Status of Quadrant-type Waveguide-damped Structure Fabrication and Single-Cell SW Cavity Test

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1. Status of Quadrant-type Waveguide-damped Structure (TD24_QUAD) Fabrication

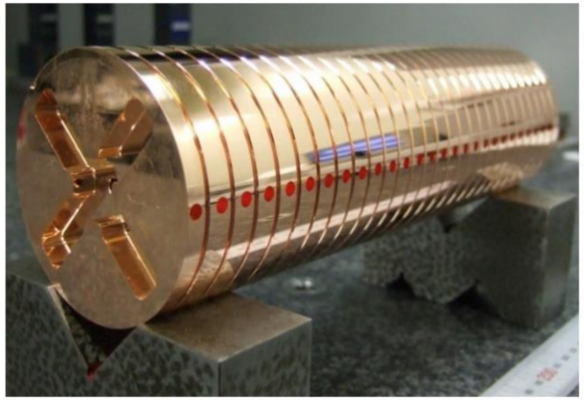
2. Status of Single-Cell SW Cavity Test

Fabrication Status of TD24_QUAD

Disk-type v.s. Quadrant(or Half)-type

Disk-type

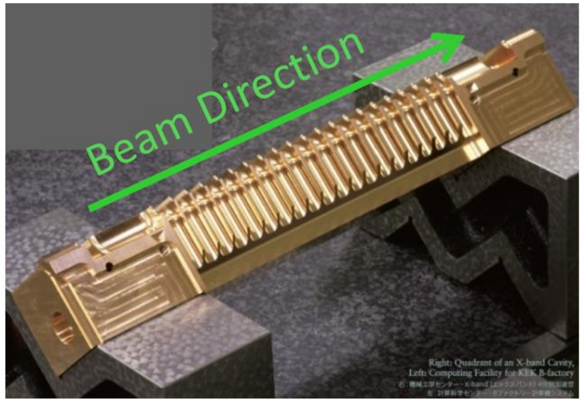
A damped disk



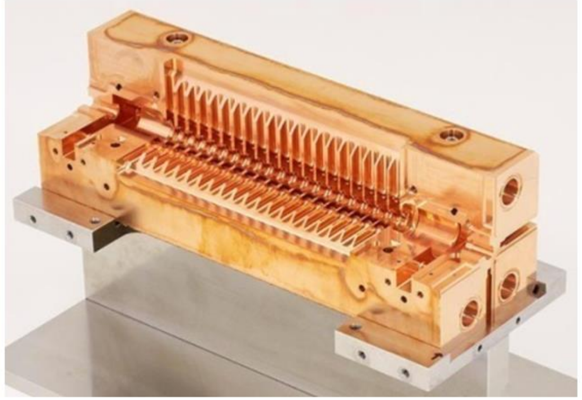
Disks stacked and bonded

- Advantages
  - ✓ Machining by turning
  - ✓ Very smooth surface (Ra = ~30 nm)
  - ✓ Shallow machining damage (< 1 μm)
- Disadvantages
  - ✓ Ultra-high-precision machining of dozen of disks
    →Stack and bonding
  - ✓ Great care needed
  - ✓ **Surface currents flow across disk-to-disk junctions.**

Quadrant-type



A Quadrant



Three Quadrants

- Advantages
  - ✓ **Surface currents do not flow across any bonding junction.**
  - ✓ Simple machining by five-axes milling machines
  - ✓ Simple assembly process
    → Possibility of significant cost reduction
- Disadvantages
  - ✓ Not very smooth surface (Ra = ~ 0.5 μm)
  - ✓ Deep machining damage (10 - 20 μm)
  - ✓ **Virtual leak from quadrant-to-quadrant junctions**
  - ✓ **Field enhancements at the corners of quadrants**

DESIGN IMPROVEMENT

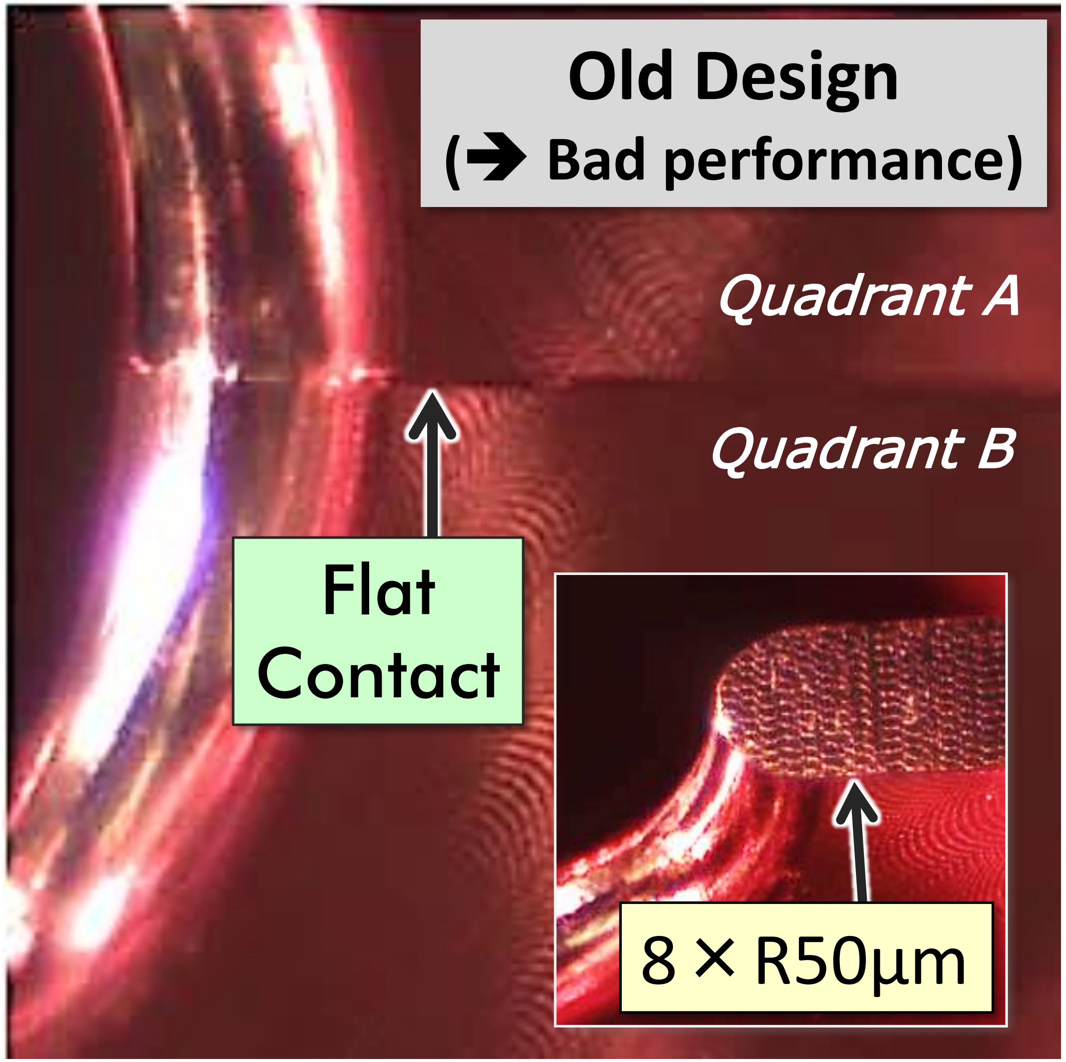
to
- ✓ Avoid virtual leak
- ✓ Suppress the field enhancement

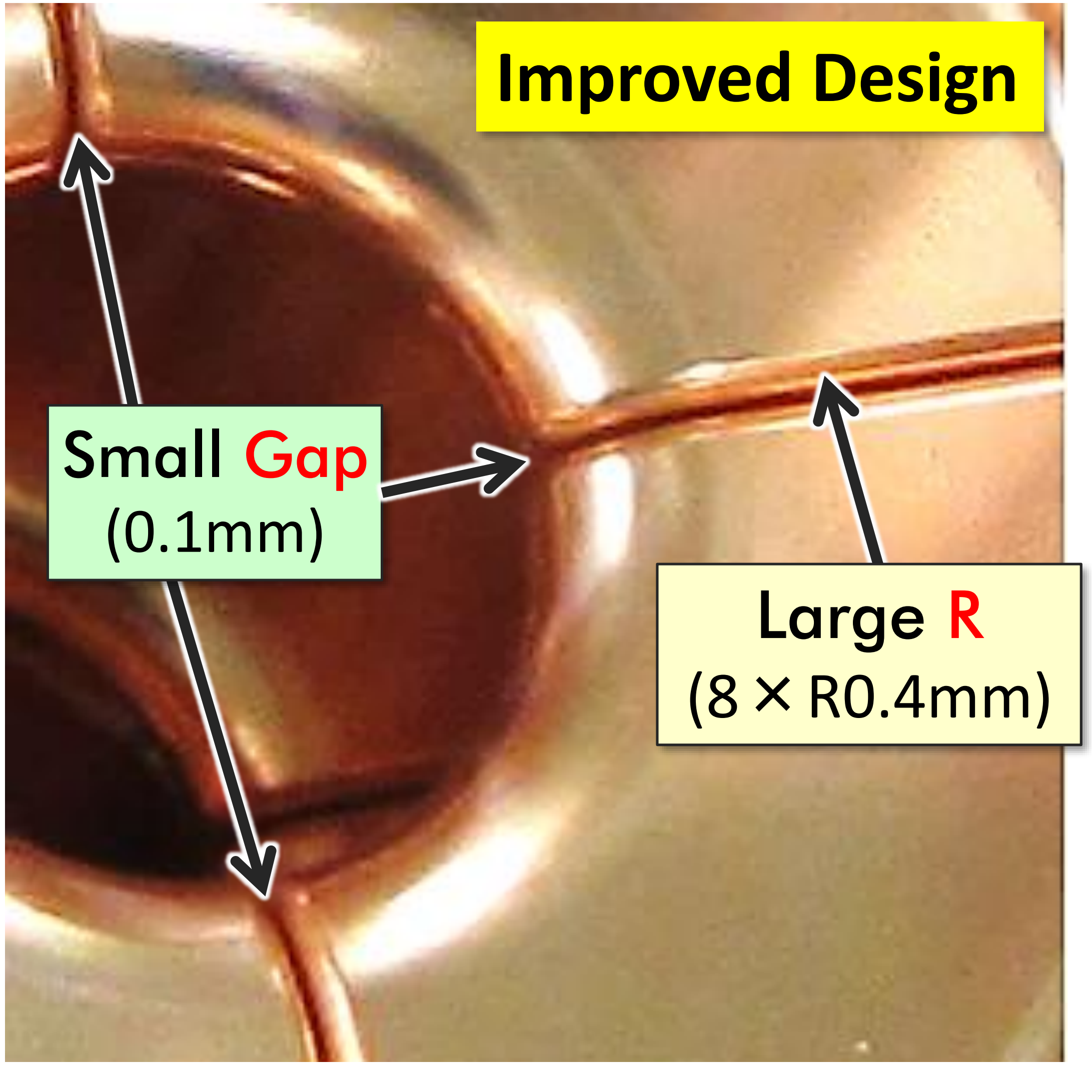
The chamfer radius and small-gap size were optimized based on simulation to minimize

A) Field enhancement at the corner of the quadrants (→ +25%)

B) Deterioration of the shunt impedance (→ -2%)

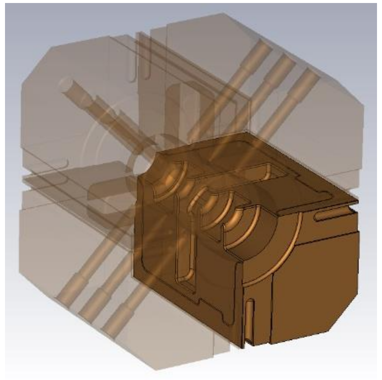
For details, see T. Abe *et al.*, "Fabrication of Quadrant-Type X-Band Single-Cell Structure used for High Gradient Tests," presented at the 11th Annual Meeting of Particle Accelerator Society of Japan (2014), Paper ID: SUP042.

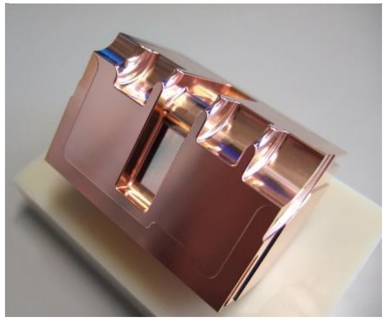


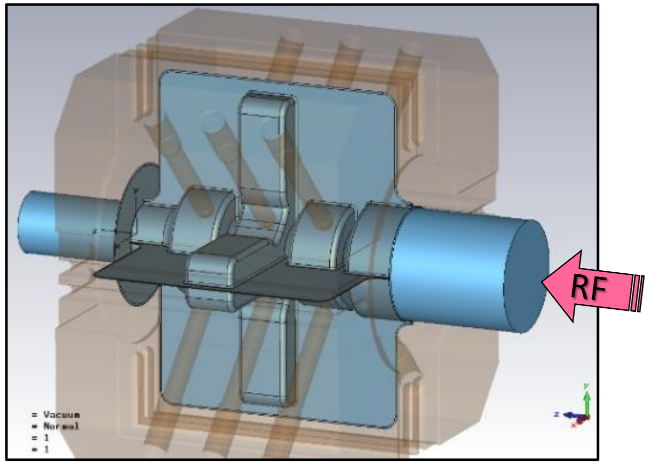


Demonstration of the High-Gradient Performance with a single-cell SW cavity

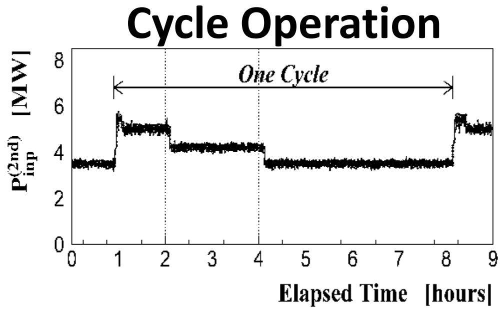
(SW: Standing Wave)







T. Abe *et al.*, "*High-Gradient Test Results on a Quadrant-Type X-Band Single-Cell Structure,*" presented at the 14th Annual Meeting of Particle Accelerator Society of Japan (2017), PaperID: WEP039.



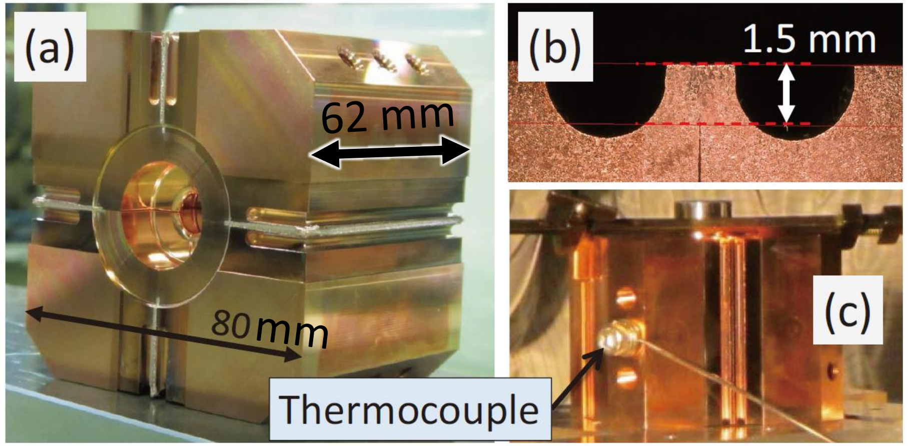
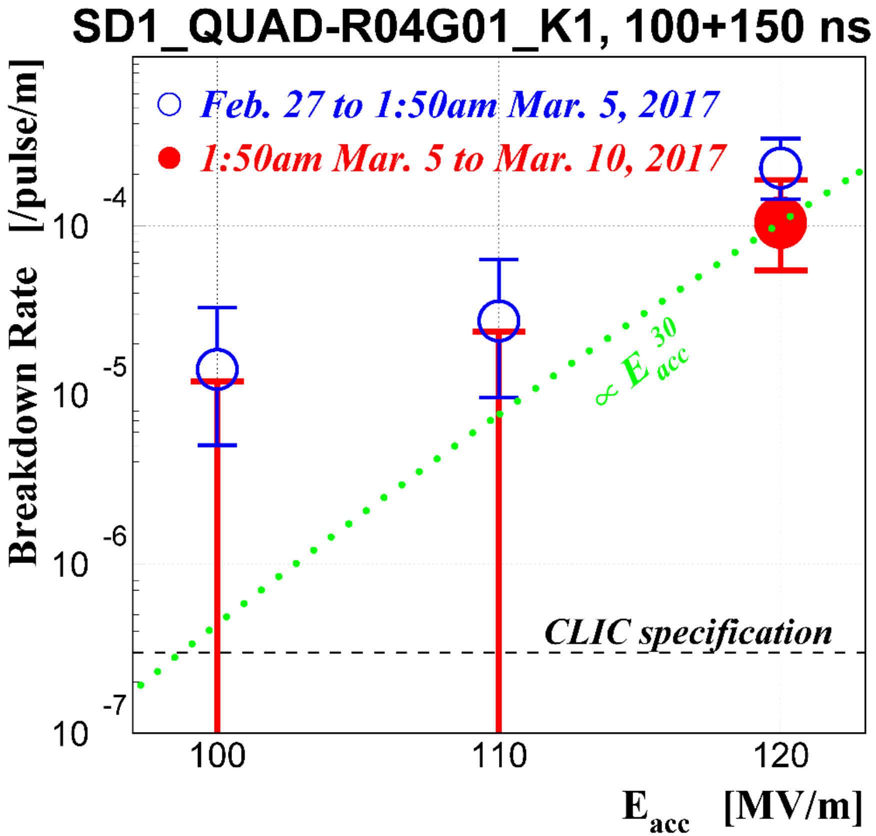
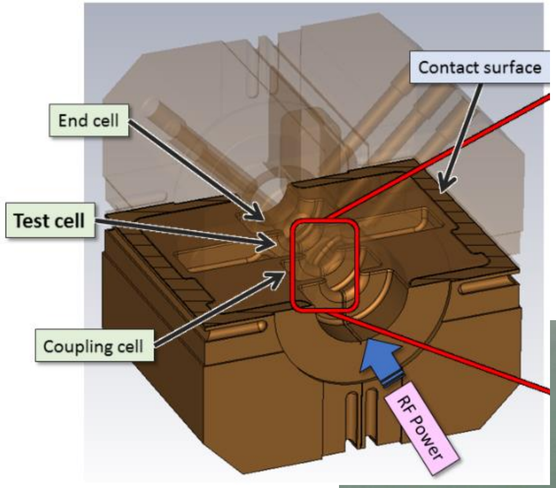


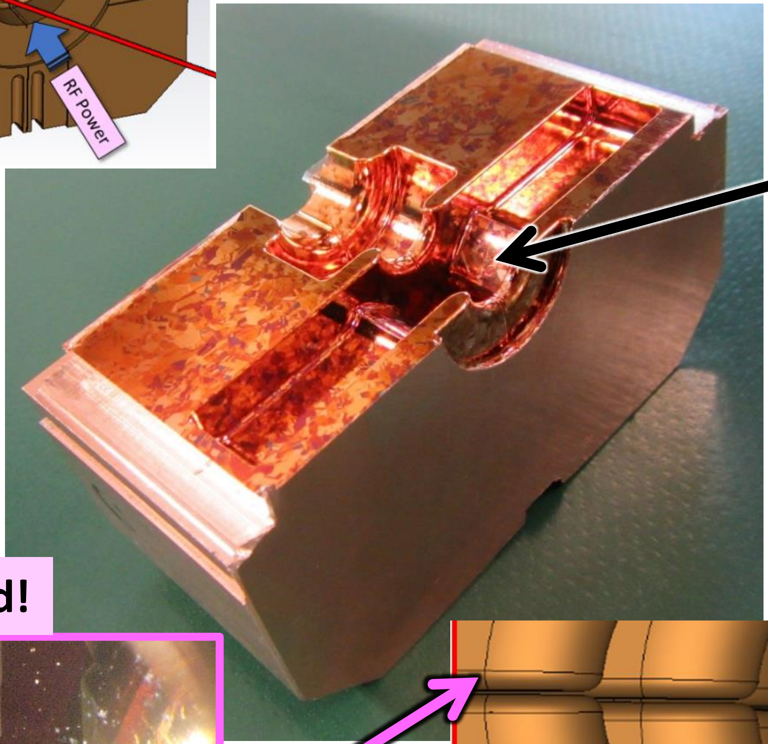
Figure 12: EBW of the quadrants. (a) After the EBW. (b) Welding penetration depth for the EBW conditions described in [13]. (c) A thermocouple is attached.



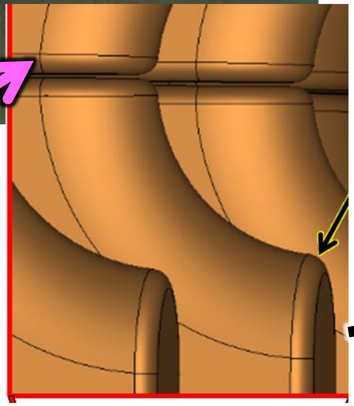
Good high-gradient performance demonstrated
➔ Multi-cell traveling structure

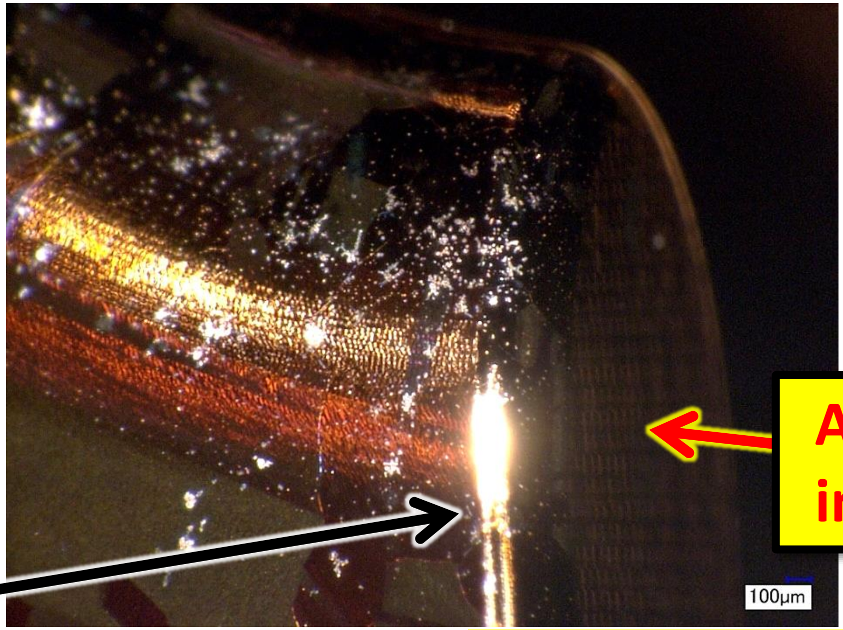
Postmortem of SD1_QUAD-R04G01_K1





BD spots aligned!





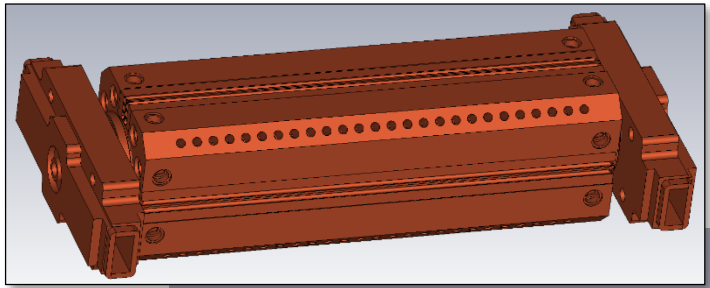
Almost no damage in the 0.1-mm gap!

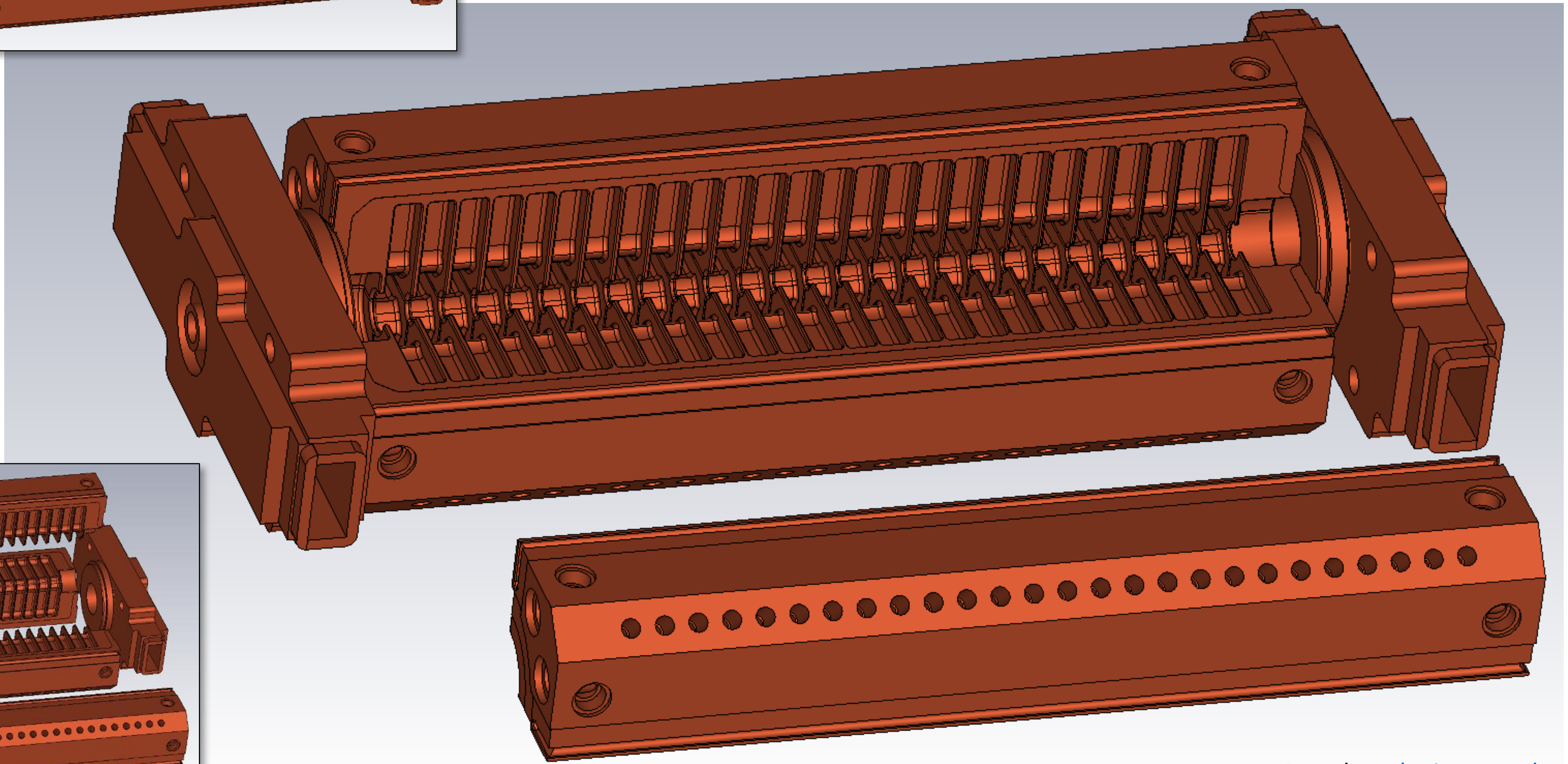
The small 0.1-mm gap successful!

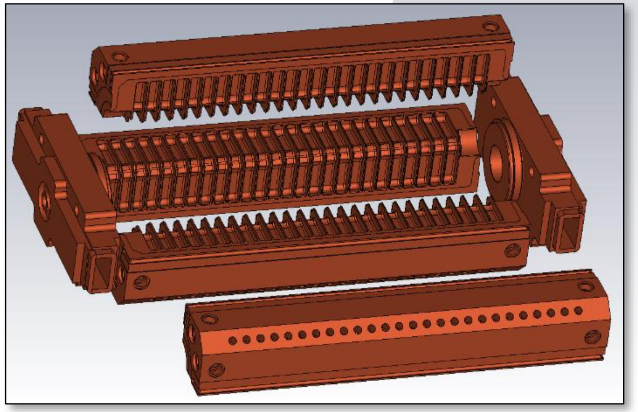
Currently fabricating "TD24R10_QUAD-R04G01"

Round chamfer: 0.4 mm

Gap between quadrants: 0.1 mm



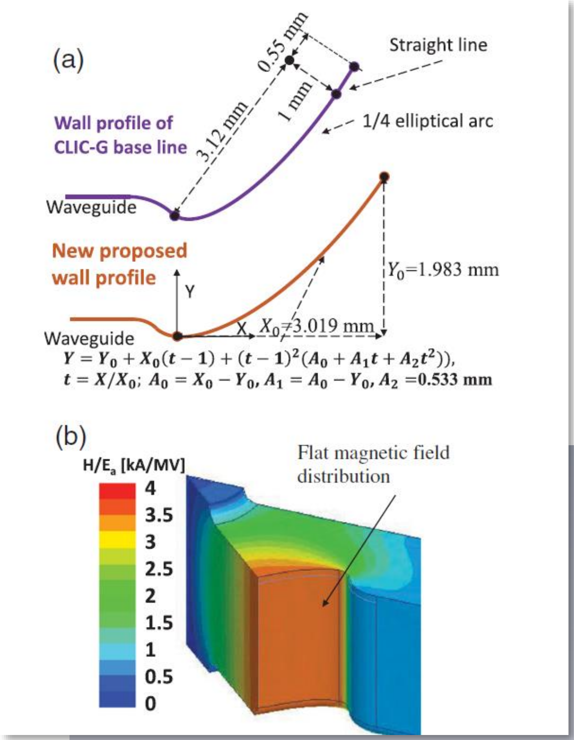


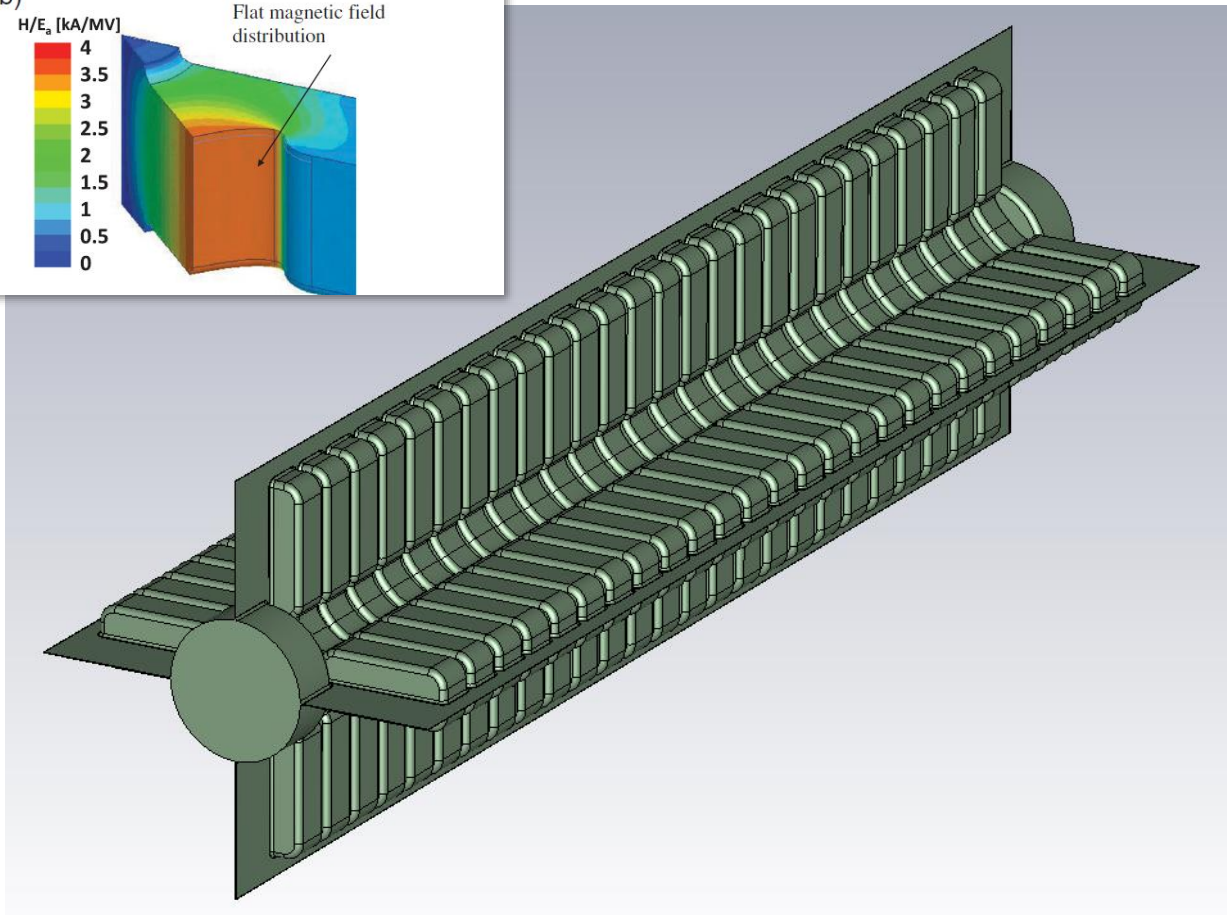


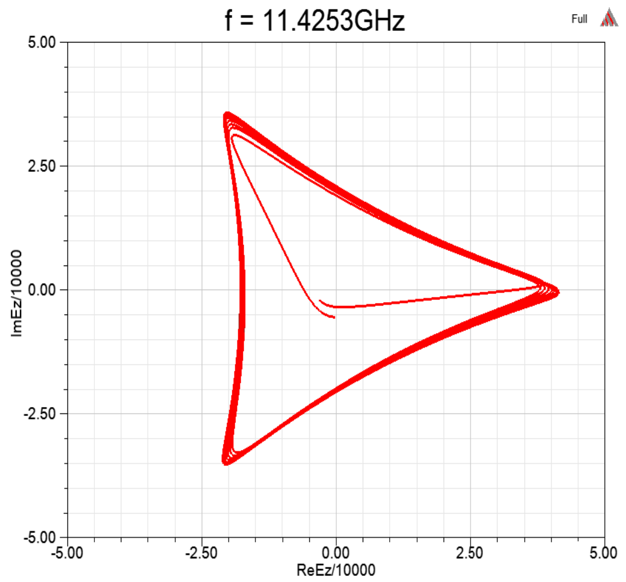
Based on the improved quadrant design

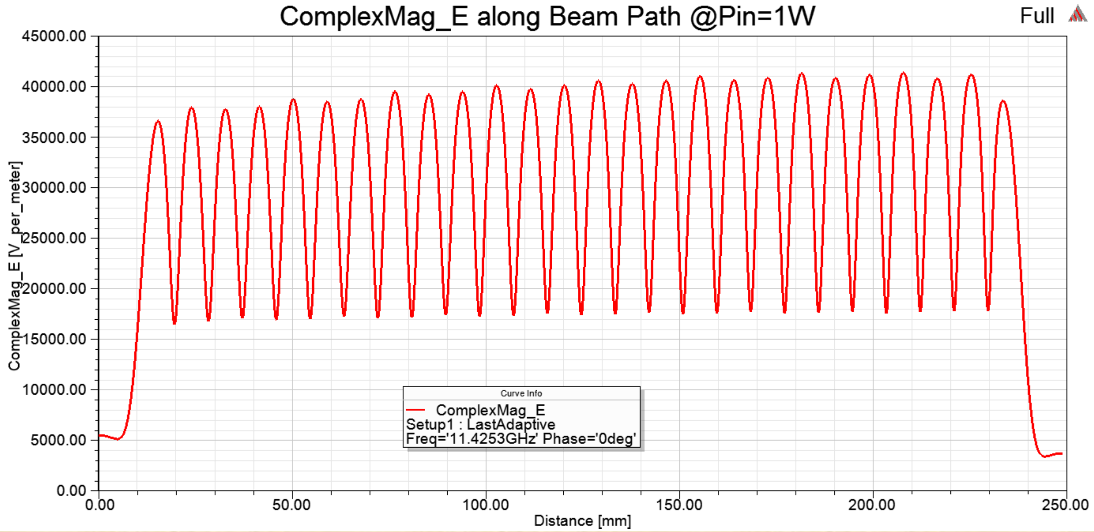
Cavity Design based on CLIC-G*

Made by Jiayang Liu (THU) and Alexej Grudiev (CERN)

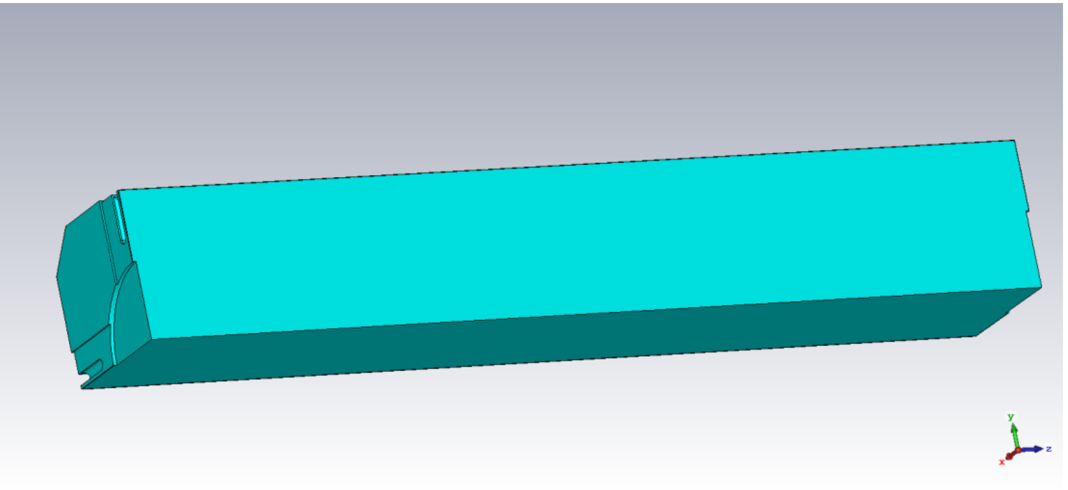




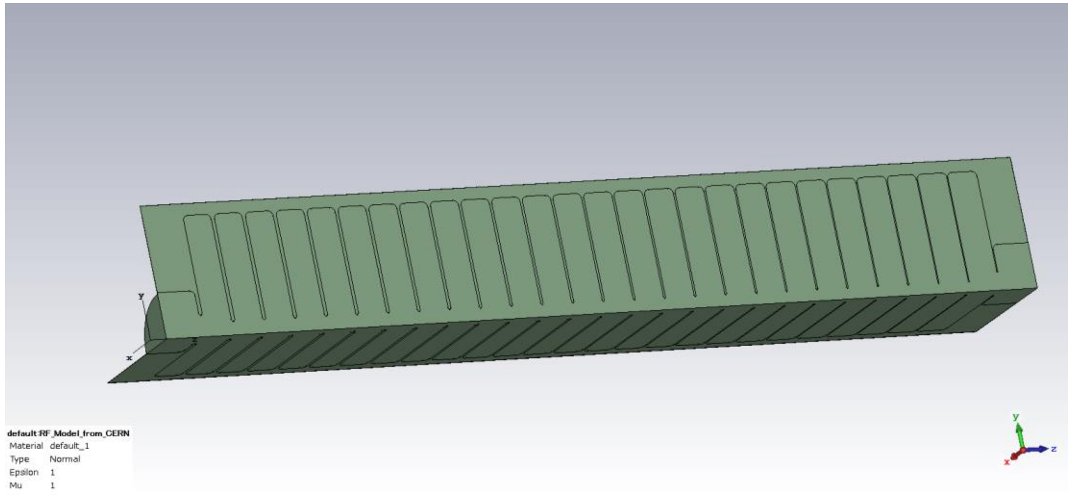




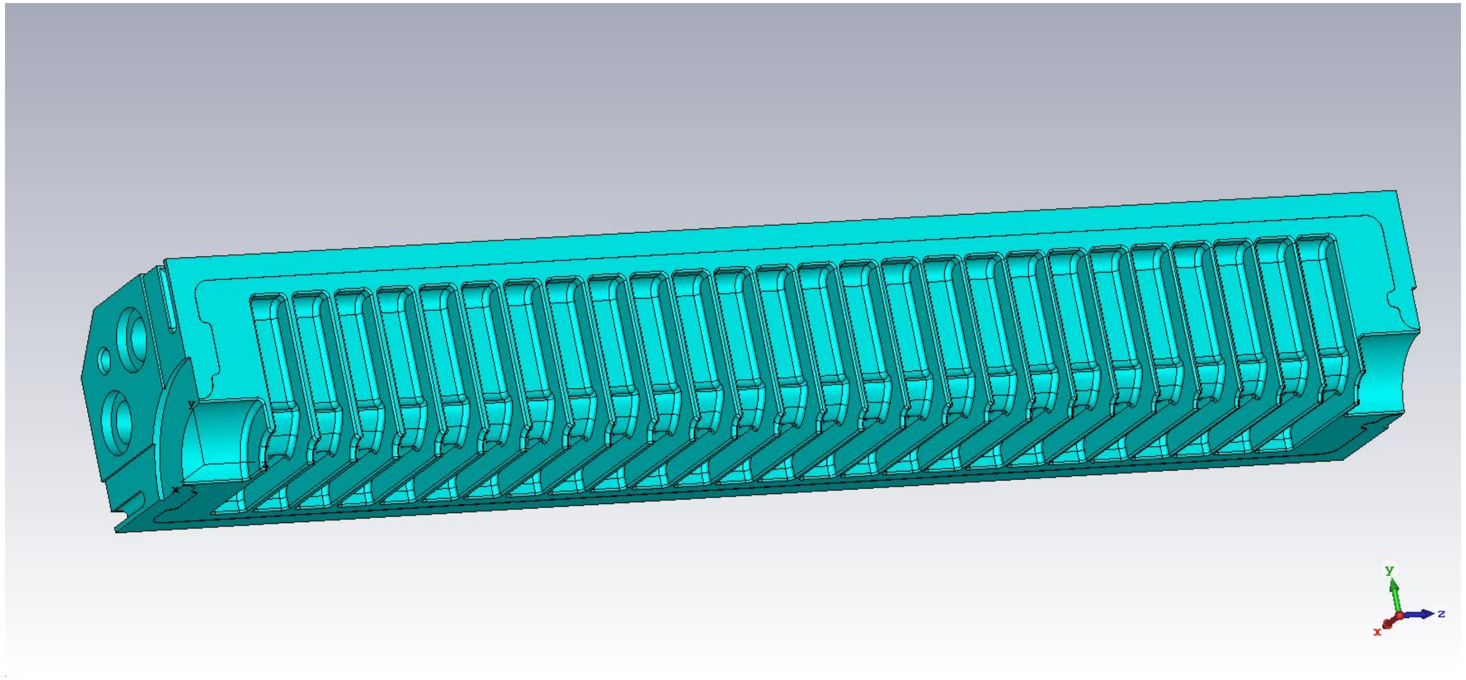
From the Cavity Design to the 3D Mechanical Drawing



minus

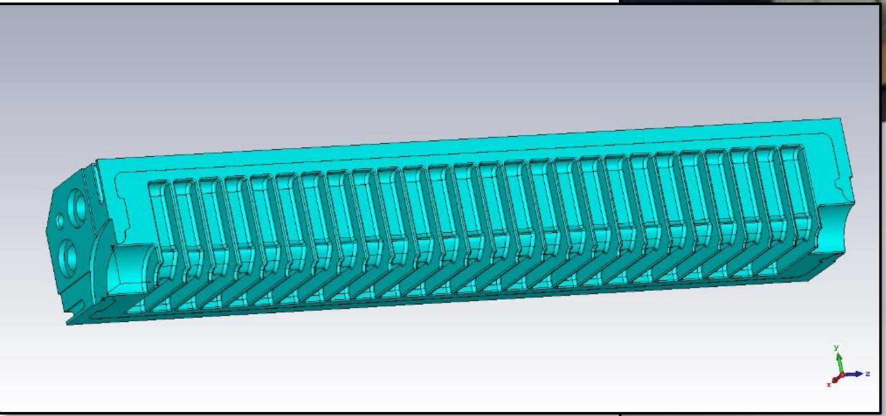


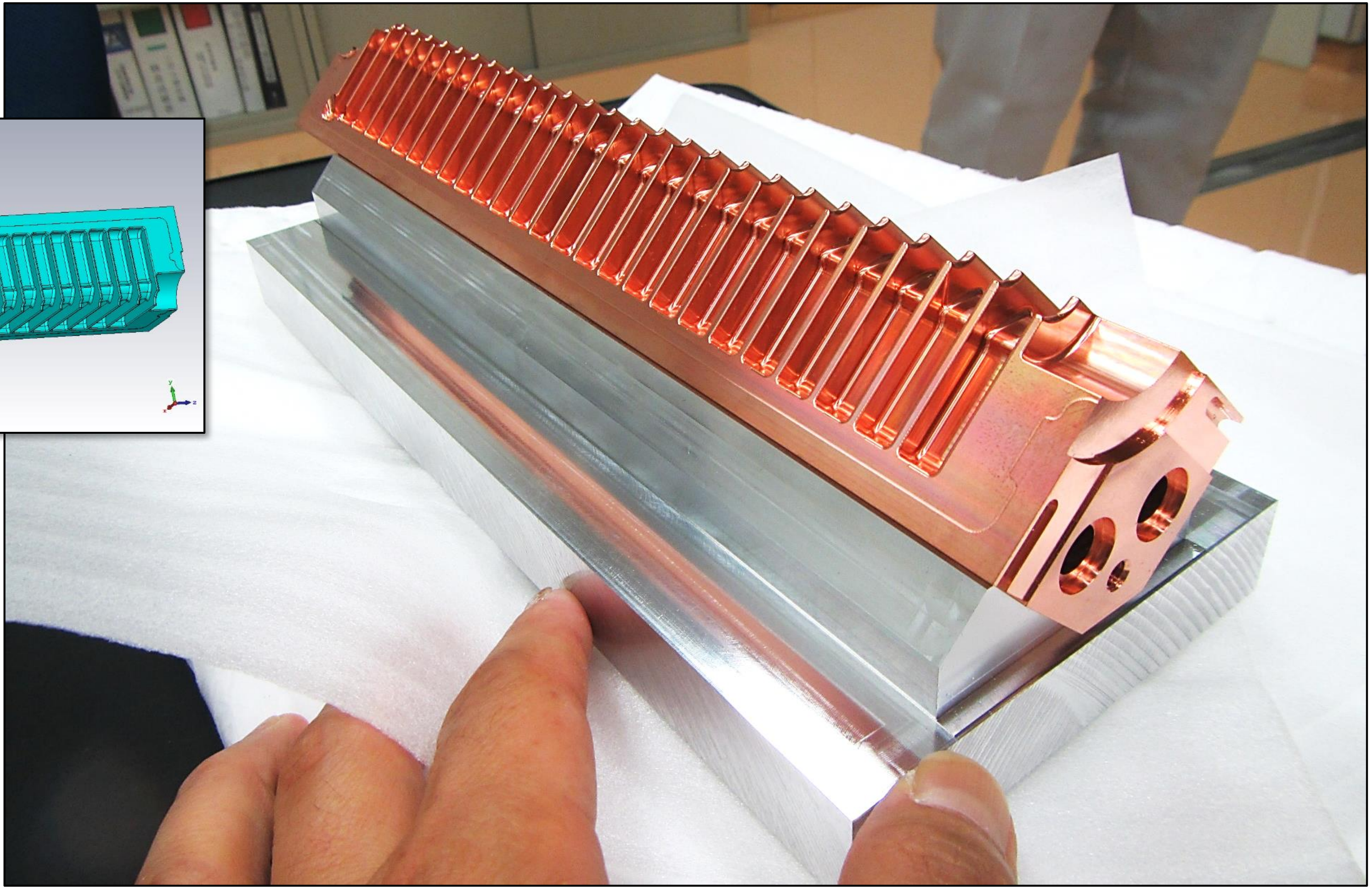
➔



A Quadrant Machined with Ultraprecision Milling

By U-Corporation

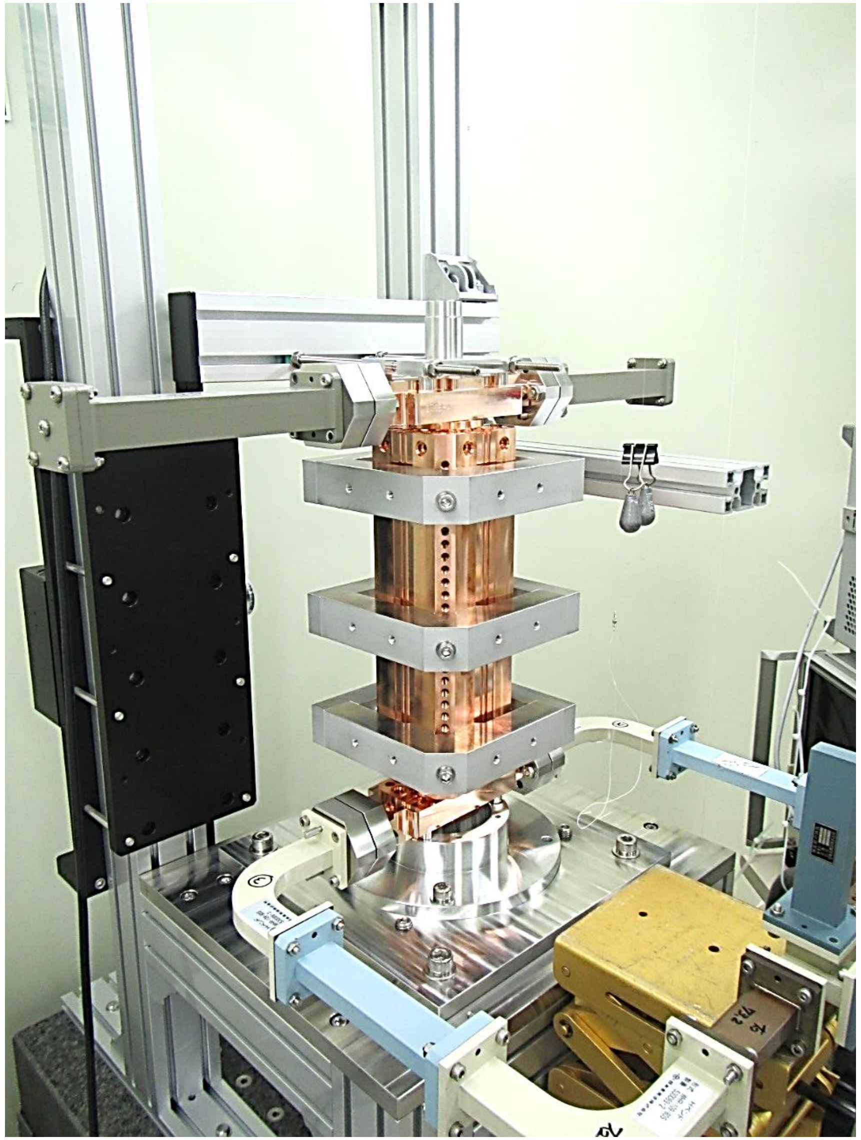




RF Measurement before EBW (1/3)

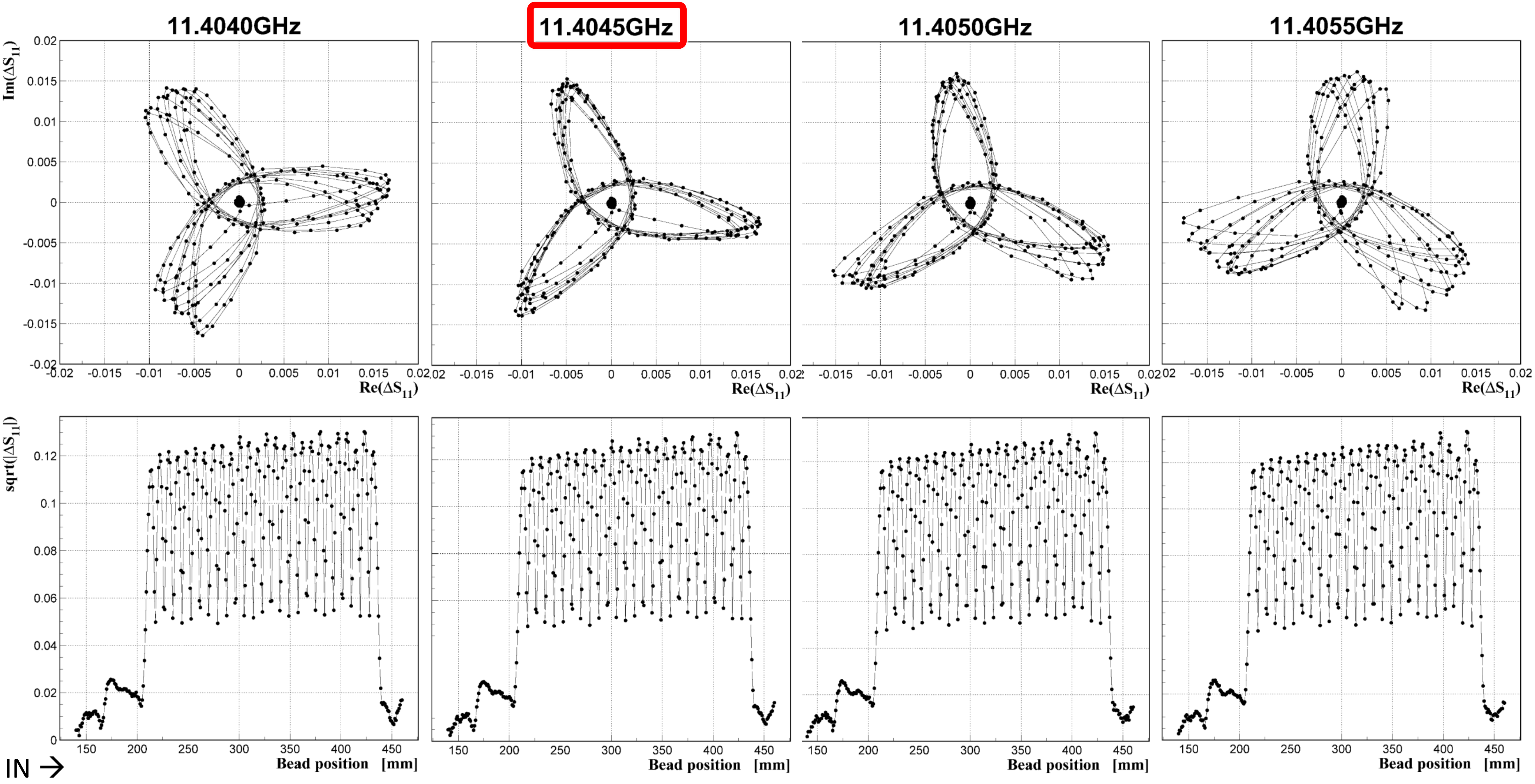
With the four quadrants clamped

(<u>EBW</u>: <u>E</u>lectron-<u>B</u>eam <u>W</u>elding)



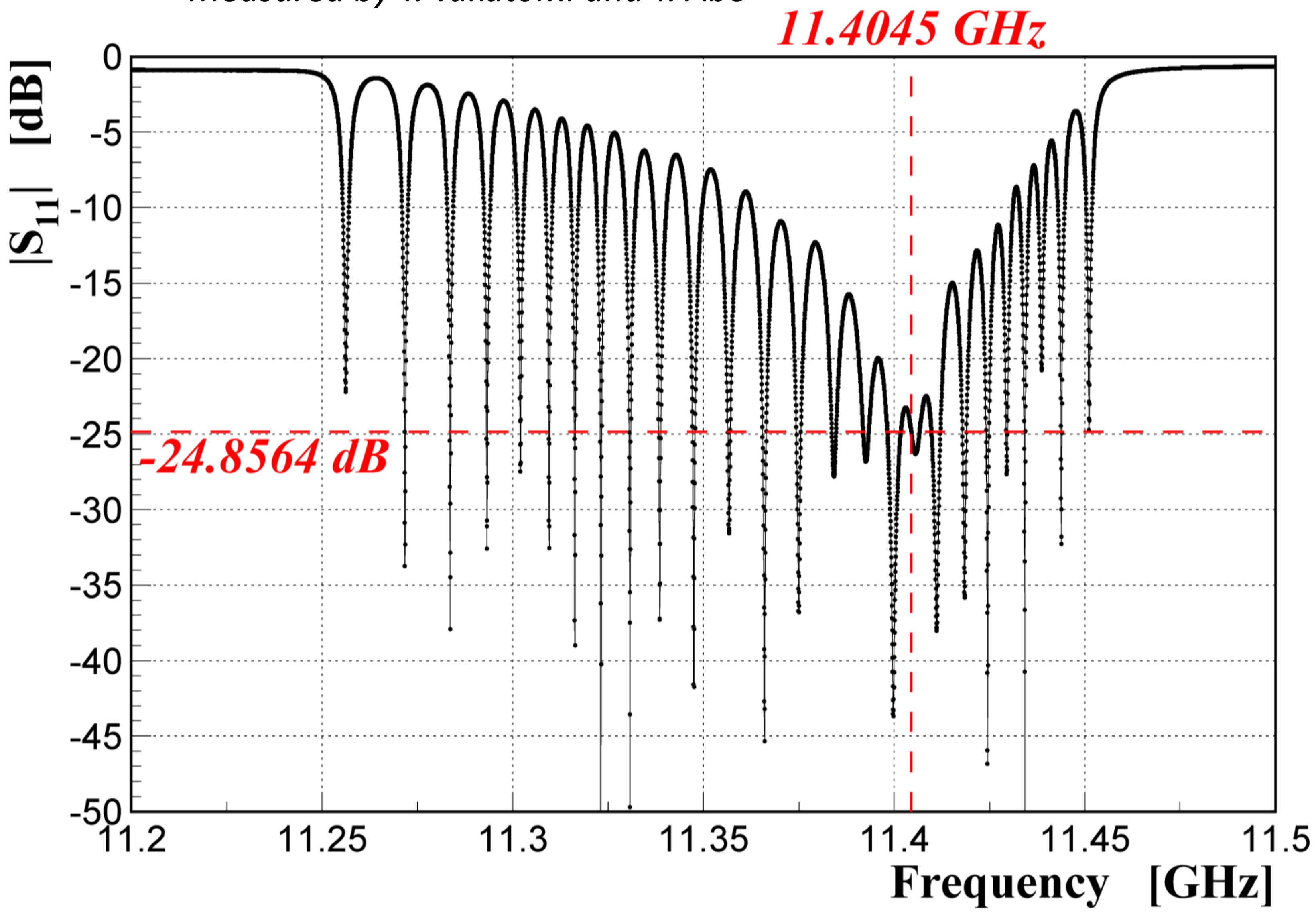
RF Measurement before EBW (2/3)

Measured by T. Takatomi and T. Abe



RF Measurement before EBW (3/3)

Measured by T. Takatomi and T. Abe

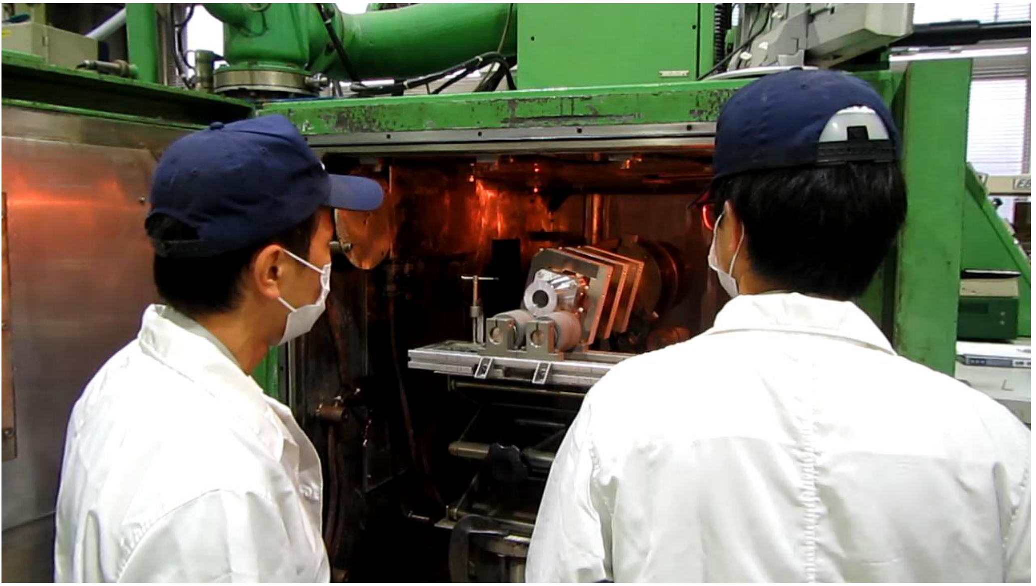


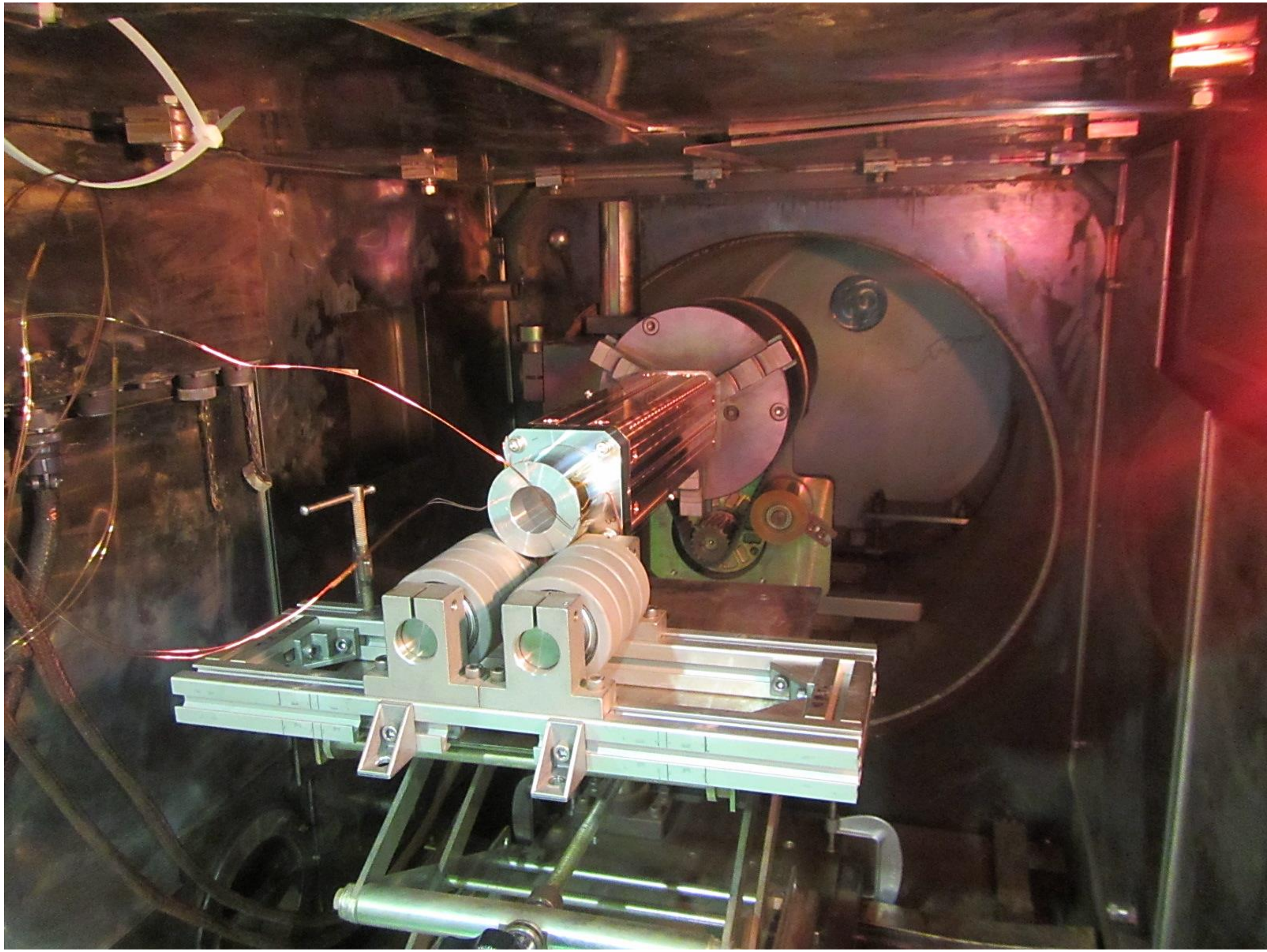
➔11.4084 GHz (vac)
➔11.4074 GHz (vac&30degC)

~10 MHz increase
Expected through EBW

EBW on the side surfaces

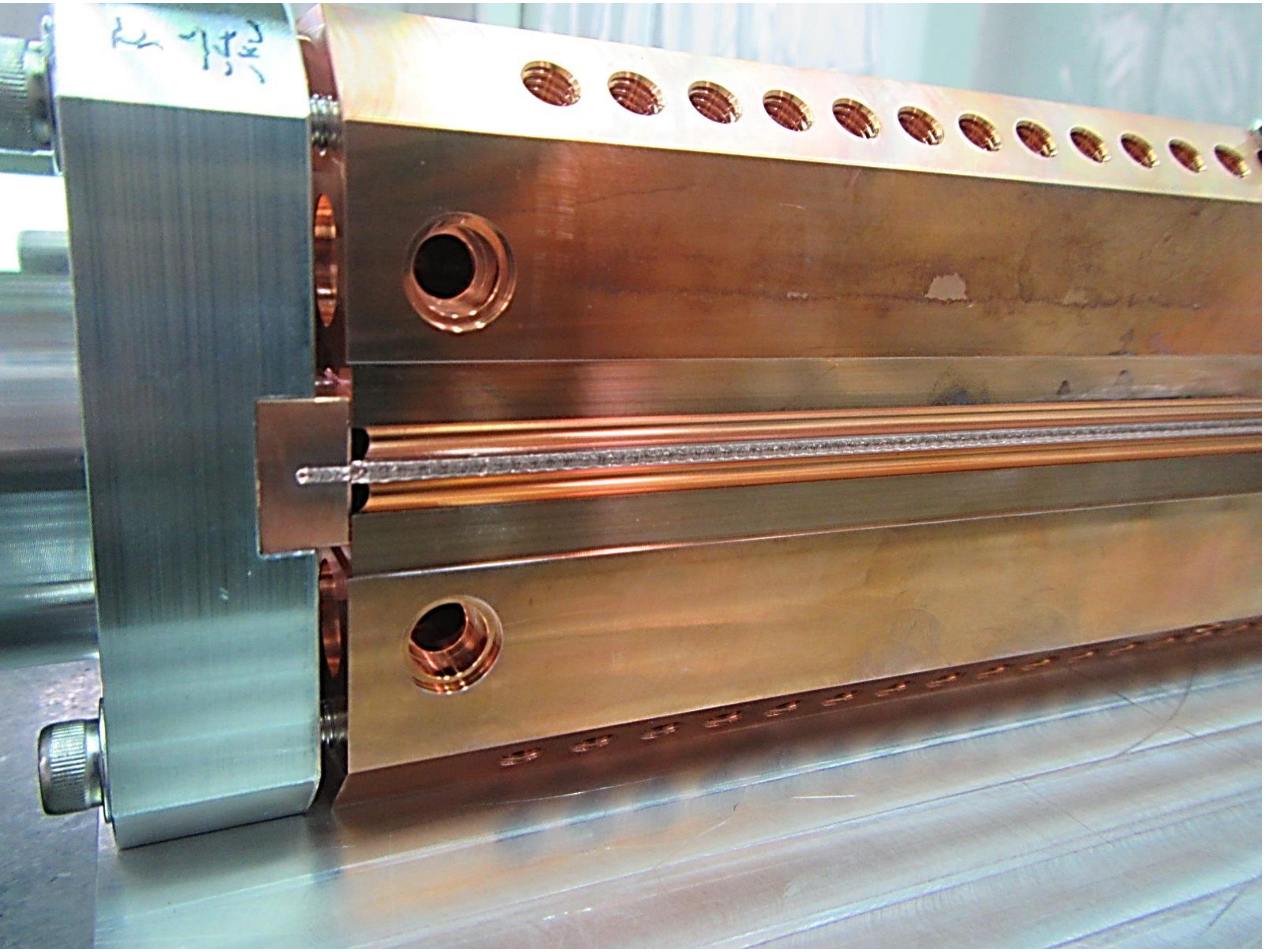
By TAIYO EB tech

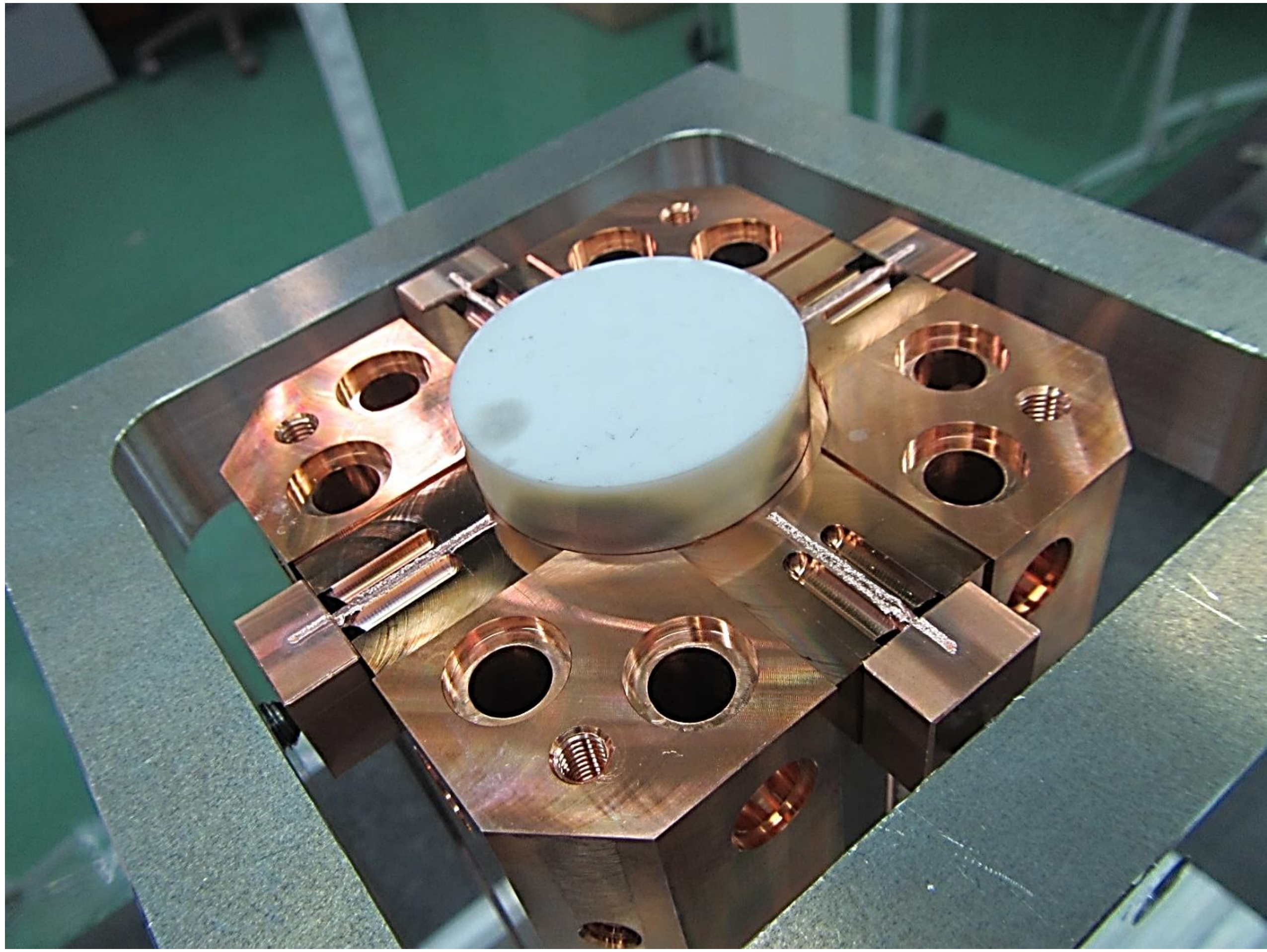




Four Quadrants Bonded with the EBW

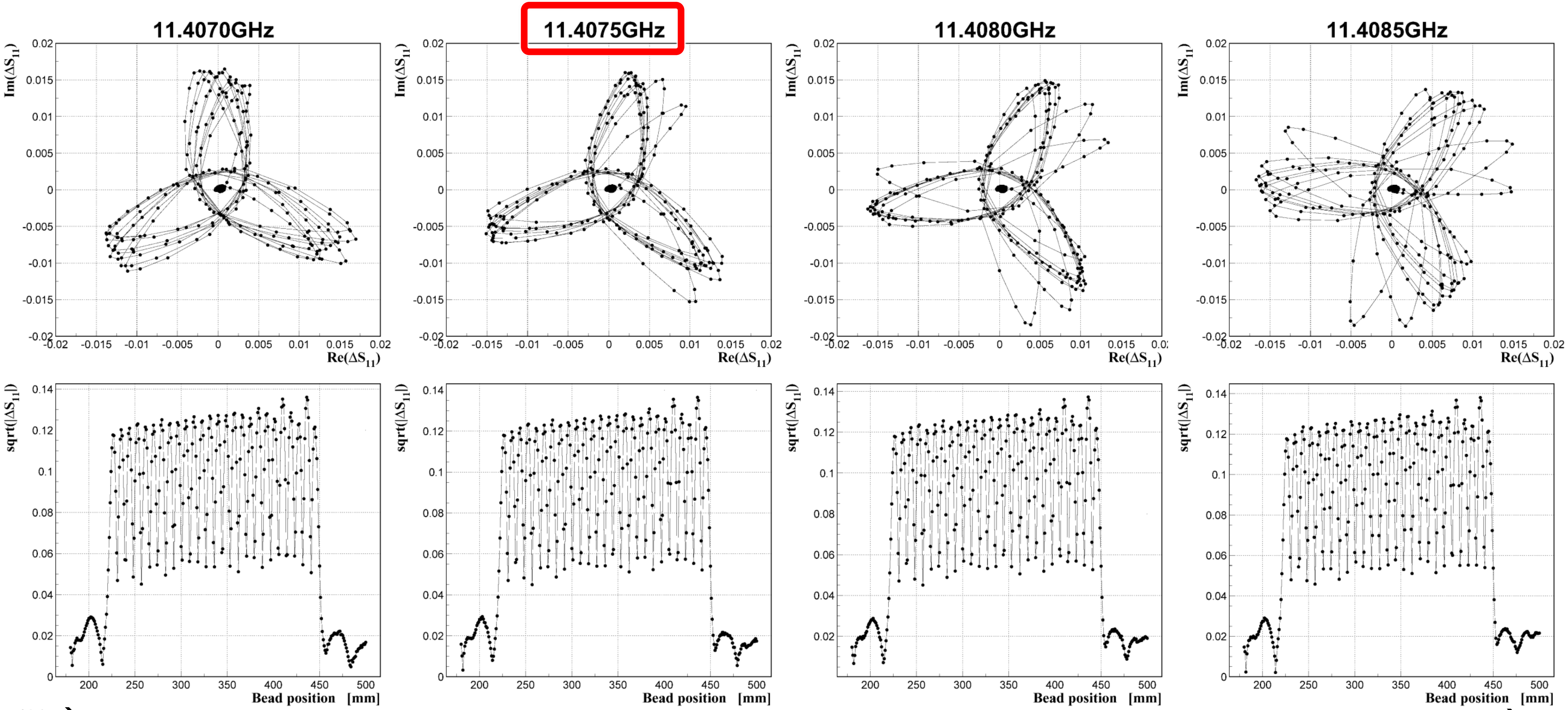
(EBW: Electron-Beam Welding)





RF Measurement after the EBW

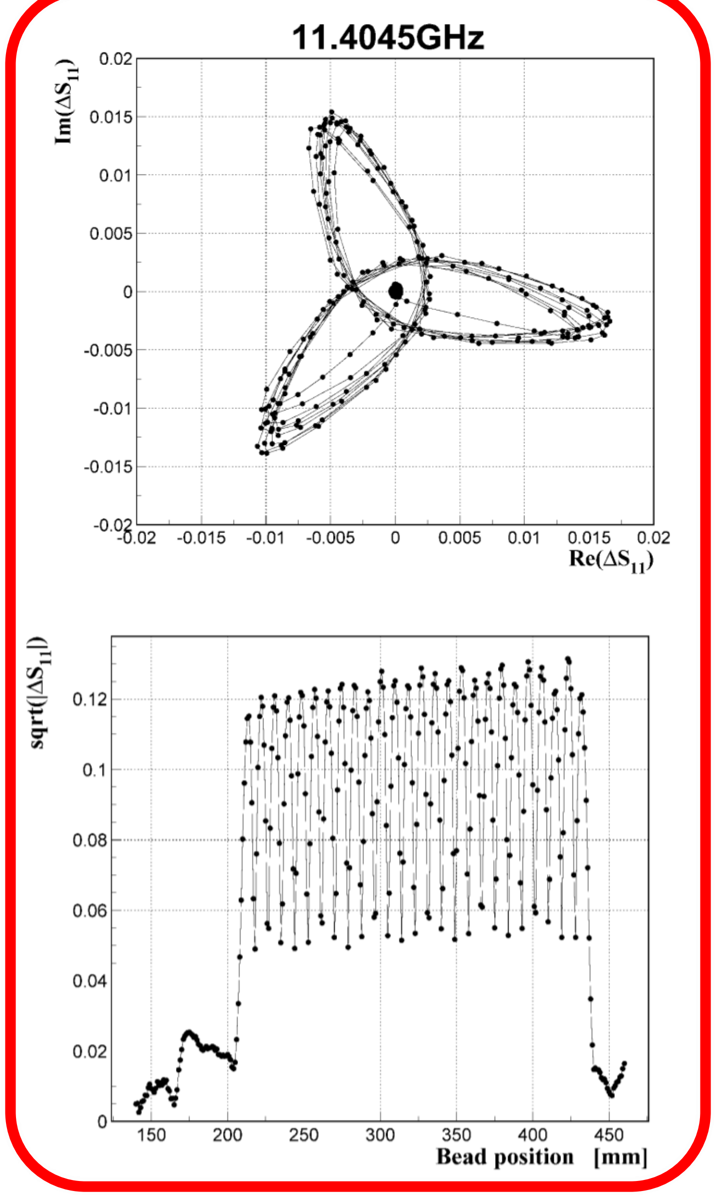
Measured by T. Takatomi and T. Abe

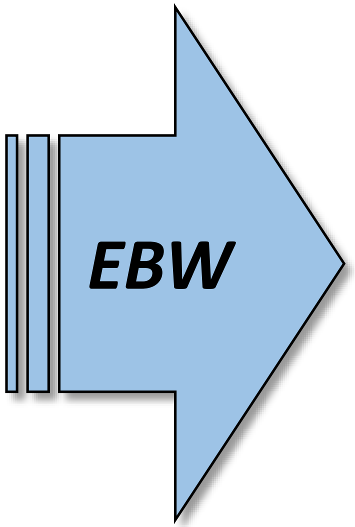


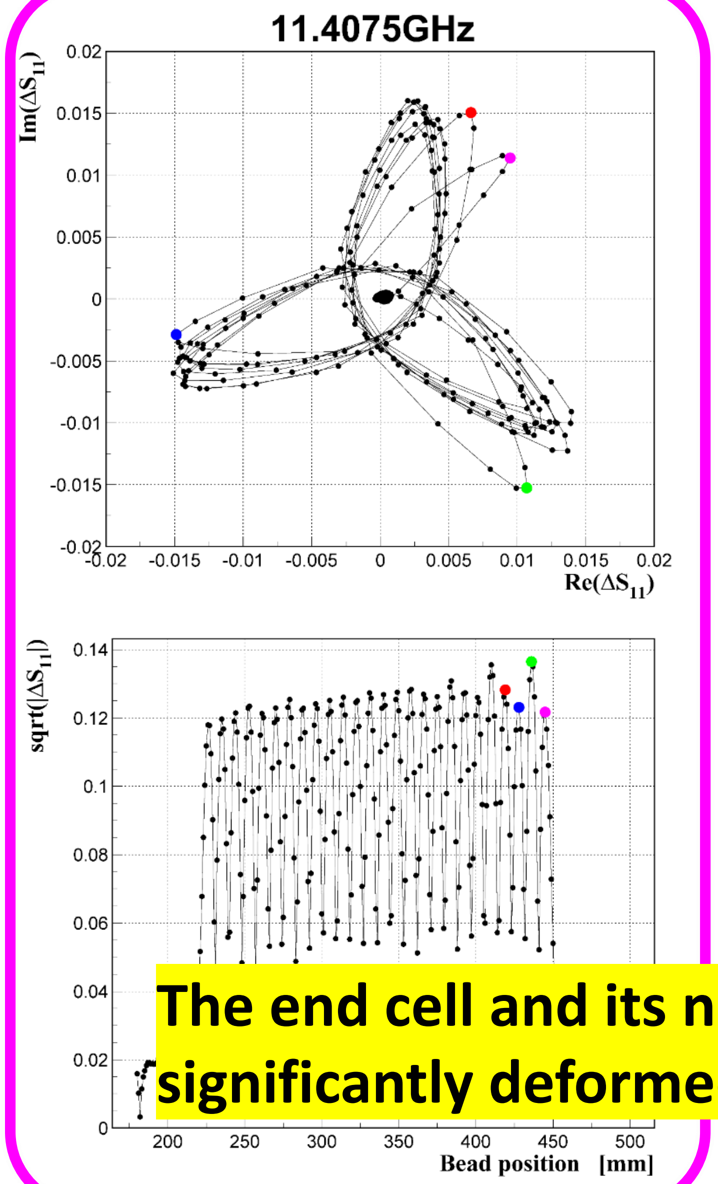
IN →

→ OUT

Before and after the the EBW

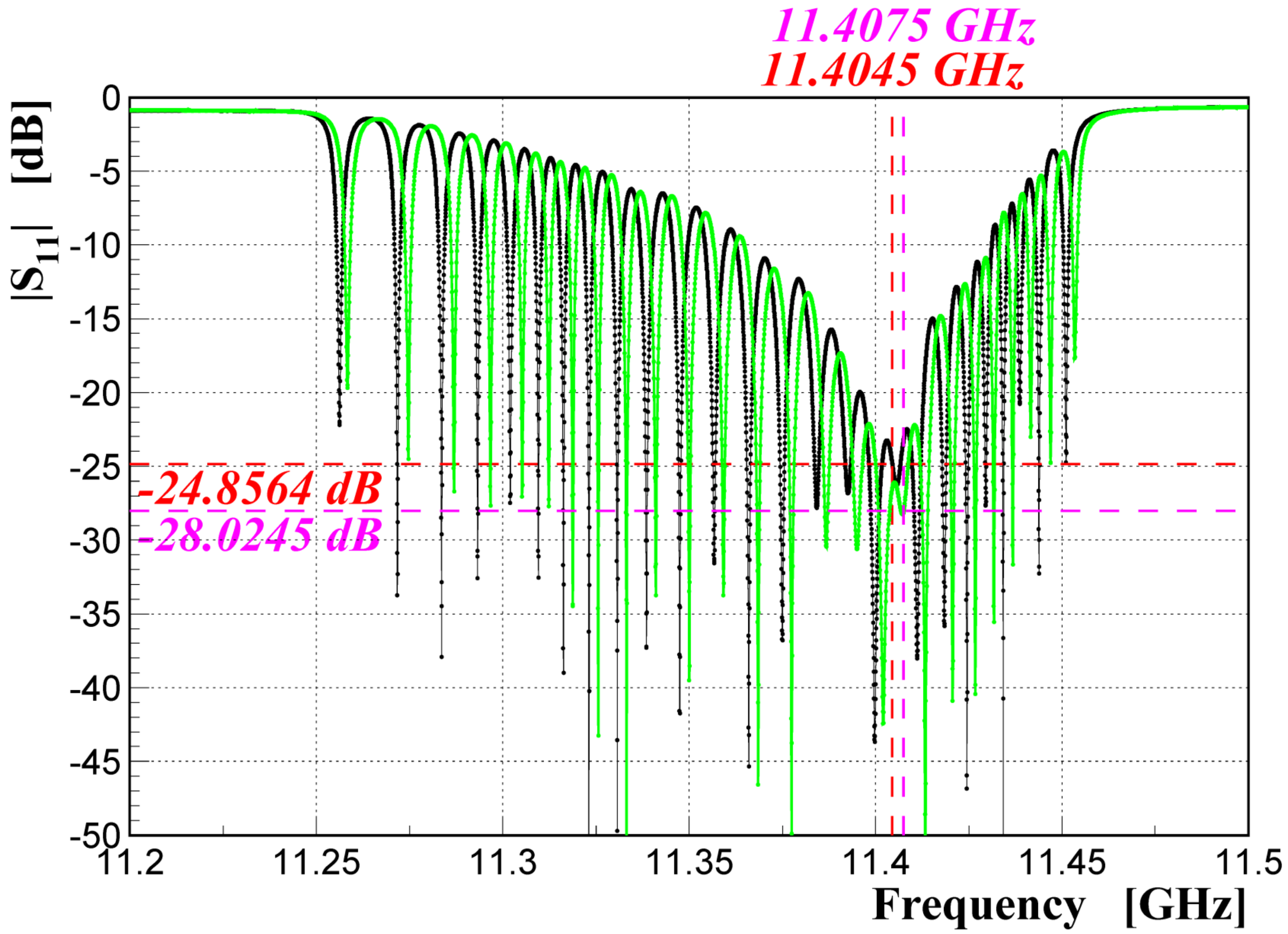




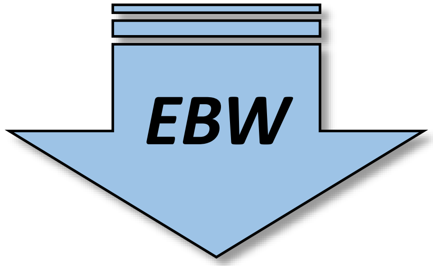


The end cell and its neighboring cells significantly deformed

Before and after the EBW



11.4074 (vac&30degC)



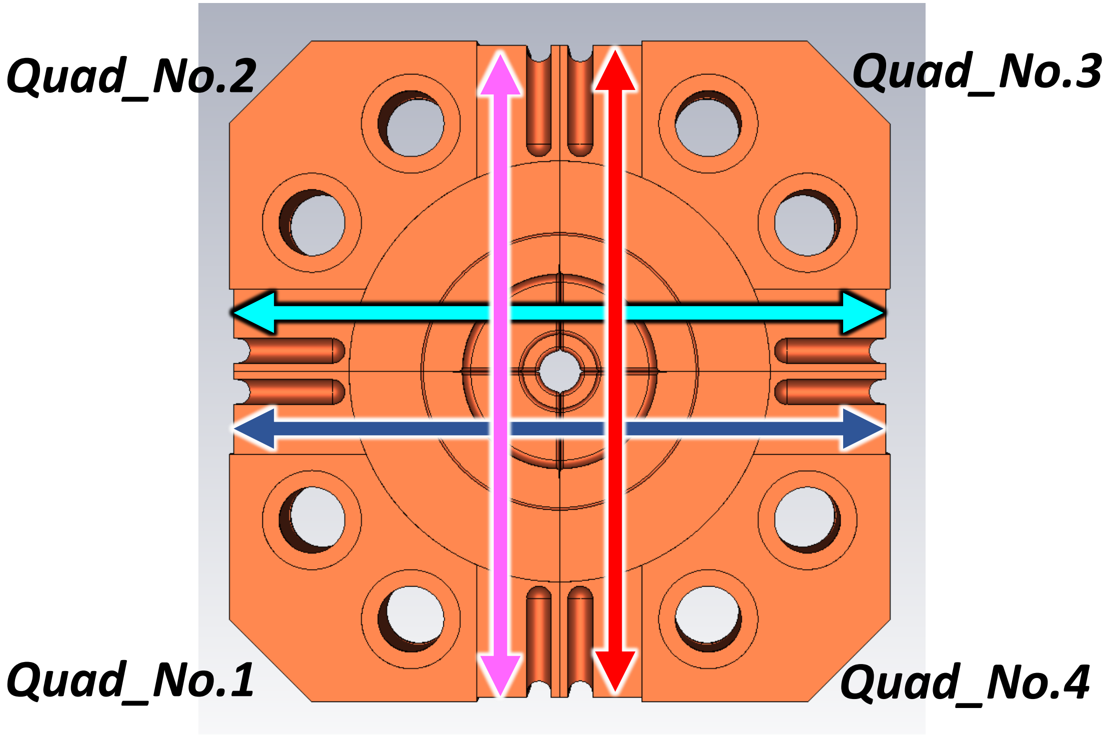
11.4099 GHz (vac&30degC)

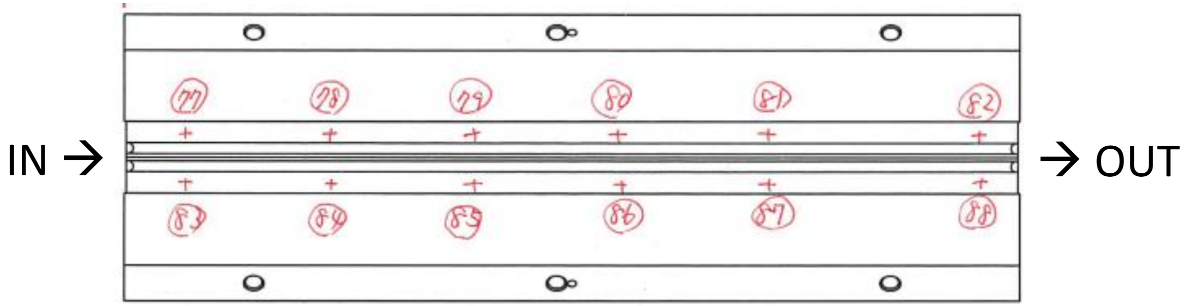
+2.5 MHz

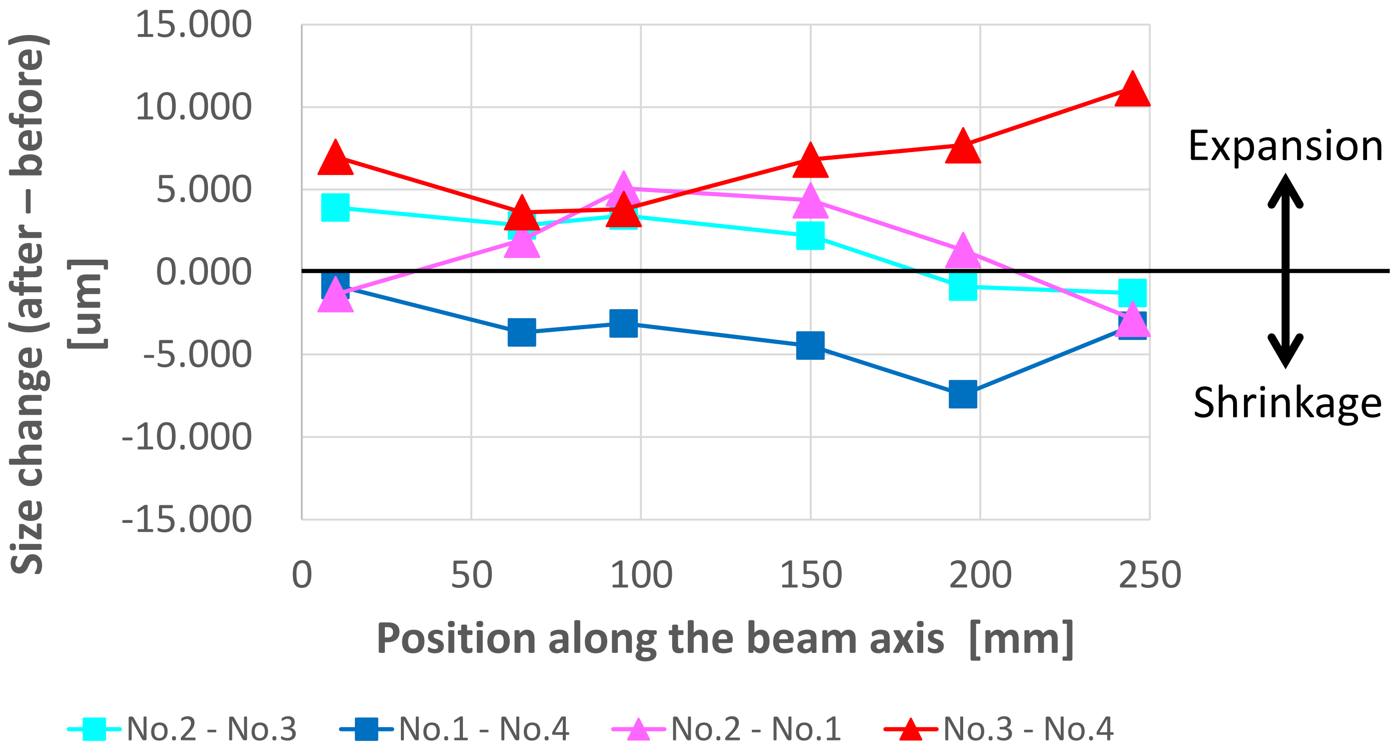
(We expected ~10 MHz increase by the EBW.)

Change in Transverse Size Measured using a CMM (Carl Zeiss UPMC 850 CARAT)

By T. Takatomi (KEK / Mechanical Engineering Center)



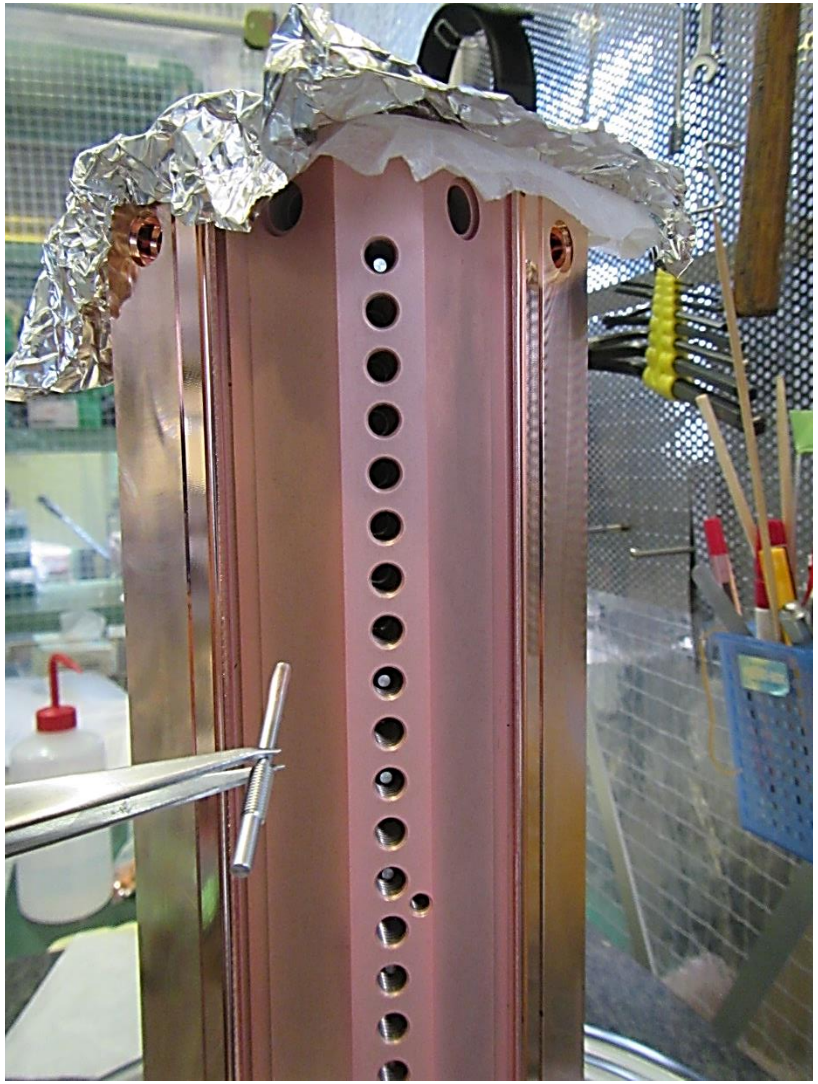




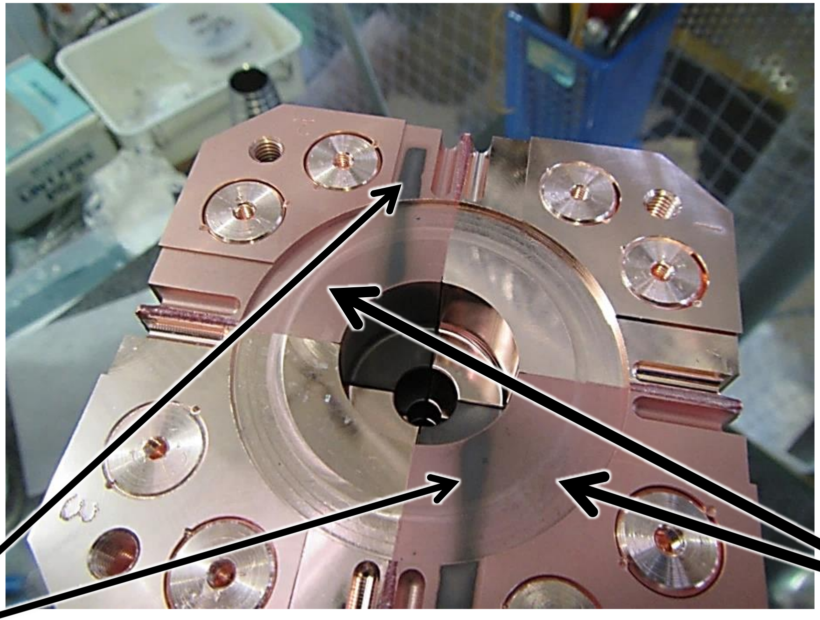
- ✓ **Average size change: +1.5 μm**
- ✓ **The quadrants largely deformed around the end cell**

After brazing tuner pins…

First time to be processed at a high temperature

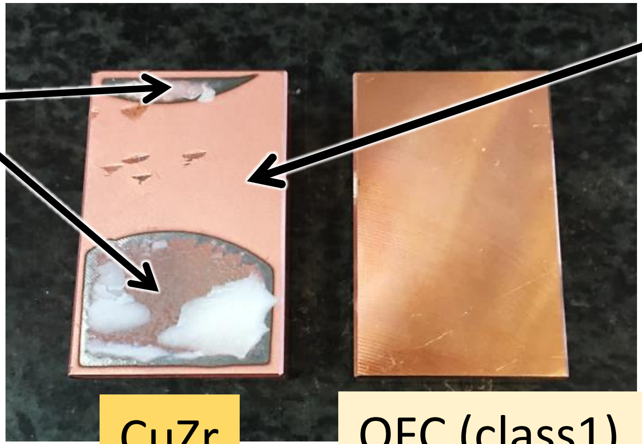


Most of the tuner pins dropped!



Pearskin!

Alumina ceramics
put here

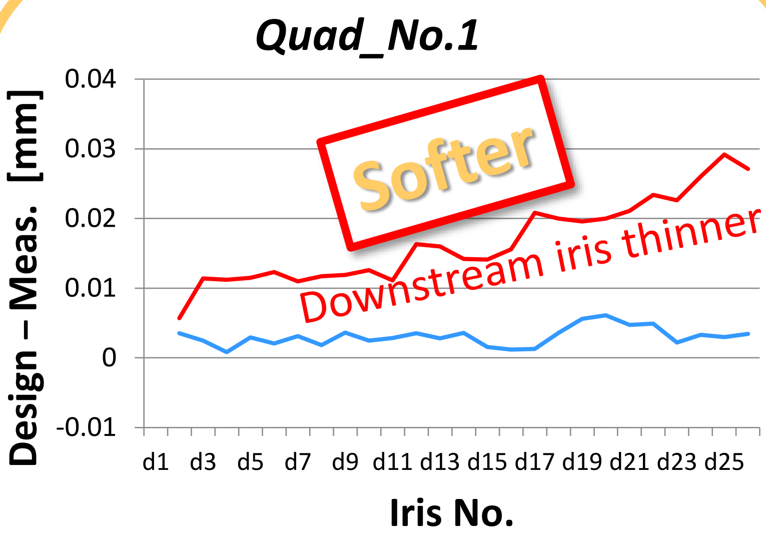


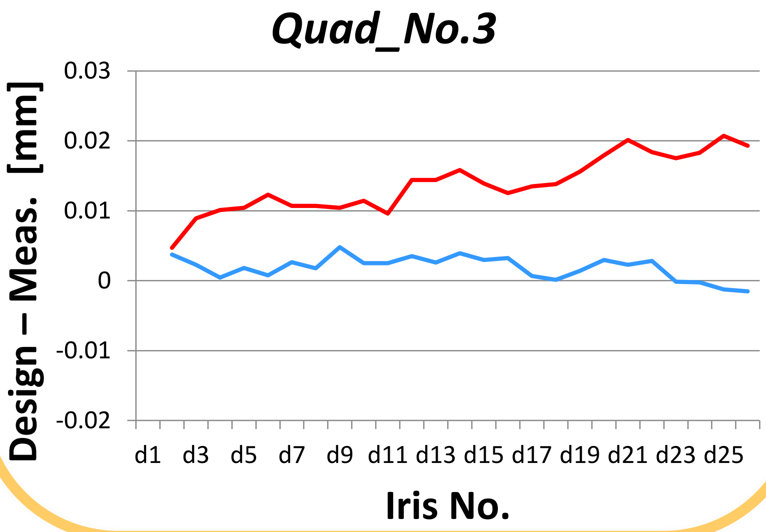
CuZr

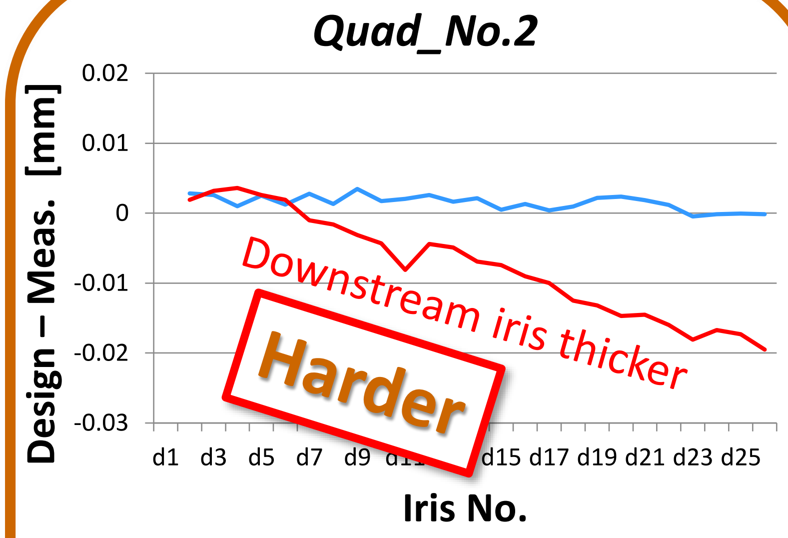
OFC (class1)

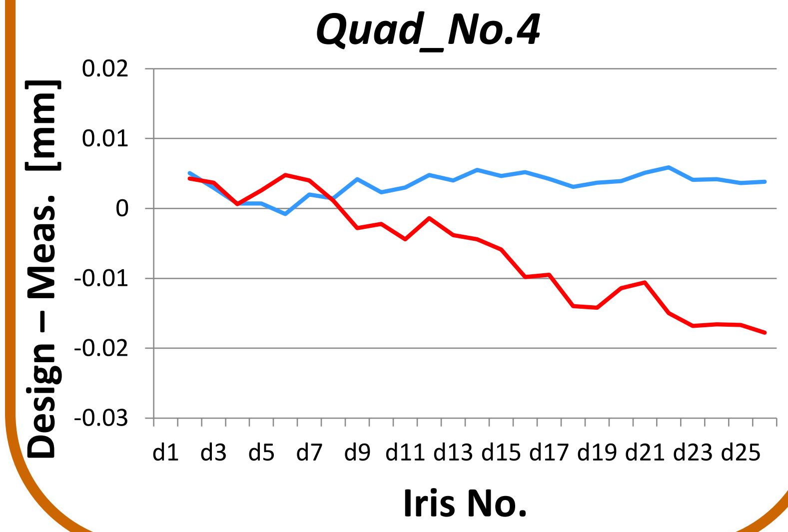
🡐 High-temperature-treated copper plates made of CuZr and pure copper (OFC, class1)

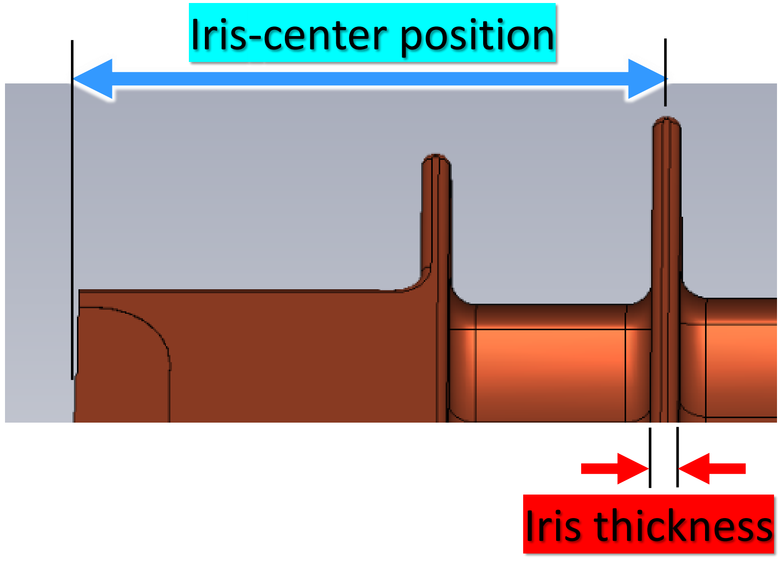
Longitudinal Size Measurement after the Final Machining





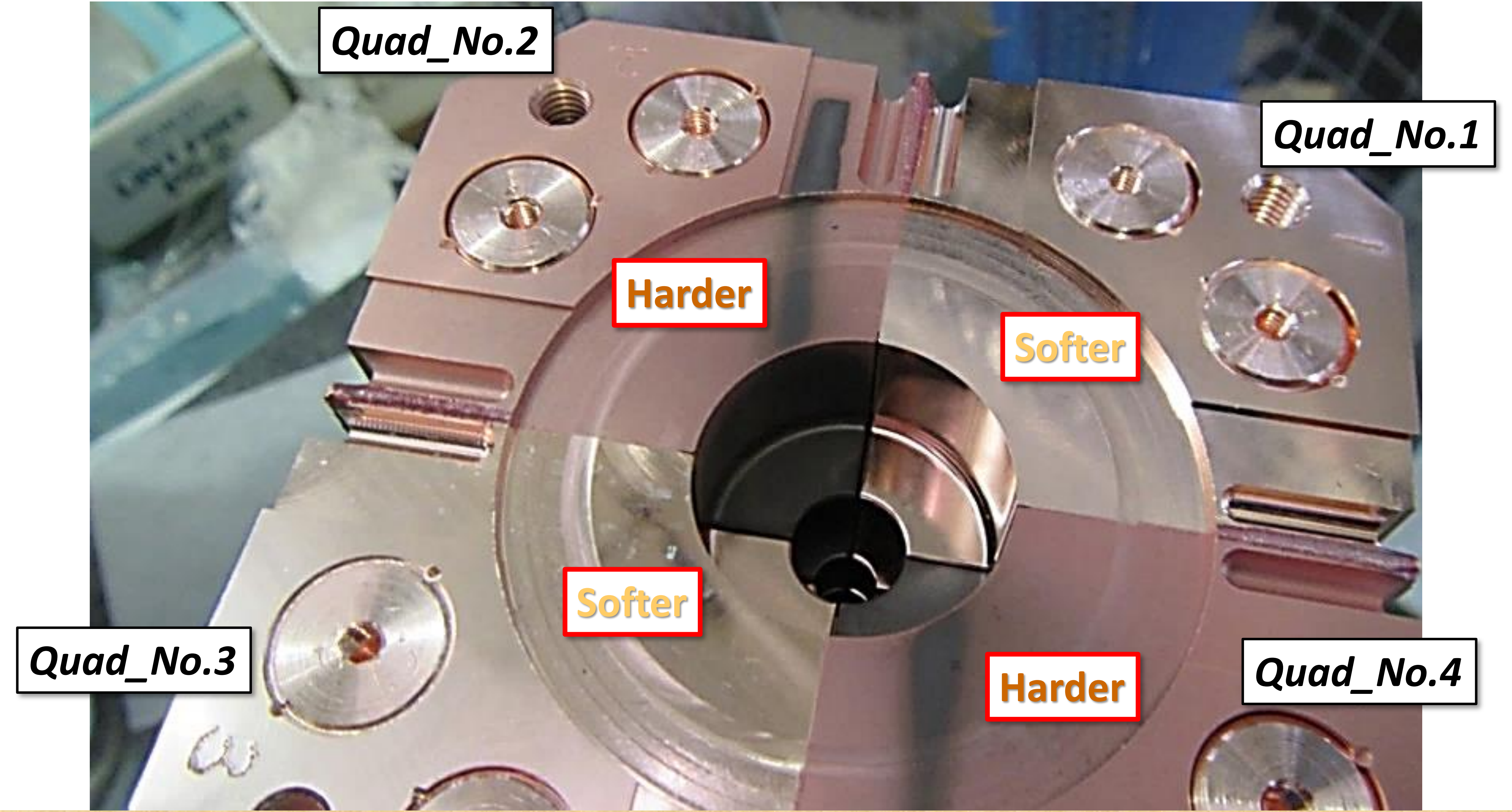






- ✓ Iris-center positions accurate (+- 5 μm)
- ✓ Iris thicknesses depend on iris numbers.
  - ➢ Signs of the slopes different between No.1,3 and No.2,4

Assuming different hardness between No.1,3 and No.2,4, the difference in the slope sign originates from the difference in wear volume on the ball end mills.


Quad_No.2
Quad_No.1
Harder
Softer
Softer
Harder
Quad_No.3
Quad_No.4

Updated Schedule on TD24_QUAD

① Milling of quadrants to be completed by March 2019

② RF & size meas. → EBW → RF & size meas. by April 2019

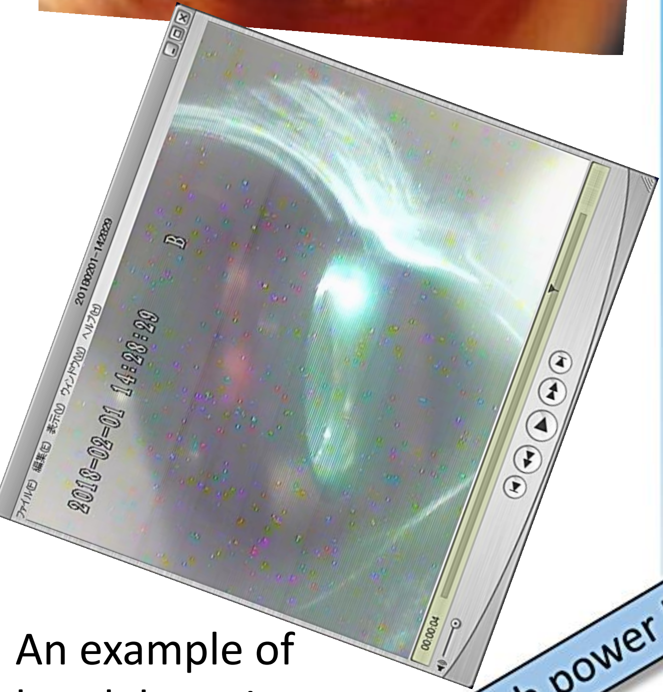
③ Brazing of tuner pins, couplers, etc. by May 2019

④ High-gradient test to be started before summer 2019

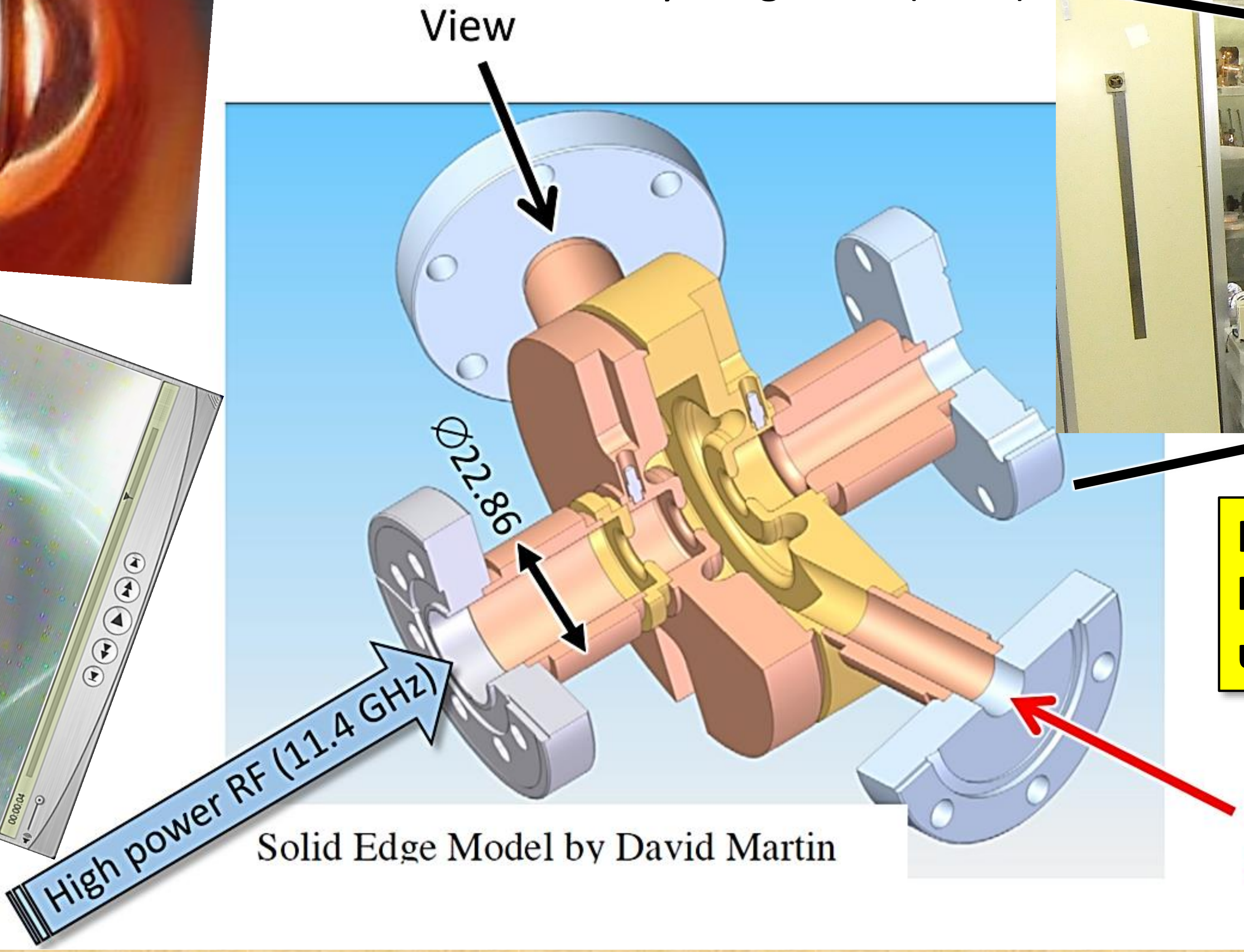
Single-Cell SW Cavity Test at Nextef / Shield-B

DUT: SLAC Full-Choke Cavity

(For details, see SLAC-PUB-15145)

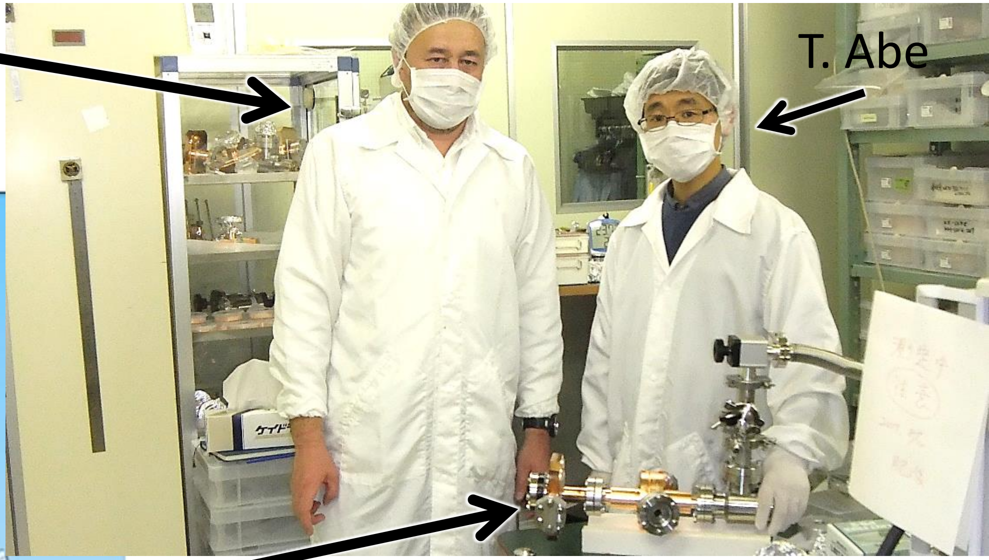


An example of breakdown image



Solid Edge Model by David Martin

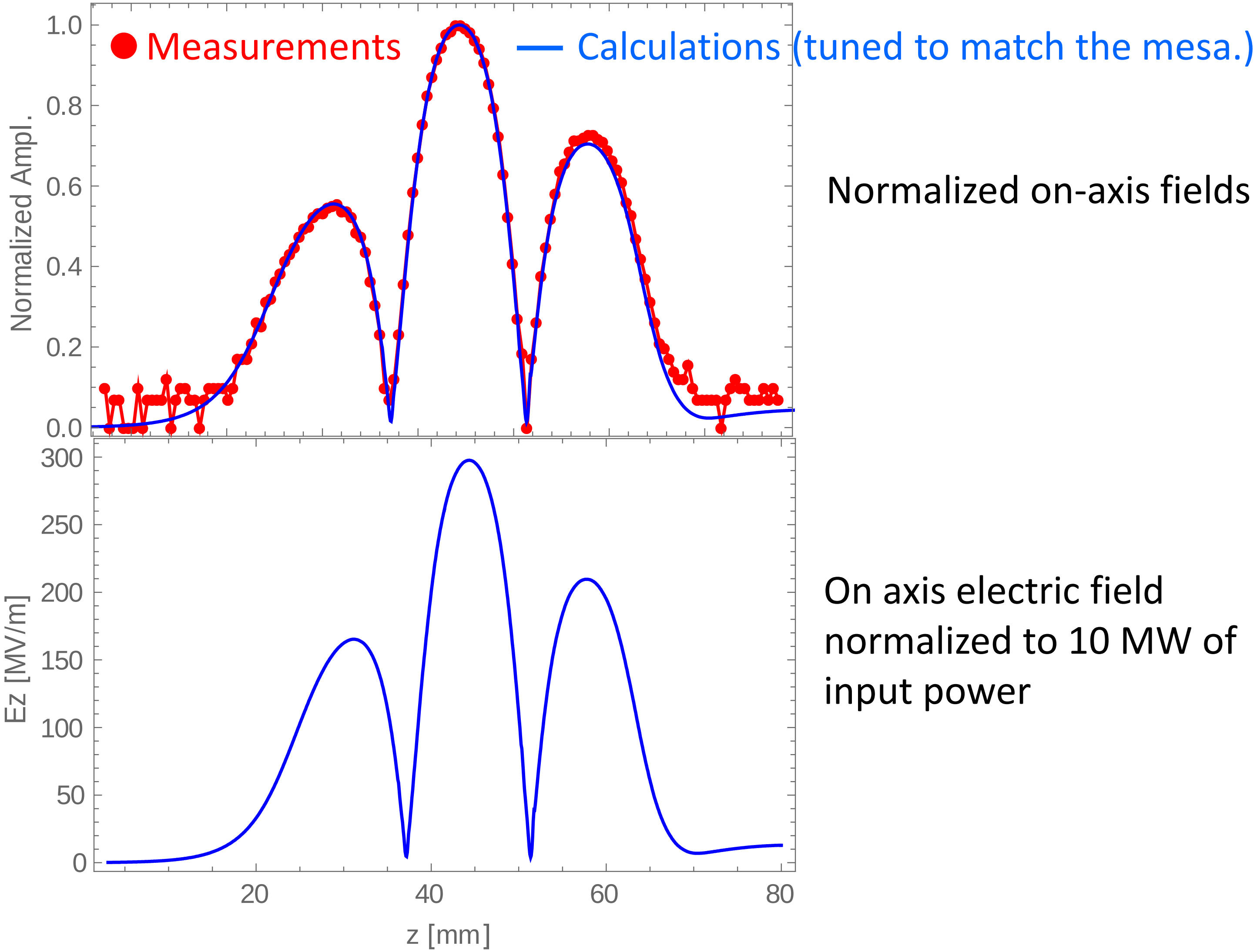
(During the RF measurement in KEK)



High-power RF conditioning done by Valery Dolgashev up to E_{acc} = ~150 MV/m

Fields in Full-Choke cavity, *normalized to 10 MW of input power*

V. Dolgashev

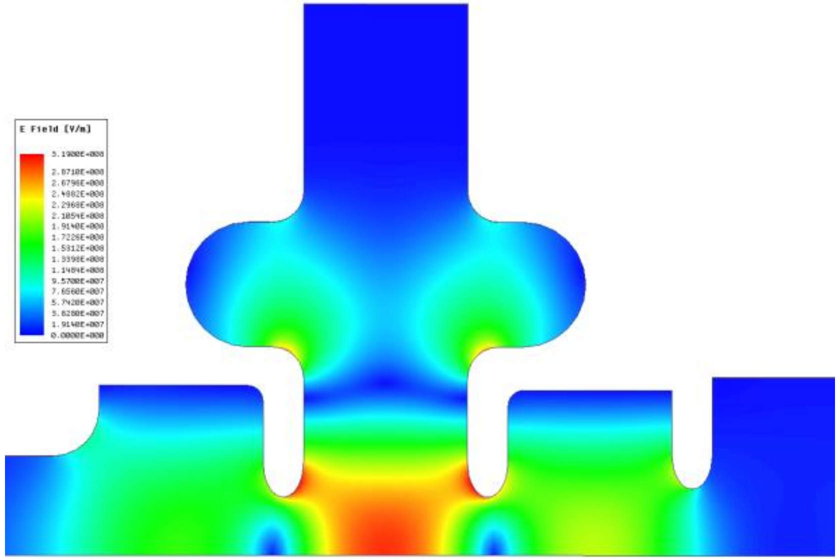


Normalized on-axis fields

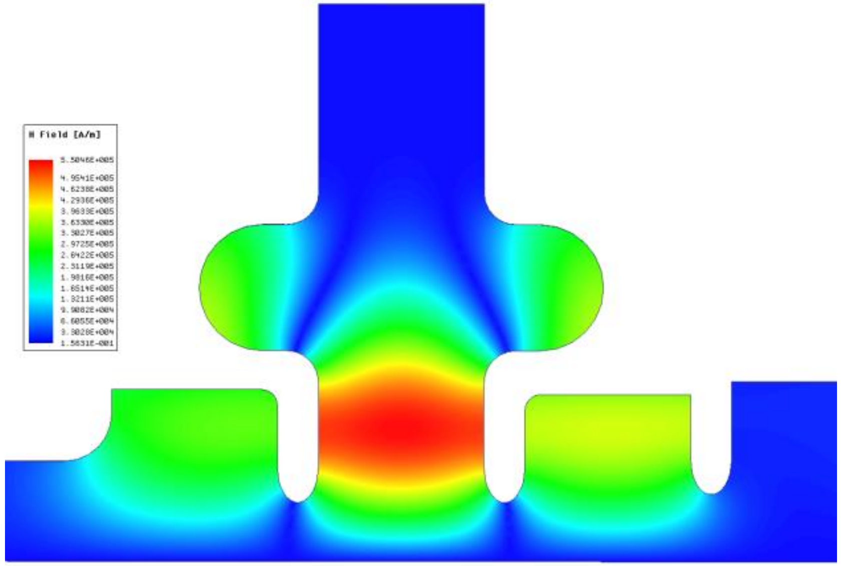
On axis electric field normalized to 10 MW of input power

Fields in Full-Choke cavity, normalized go 10 MW of wall losses

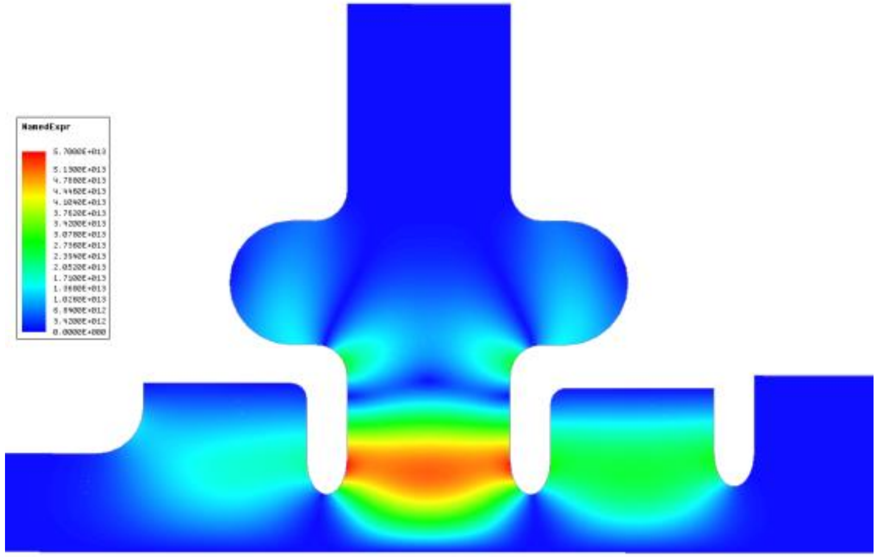
V. Dolgashev



Surface electric field,
E_{max} = 319 MV/m



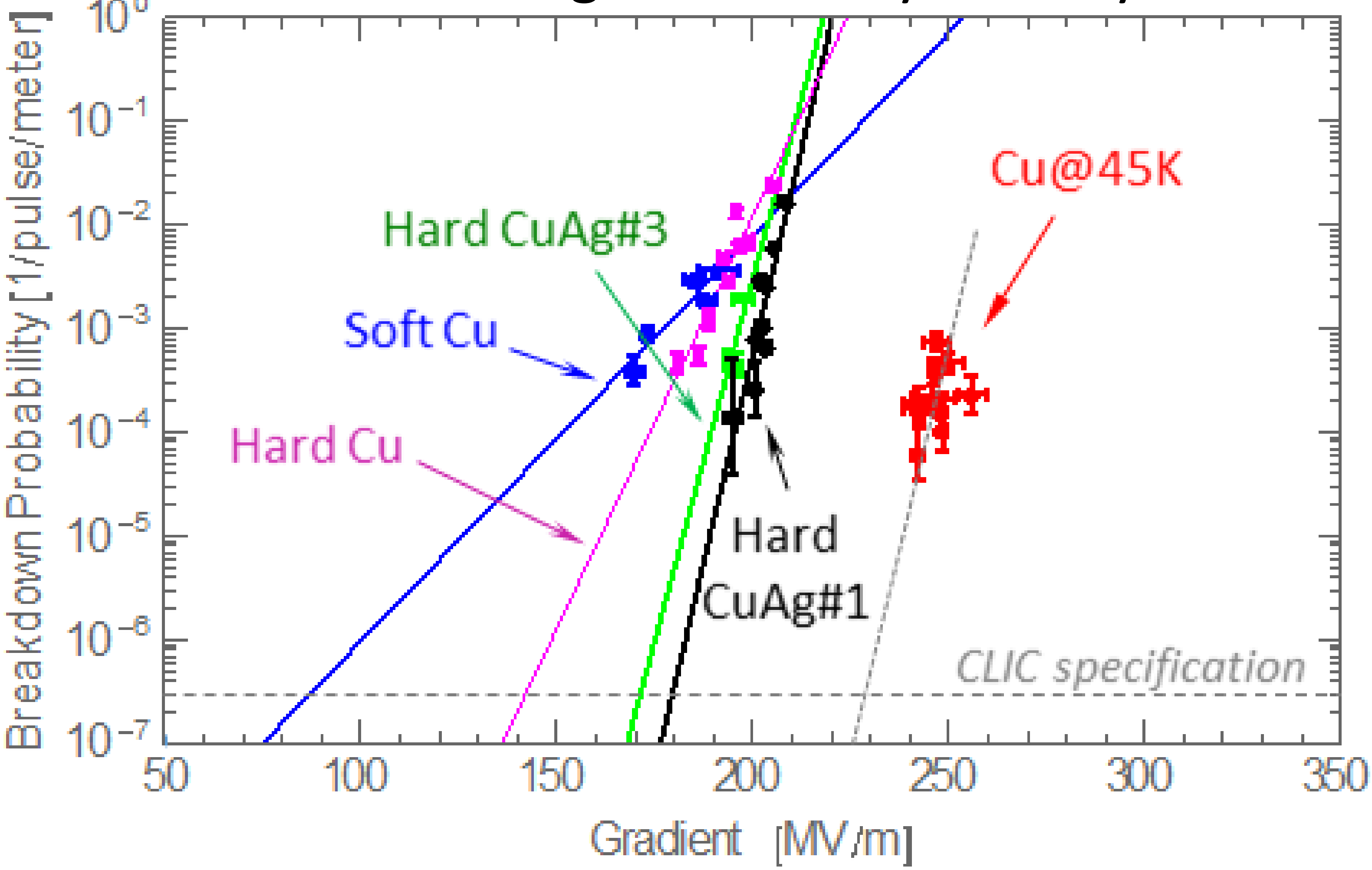
Surface magnetic field
H_{max} = 526 kA/m



Surface Poynting vector
$P_{max} = 5.7 \times 10^{13}$ W/m^2

Motivation

Results of single-cell cavity tests by SLAC



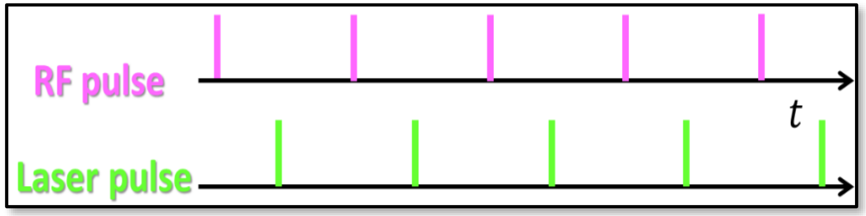
BDR determined by

✓Material hardness?

✓Thermal stress?

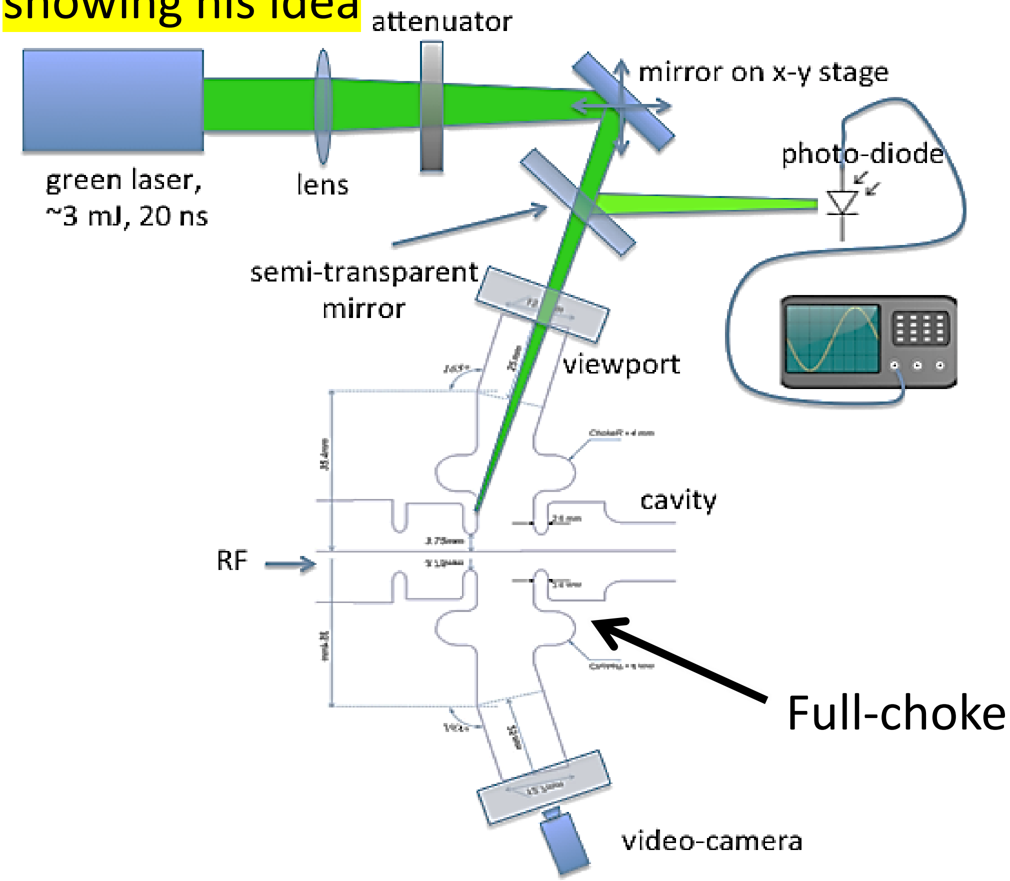
High-Power Pulsed Laser

To make local thermal stress



- ✓ *RF and laser pulses are independent thermally.*
- ✓ *Additional metal fatigue accumulate ➔ BDR increase ?*

Sketch of Valery Dolgashev (SLAC) showing his idea



Independent vacuum chamber containing a copper coupon for irradiation tests (Y. Higashi made)

Beam splitter

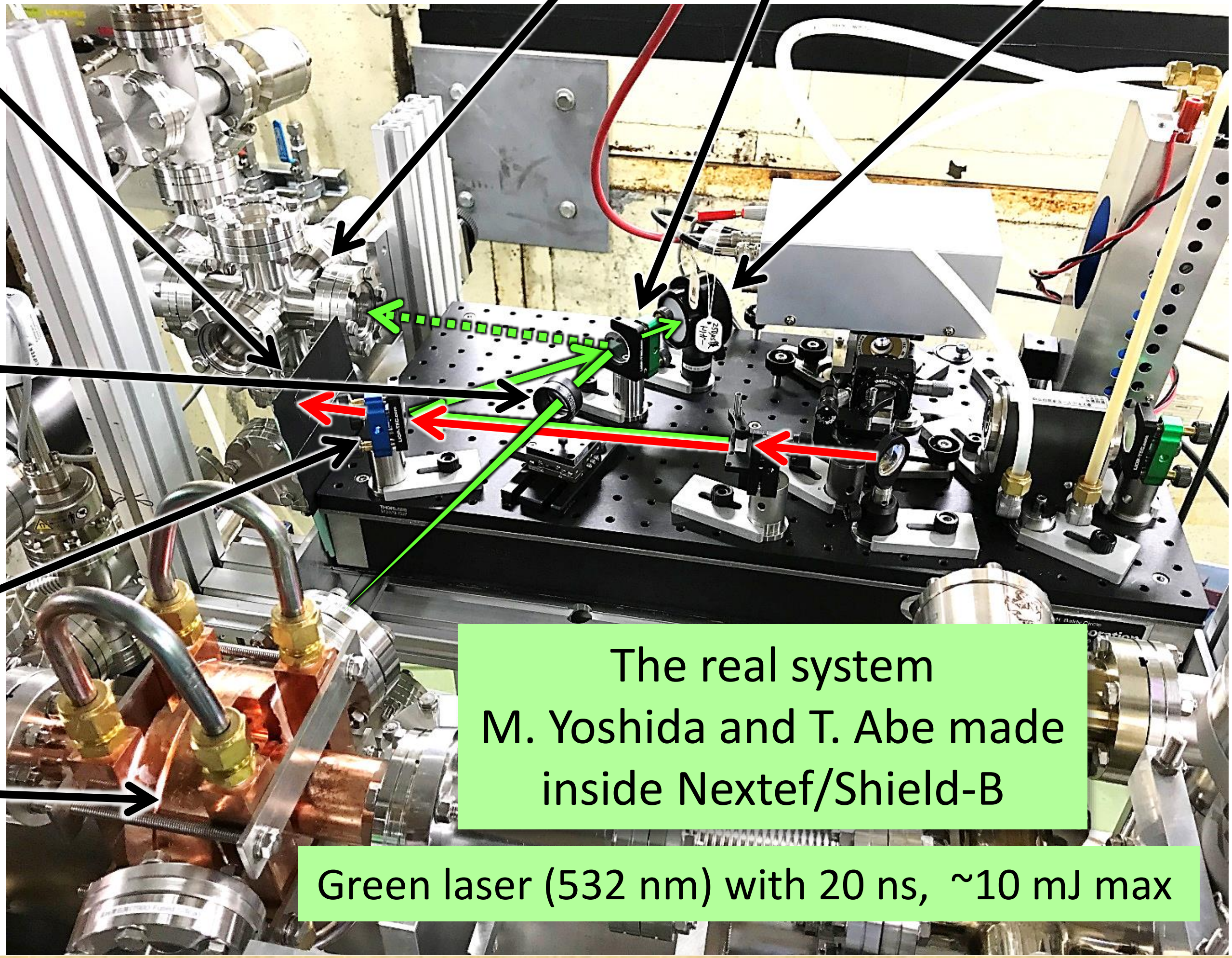
Laser power sensor

Dump

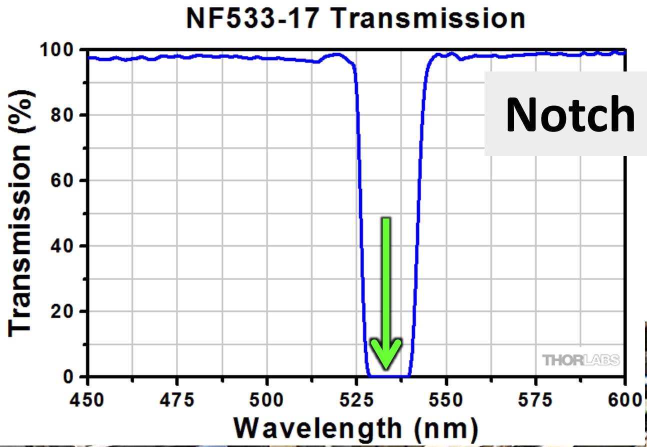
Focus lens

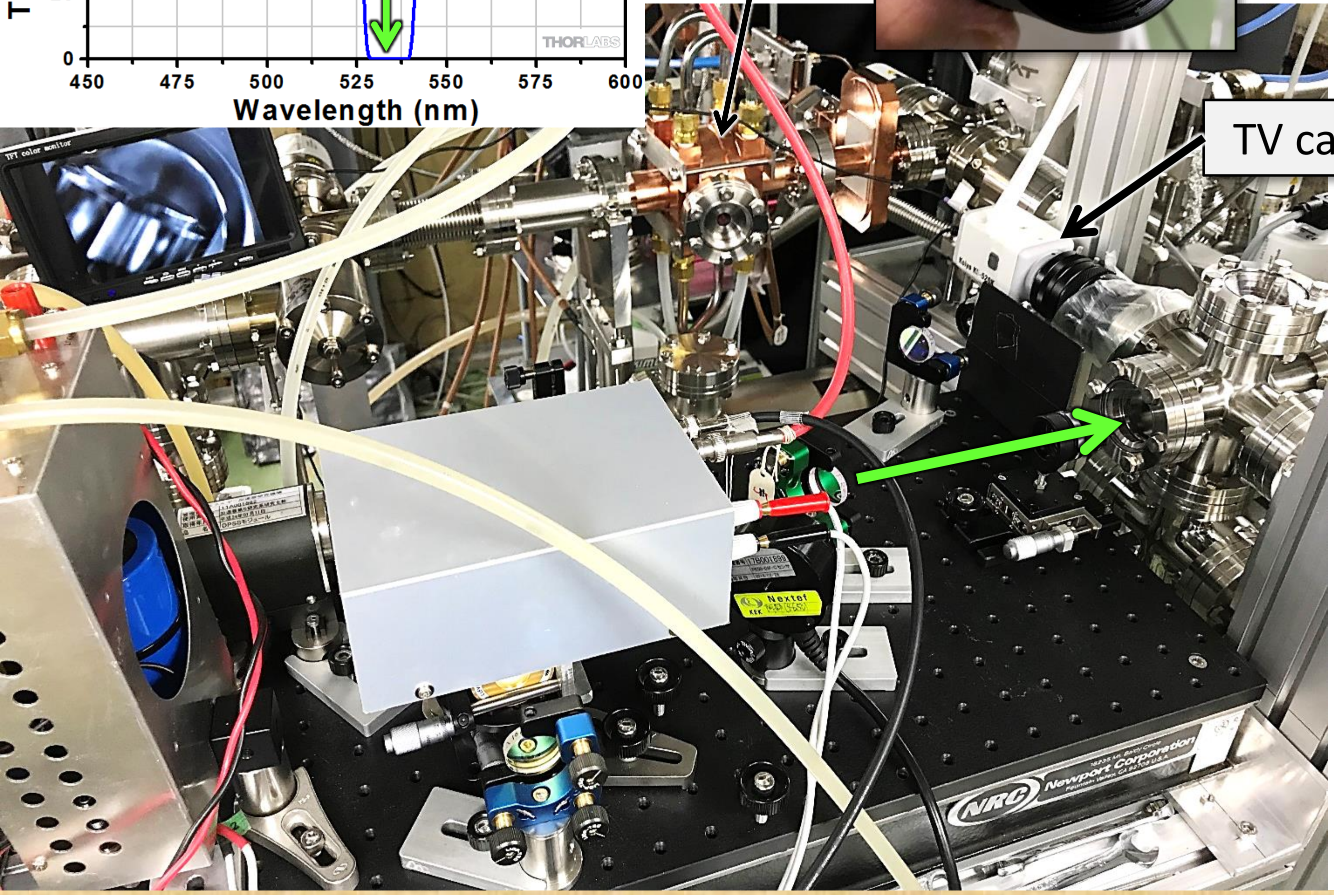
Longpass mirror

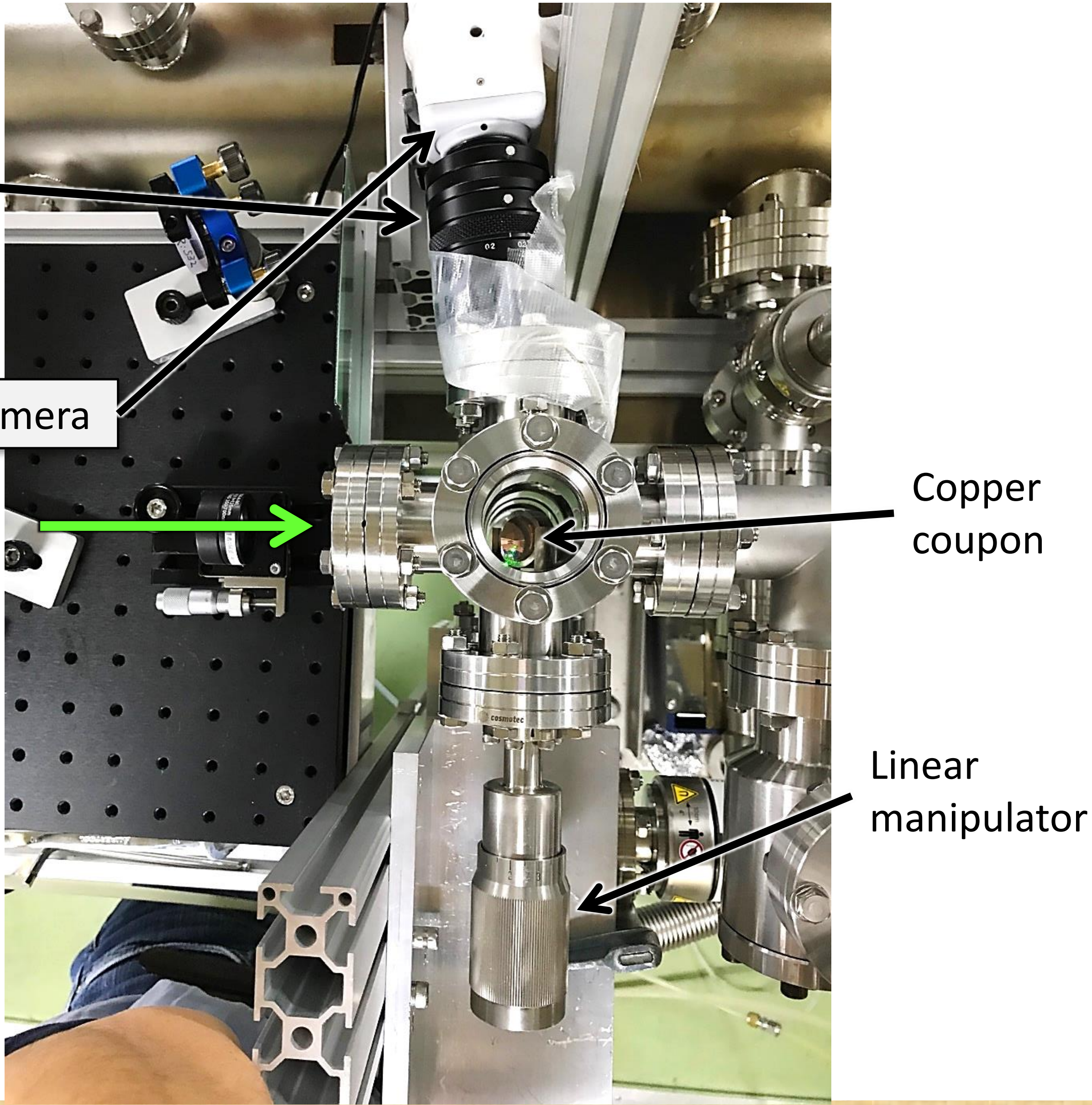
Full-choke cavity



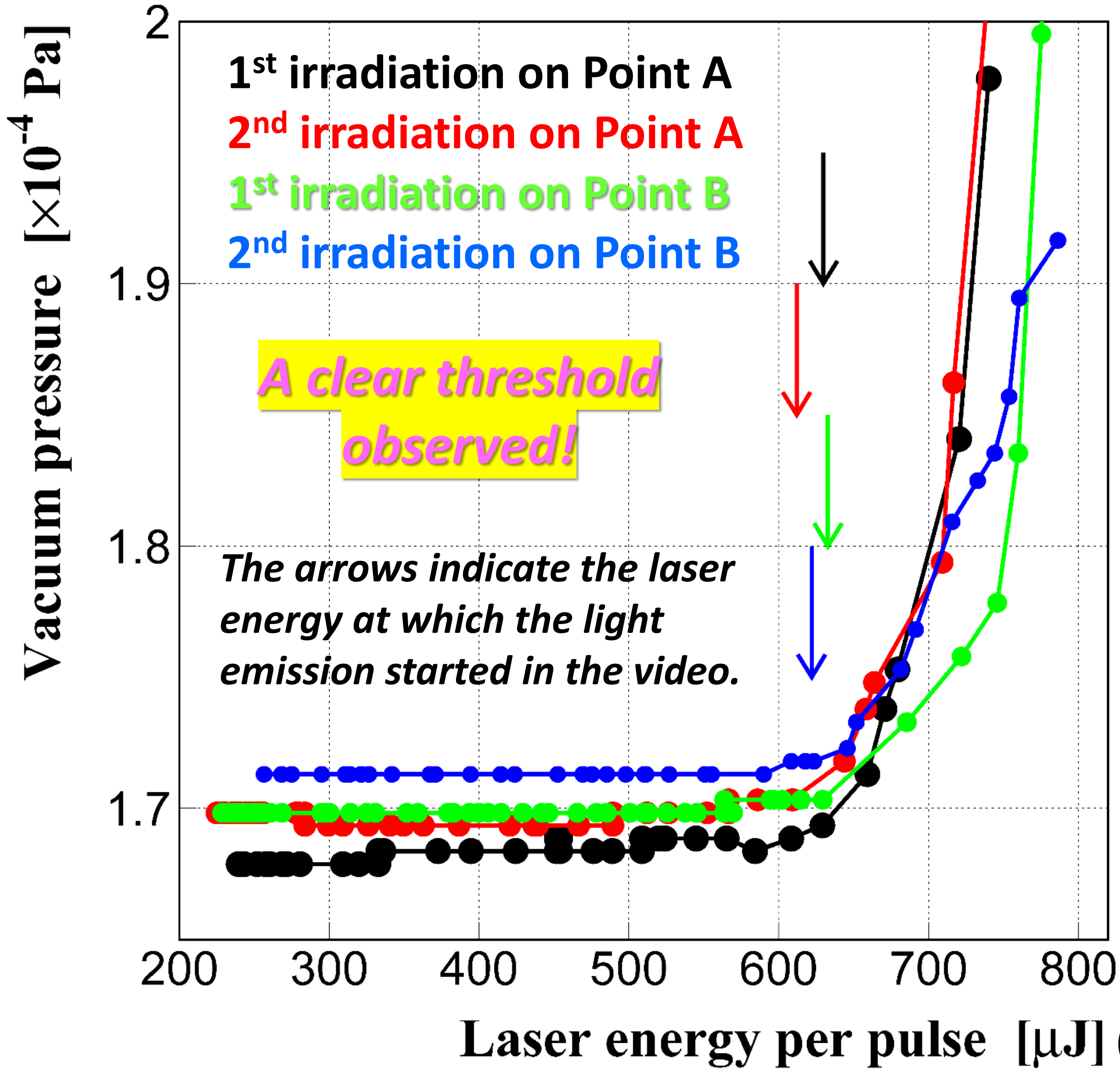
Laser Power-Density Calibration based on Ablation Threshold





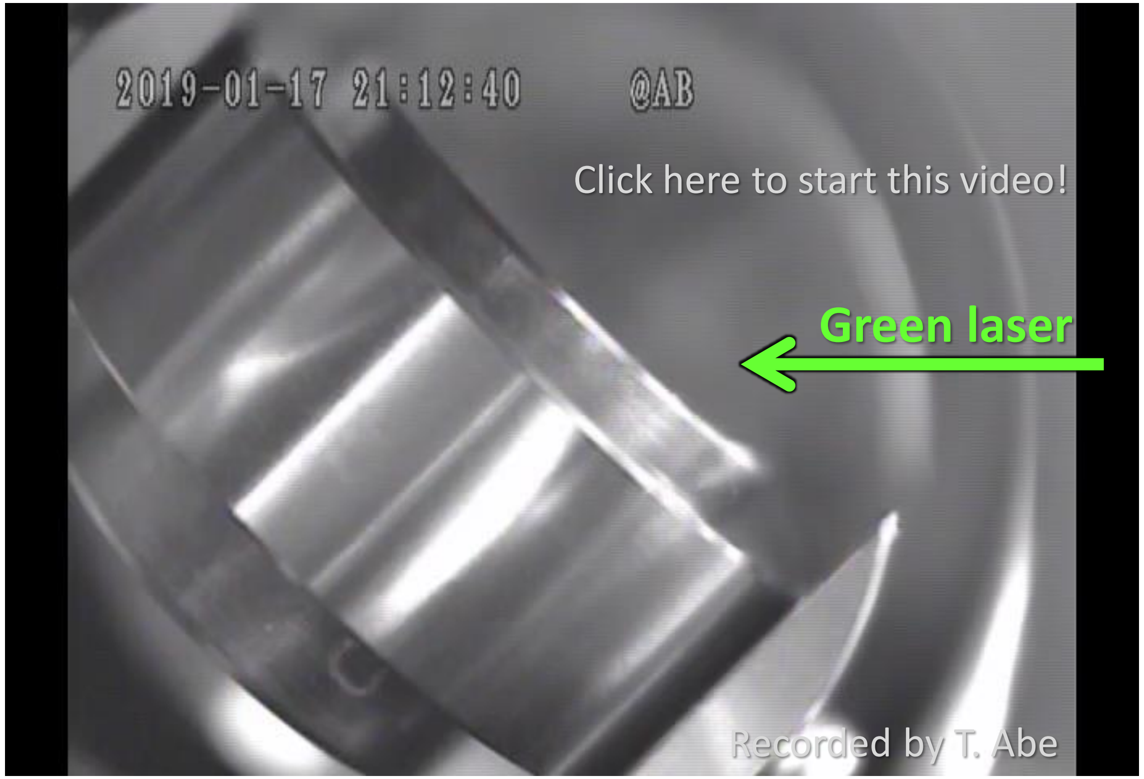


Laser Power-Density Calibration based on Ablation Threshold



(with prelim. calib.)

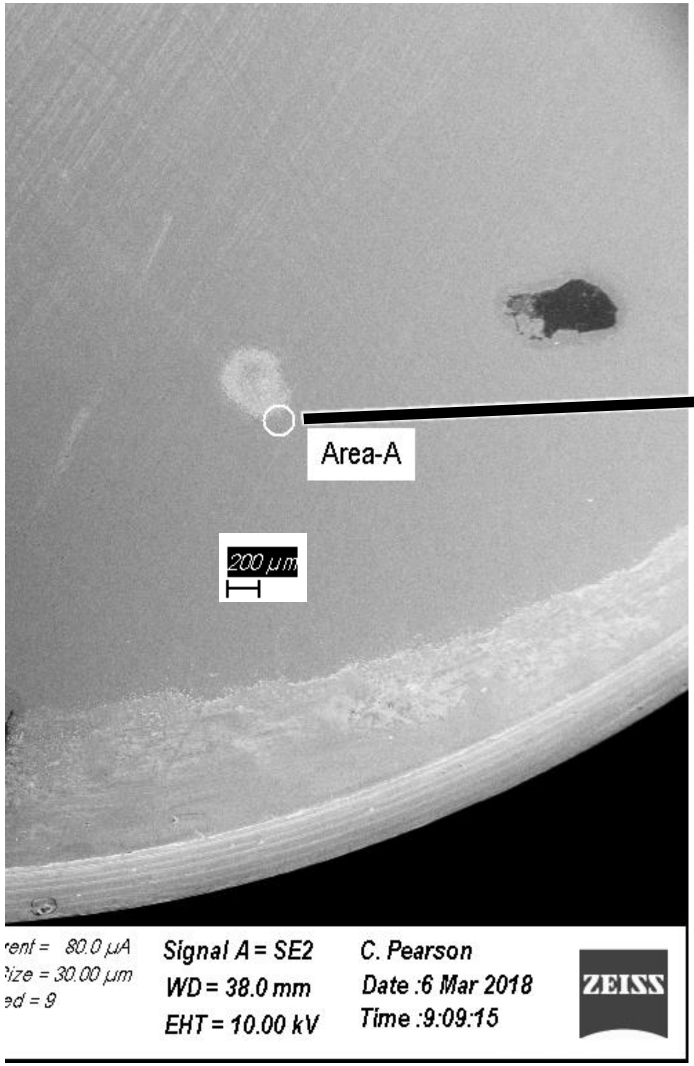
1st irradiation on Point A

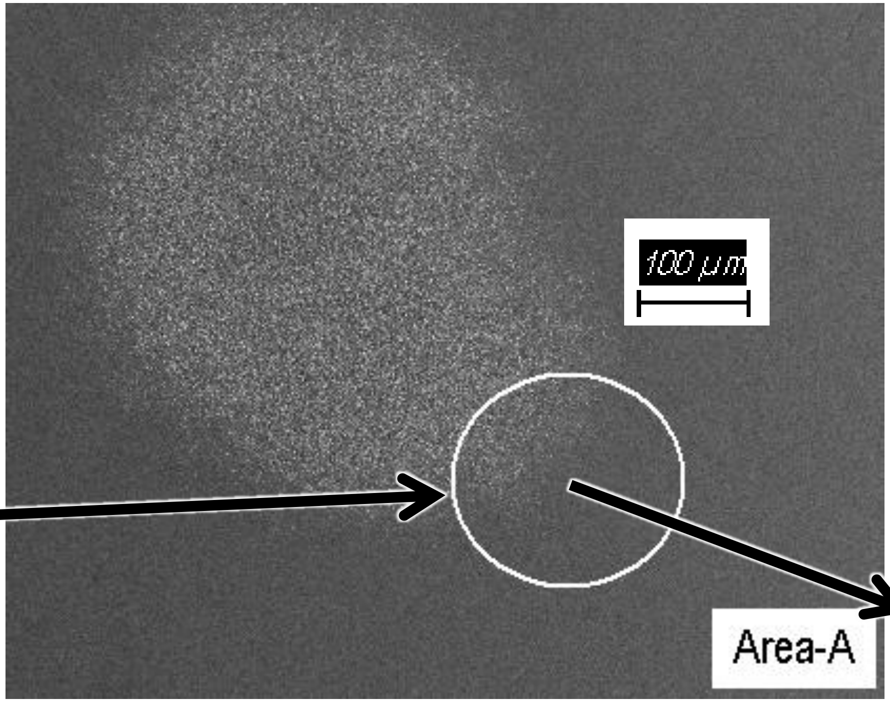


Valery Dolgashev predicted that there should be a clear threshold in the vacuum-pressure response, which corresponds to the ablation threshold.

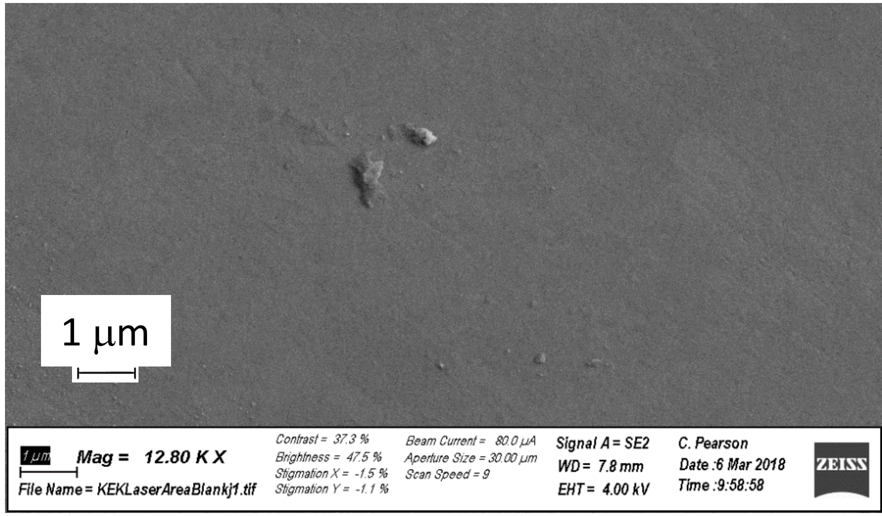
THE SPECTRUM OF THE EMITTED LIGHT WILL BE MEASURED BY USING A HYPERSPECTRAL CAMERA

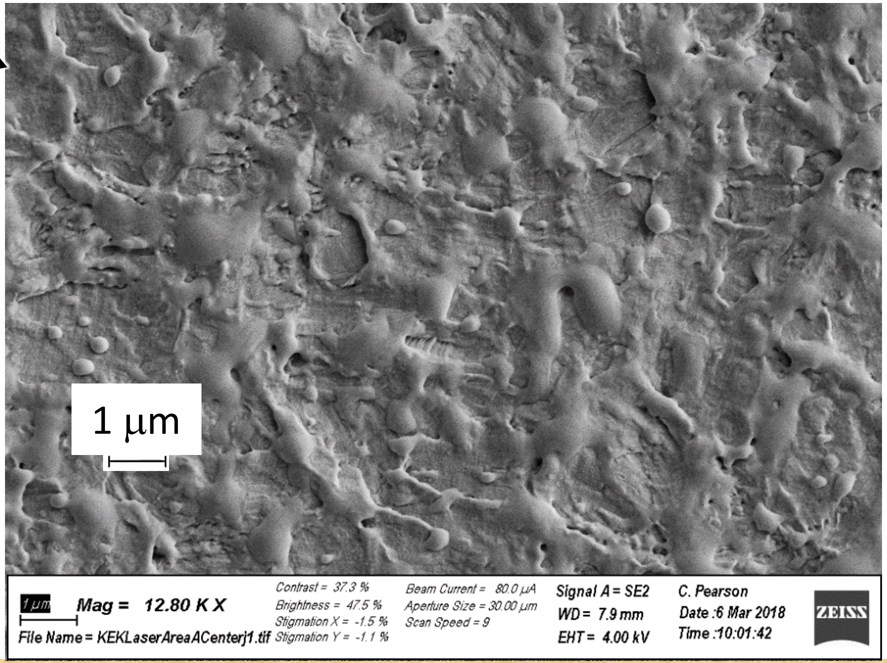
SEM images show pulse heating damage from the green laser.





Normal surface





SEM images by Chris Pearson (SLAC)

SUMMARY

- TD24_QUAD status

(EBW: Electron-Beam Welding)

  - The fabrication had been successful until the EBW.
  - Two of the four quadrants turned out not to be pure copper after the first high-temperature process of brazing.
    - Most probably CuZr
  - We have decided to started over; need additional several months.
  - High-gradient test to be started before summer 2019

- Full-choke single-cell cavity test with laser
  - Everything just ready for high-gradient test, including the high-power pulsed laser system
  - Compare BDRs with or without the laser irradiation for various irradiation positions

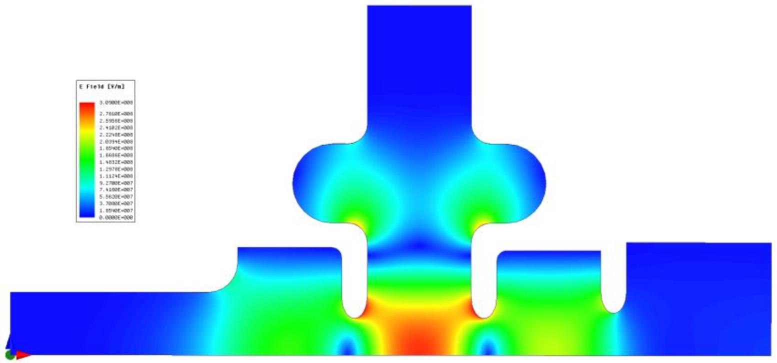
- Other single-cell test cavities
  - Two TD24-based damped cavities (with the disks brazed or diffusion-bonded) waiting to be tested
  - Undamped cavities made of large-grain copper

THANK YOU FOR YOUR ATTENTION!

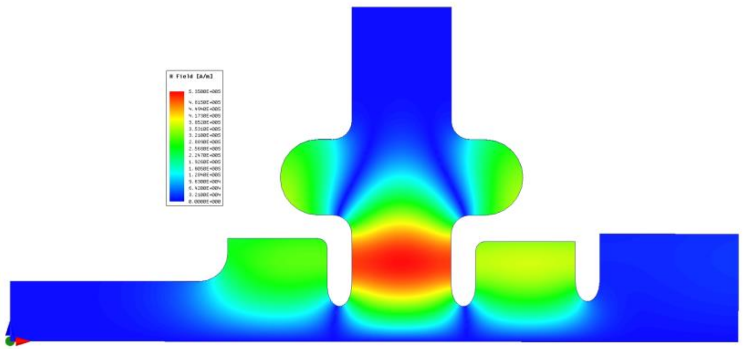
Backup Slides

Fields in Full-Choke cavity, *normalized to 10 MW of input power*

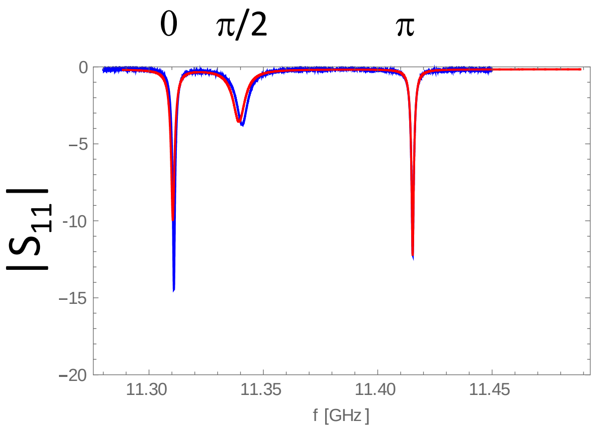
V. Dolgashev



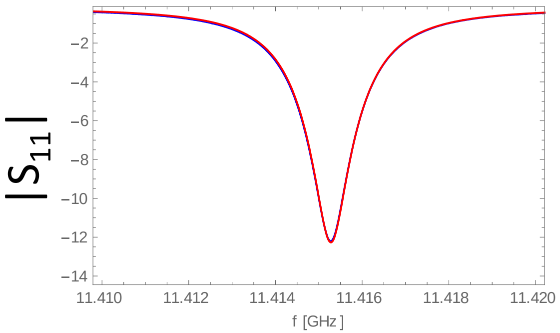
Surface electric field, E_{max} = 309 MV/m

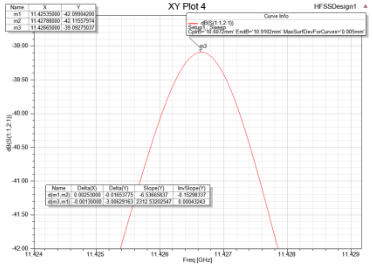


Surface electric field, H_{max} = 510 MV/m



π mode





Measured (Blue) and calculated S11 (Red), 0.15 dB losses added to calculated S11., S11_HFSS= 0.24774

Qloaded = 4516.46
beta= 1.659, **Qo = 12009**

Parameters of periodic structures

V. Dolgashev

Name	A2.75-T2.0-Cu	A3.75-T1.66-Cu	A3.75-T2.6-Cu	A3.75-T2.6 FullChoke-Cu	A5.65-T4.6-Choke-Cu	A5.65-T4.6-Cu	*T53VG3*
Stored Energy [J]	0.153	0.189	0.189	**0.471**	0.333	0.298	*0.09*
Q-value	8.59E+03	8.82E+03	8.56E+03	**13.5E+3**	7.53E+03	8.38E+03	*6.77E+03*
Shunt Impedance [MOhm/m]	102.891	85.189	82.598	**52.4**	41.34	**51.359**	*91.772*
Max. Mag. Field [A/m]	2.90E+05	3.14E+05	**3.25E+05**	**3.22E+5**	4.20E+05	4.18E+05	*2.75E+05*
Max. Electric Field [MV/m]	203.1	268.3	202.9	203.3	212	211.4	*217.5*
Losses in a cell [MW]	1.275	1.54	1.588	**2.501**	3.173	**2.554**	*0.953*
a [mm]	2.75	3.75	3.75	3.75	5.65	5.65	*3.885*
a/lambda	0.105	0.143	0.143	0.143	0.215	0.215	*0.148*
Hmax*Z0/Eacc	1.093	1.181	1.224	1.215	1.581	1.575	*1.035*
t [mm]	2	1.664	2.6	2.6	4.6	4.6	*1.66*
Iris ellipticity	1.385	0.998	1.692	1.692	1.478	1.478	*1*
Peak Poynting vector [W/um^2]				21.4			

End of This File