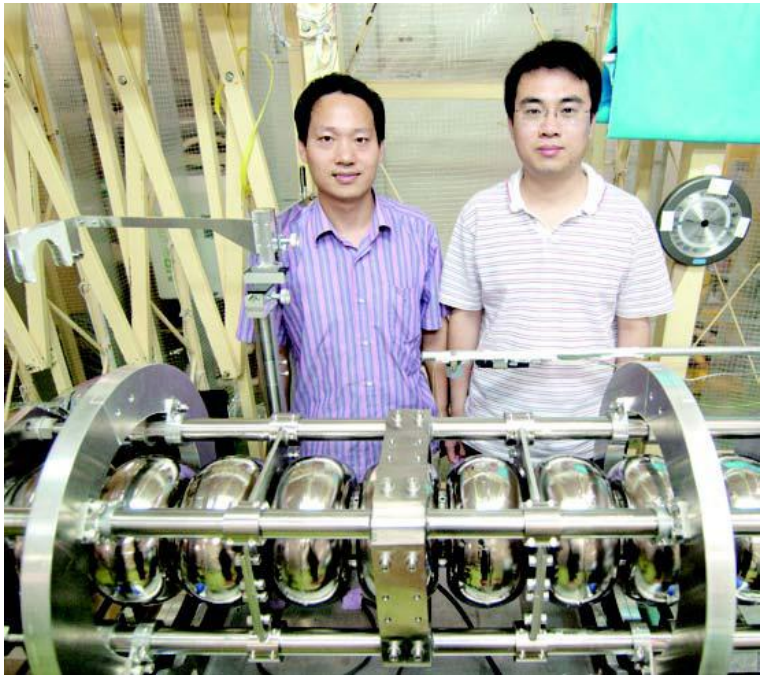
Acknowledgement

- Many thanks to the strong collaboration and great help from KEK STF colleagues: Eiji Kako, Hitoshi Hayano, Shuichi Noguchi, Kirk Yamamoto, Ken Watanabe, Toshio Shishido, Nobu Toge
- We also appreciate Kenji Saito and Fumio Furuta of KEK, Timergali Khabiboulline and Allan Rowe of FNAL, Peter Kneisel of JLAB and other experts for their important help and suggestions
- We are very grateful to the support from Kaoru Yokoya, Akira Yamamoto, Seiya Yamaguchi, Bob Kephart and Shekhar Mishra

IHEP ILC 1.3 GHz SRF R&D Team

- 9-cell Cavity: *Jie Gao, Jiyuan Zhai, Zhongquan Li, Tongxian Zhao, Dazhang Li, Zhenchao Liu, Jingru Zhang*
- Input Coupler: *Weiming Pan, Tongming Huang, Qiang Ma*
- Cryomodule & Cryogenics: *Shaopeng Li, Rui Ge, etc.*
- LLRF & Tuner: *Yi Sun, Guangwei Wang, Feng Qiu, Haiyin Lin, Rong Liu, Haisheng Guo*
- HLRF: *Yunlong Chi, Kun Lv, etc.*
- SRF Facility: *Jianping Dai, Mi Hou, Qunyao Wang, etc.*
- Vacuum & Mechanical Engineering: *Qiong Xiao, Lan Dong, Lingling Men,Chunhua Li, etc.*



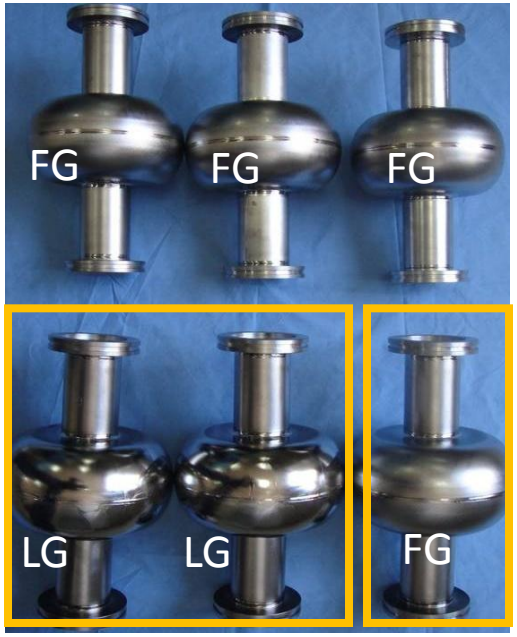


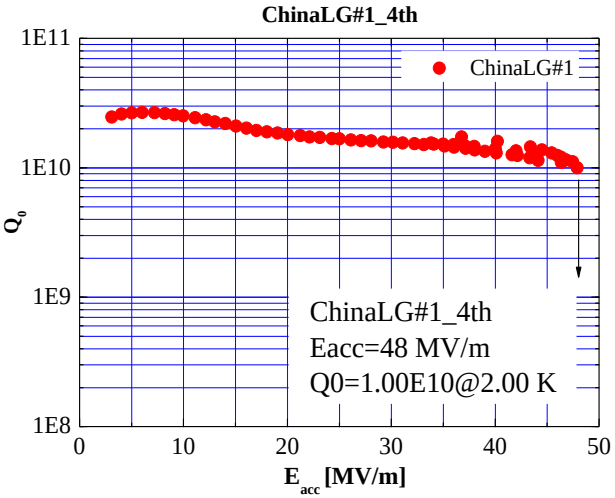

Thank you !

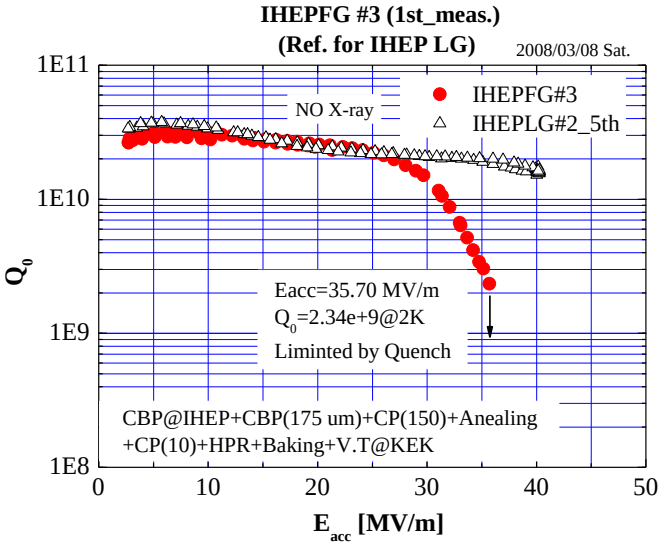
Back up

Low Loss Large Grain Single Cell Cavities

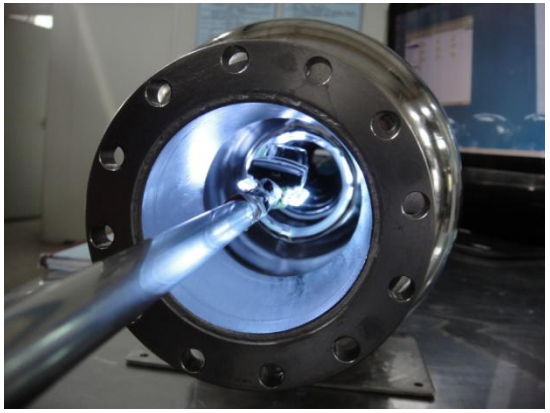
- 3 Ningxia large grain cavities, made by KEK, 48 MV/m (CBP + EP)
- 2 Ningxia large grain cavities, fabricated and processed in IHEP, tested in KEK 40 MV/m (CBP + CP)
- 1 fine grain cavity for reference study







Sputtering and CBP

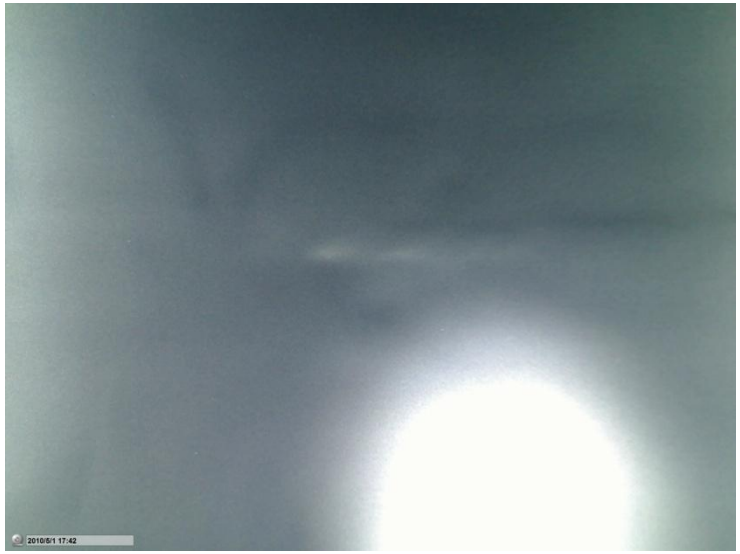


Many sputters were found in the equator area of cell#2 to cell#8. We are still investigating the reason of sputtering. The EBW vendor is expected to be qualified because they made the IHEP 40 MV/m single cell CP cavity.

Cell#3 90°before CBP

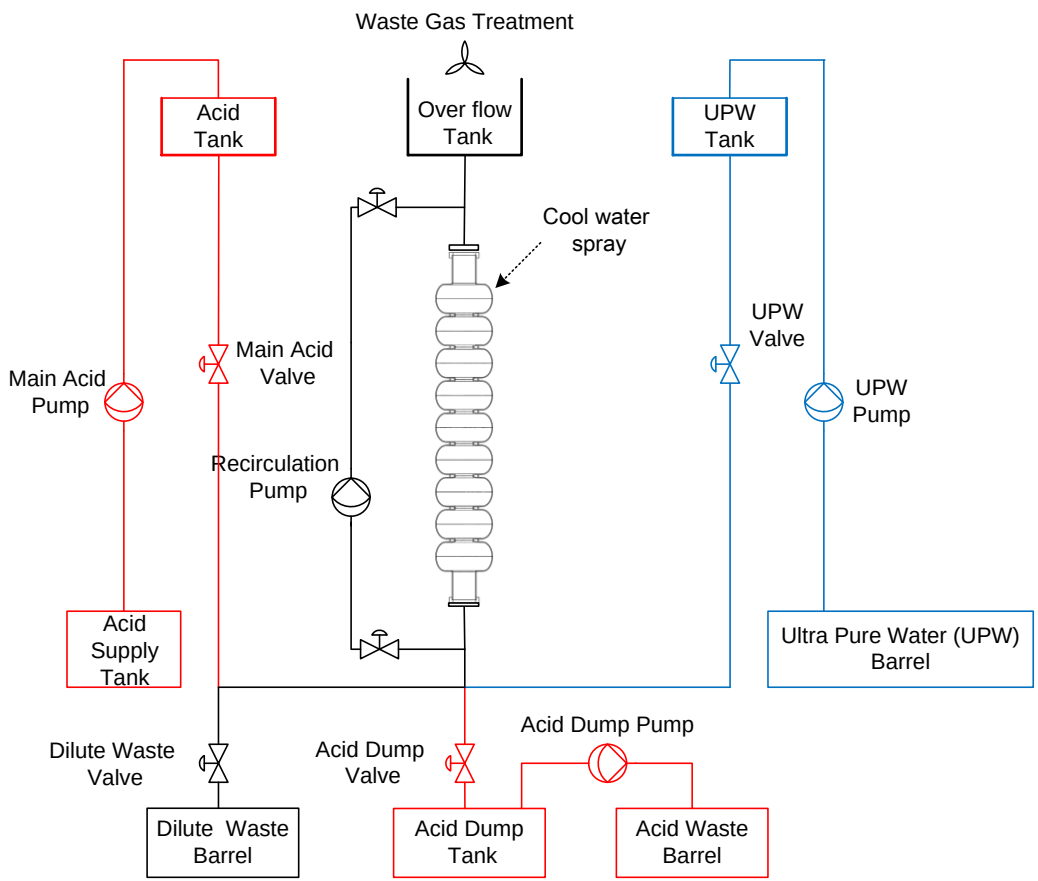
Cell#3 90°after CBP

Cell#9 90°before CBP



Cell#9 90°after CBP

BCP Facility

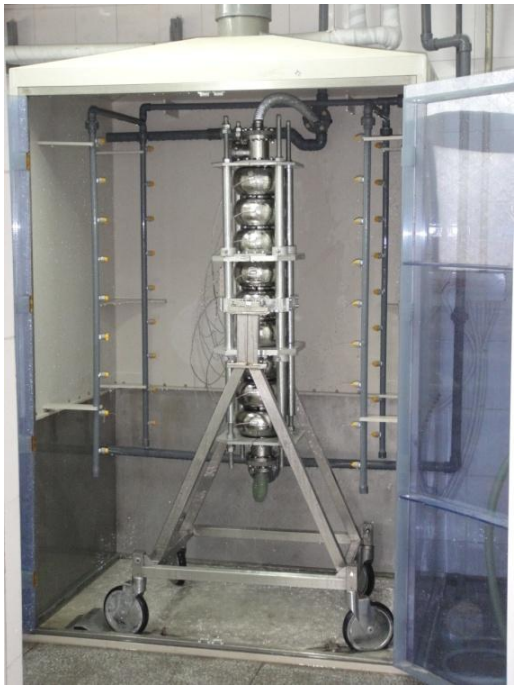


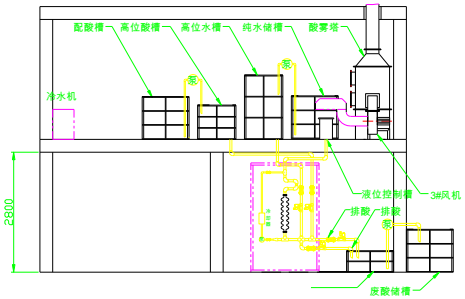
With reference to Fermilab design

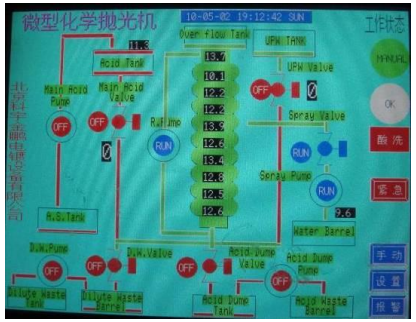
- The mixed acids fill in the cavity by gravitation from the acid storage tank in 30 seconds.
- Then the circulating pump starts and the acids go through the cavity and the 1 kW heat exchanger. The acid flow rate can be monitored and adjusted. The normal flow rate is 10 - 30 liters per minute.
- The acid temperature at the exit of the cavity and the temperature outside the cavity wall are monitored.
- Teflon coated Viton O-rings are used to seal the cavity flanges.
- The storage acid and the spray water are chilled below 10 ˚C.
- The estimated etching rate of the HF: HNO_3: H_3PO_4 1:1:2 acids is 1μm / min. The upper limit of the Nb solved in the acid is 10 g / L.

BCP

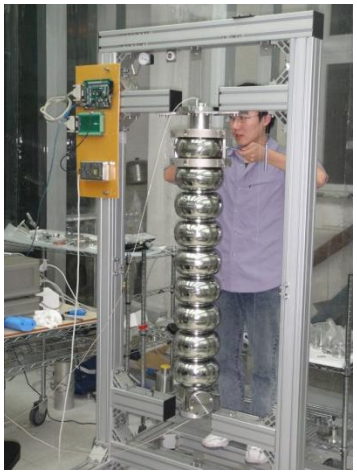
- 1st CP: 4 times CP, each time 25 minutes. For the second and fourth CP, we reversed the cavity to make the etching more uniformly. During CP, the acid temperature at the cavity exit was 13 - 15˚C. The measured etching amount of the equator wall thickness was 114 μm.
- 2nd CP: 2 times CP, each time 10 minutes, reversed.
  Abnormal temperature rise: 22 ˚C on the cavity wall.



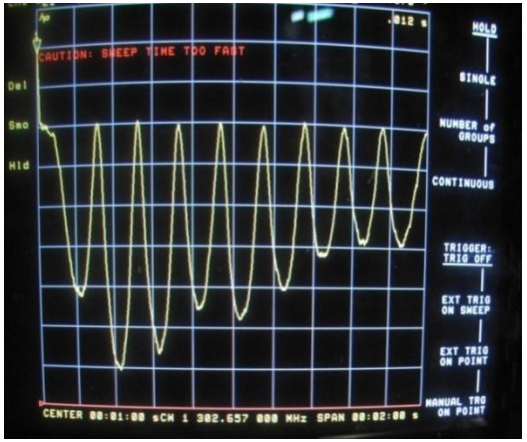


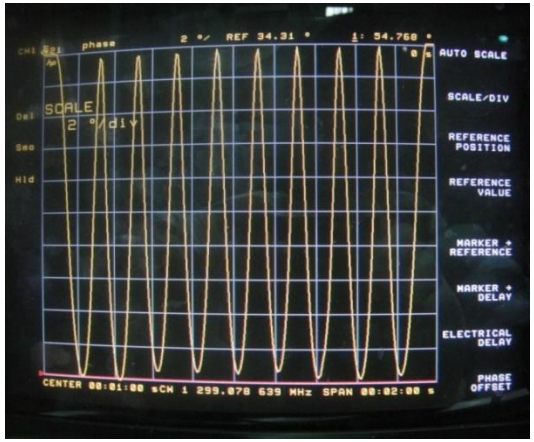


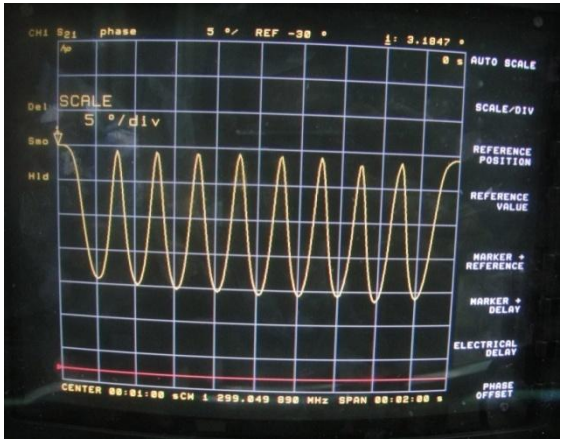
Pretuning



The pretuning machine could not squeeze more than 5 mm, then we changed to the manual pretuning



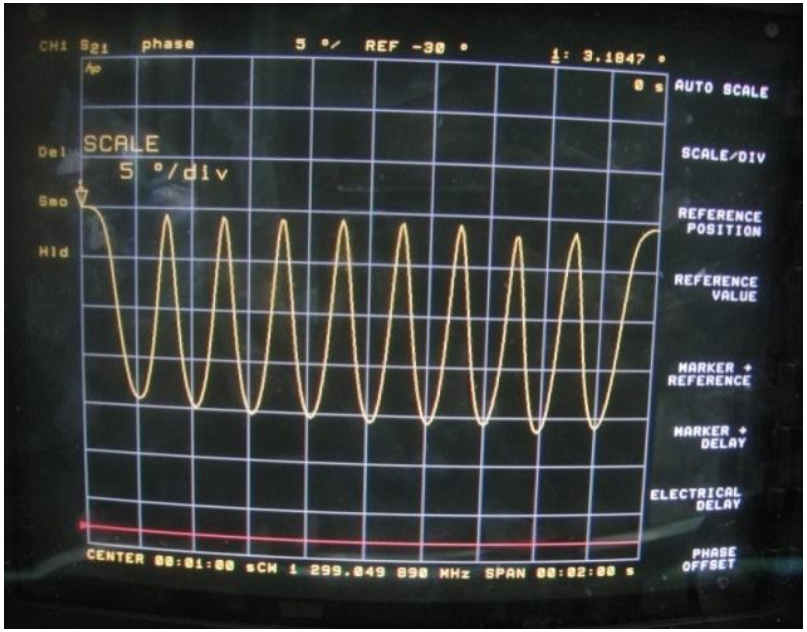




Field flatness as delivered (70%) , after pre-tuning (97.6 %), after jig fixing (94.7 %)

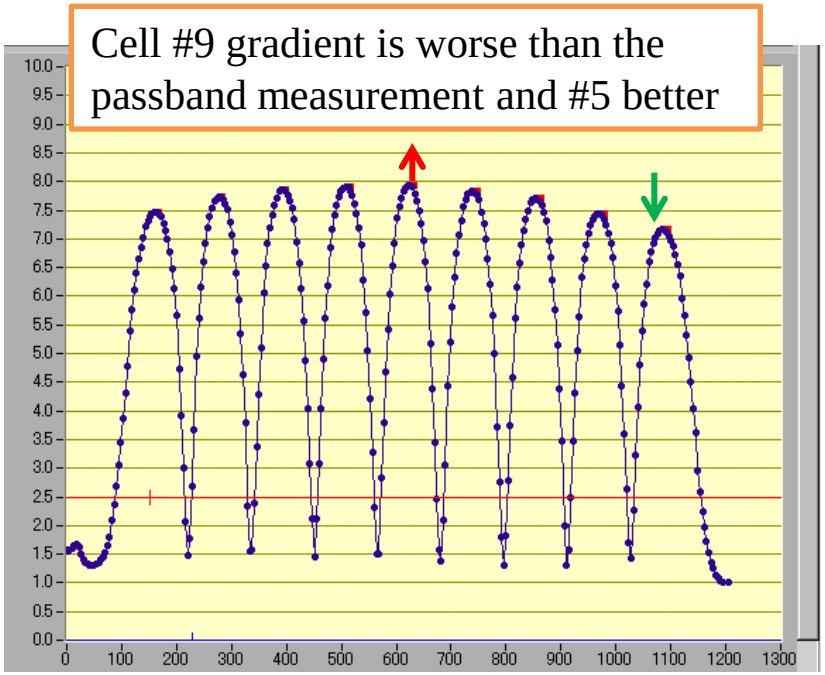
Field Flatness after VT

Final pretuning with jig : 94 %



Without jig: 97.6 %
After the final pretuning:
Leak check, 2nd CP, Ultrasonic,
Rinsing and **Shipped to KEK**

After 1st VT with jig: 90 %

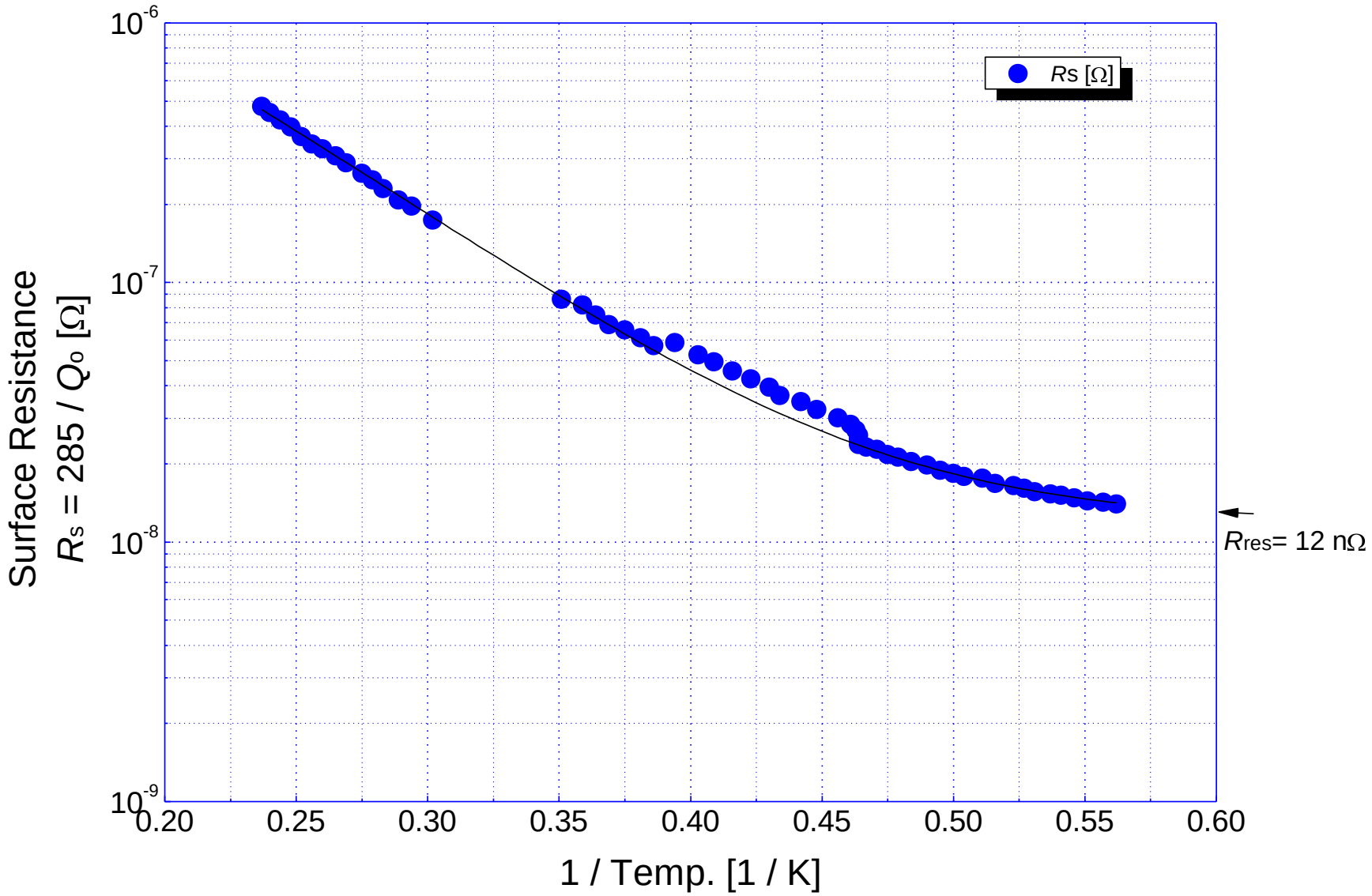


End cells frequency became lower

HPR w/ & w/o Flanges

18.1 MΩ / cm, 8 MPa, (nozzle structure)
Down speed: 25 mm / min, Up speed: 200 mm / min
Rotation speed: 15 rpm

Surface Resistance



Max Gradient in Each Cell

MV / m	Cell 1& 9	Cell 2 & 8	Cell 3 & 7	Cell 4 & 6	Cell 5	Comment
π	19.8	19.8	19.8	19.8	19.8	Quench / Self pulse: **Heat @ 9-cell equator 300º** $Q_0 = 1.6\times10^9$, $P_0 = 230$ W, X-ray >100 mSv / h
8 π / 9	18.5	18.5	12.8	7.0	0	Quench / Self pulse: **Heat @ 9-cell equator 300º** $Q_0 = 1.04\times10^9$, $P_0 = 163$ W, X-ray = 1.29 mSv / h
7 π / 9	8.4	4.4	1.7	7.0	9.0	**Power limit by F. E.** $Q_0 = 7.8\times10^8$, $P_0 = 50$ W, X-ray = 0.12 mSv / h
6 π / 9	6.2	0	6.2	6.2	0	**Power limit by F.E.** $Q_0 = 5.57\times10^8$, $P_0 = 43$ W, X-ray = 0.01 mSv / h
5 π / 9	16.7	11.5	20.7	4.0	22.0	Quench / Self pulse: **Heat @ 9-cell equator 300º** $Q_0 = 1.65\times10^9$, $P_0 = 161$ W, X-ray = 0.28 mSv / h
4 π / 9	16.3	22.5	8.6	25.4	0	Quench / Self pulse: **Heat @ 9-cell equator 300º** $Q_0 = 2.5\times10^9$, $P_0 = 141$ W, X-ray = 0.08 mSv / h
3 π / 9	16.1	32.2	16.1	16.1	32.2	Quench / Self pulse: **Heat @ 2-cell equator 330º** $Q_0 = 4.39\times10^9$, $P_0 = 143$ W, X-ray = 0.27 mSv / h
$E_{acc,\ max}$	**19.8**	**32.2**	**> 20.7**	**> 25.4**	**> 32.2**	**9-cell = 19.8 MV / m** **2-cell = 32.2 MV / m**