Vertical Electropolishing at Marui & KEK

June 2017

AWLC17

V Chouhan

Marui Galvanizing Co., Ltd

Y Ida, K Nii & T Yamaguchi (Marui Galvanizing Co., Ltd., Japan)

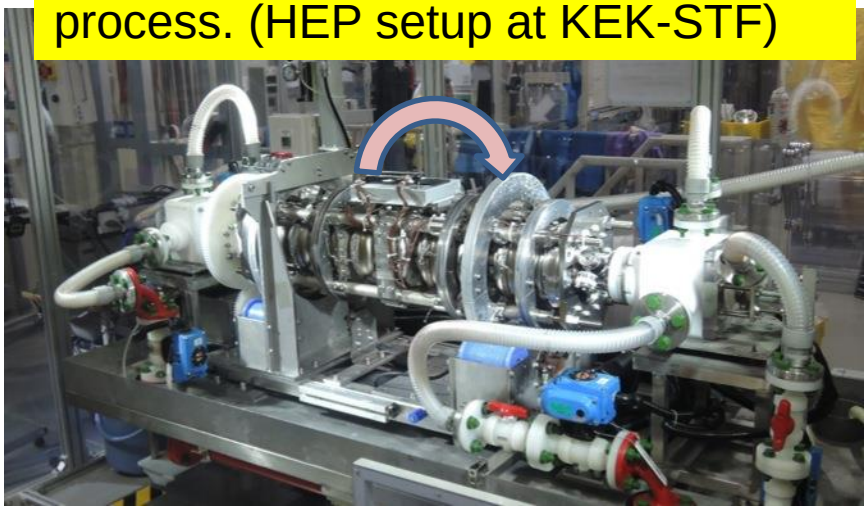
S Kato, H Hayano, T Saeki, M Sawabe & H Monjushiro (KEK, Japan)

Contents

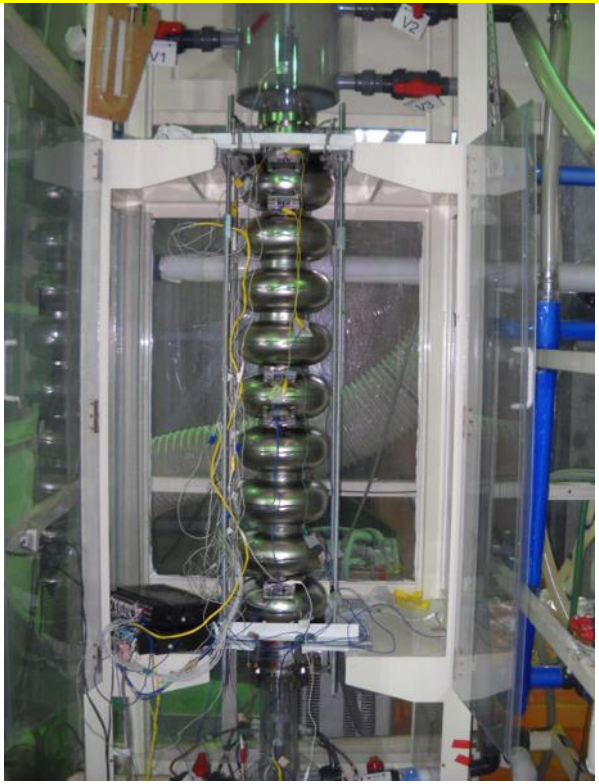
- VEP setups
- Coupon cavity & Ninja cathode
- VEP results with different Ninja cathodes
- Vertical test results
- Fabrication of 9-cell coupon cavity
- Future work
- Summary

Electropolishing at KEK & Marui

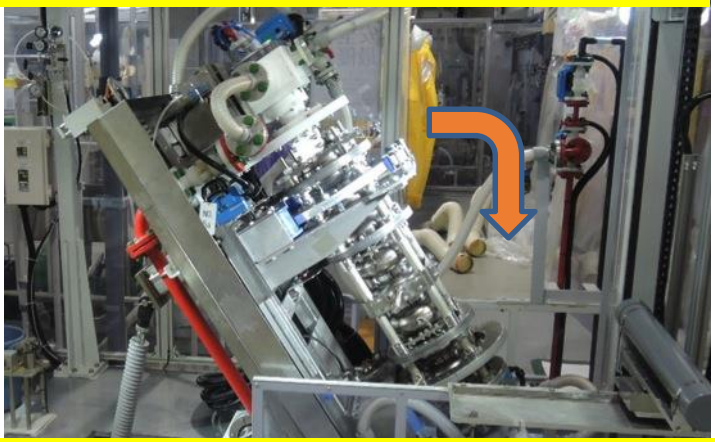
Rotation of cavity in Horizontal EP process. (HEP setup at KEK-STF)



Fixed vertical posture (Setup at Marui)



Turning the EP-bed for draining

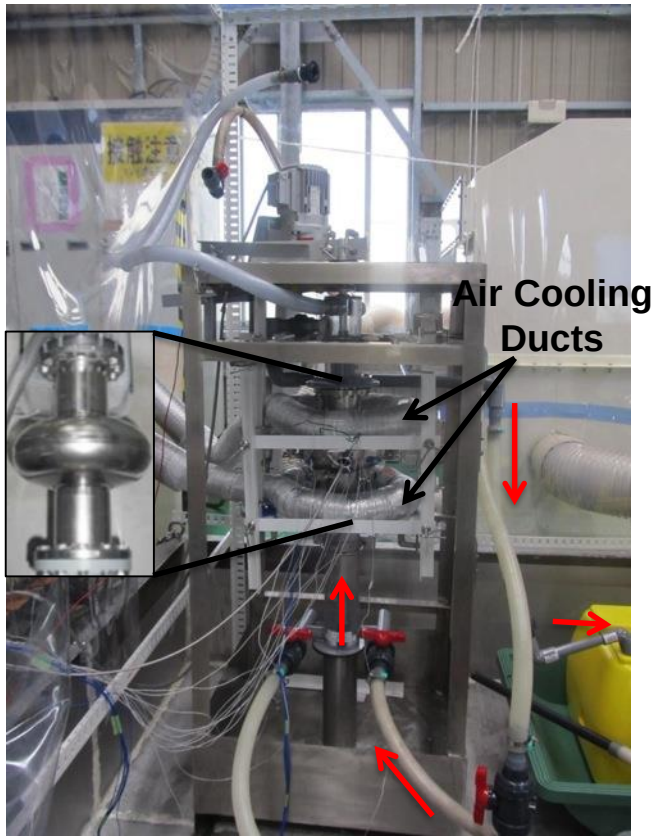


Massive and complicated system

- ILC: 16000 cavities will be required.
- VEP may be a cost effective technique.
- Marui has been working with KEK to develop VEP setup and optimize VEP parameters.

VEP Setups at Marui

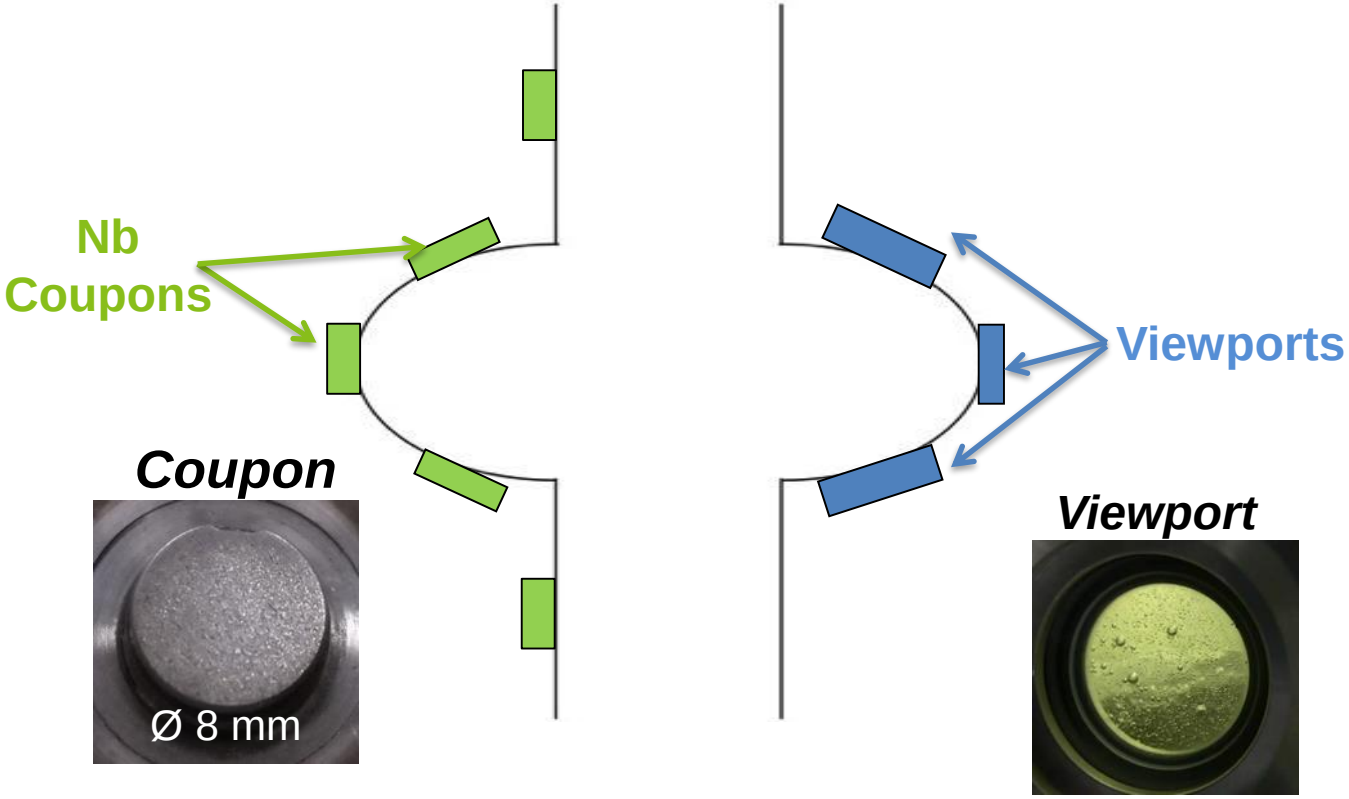
For 1-cell Cavity



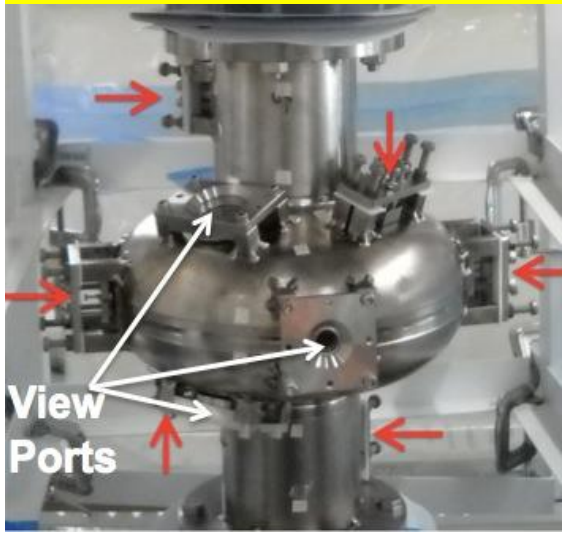
For 9-cell/1-cell Cavity

✧ Both setups were prepared with PVC materials in order to reduce the cost of surface treatment of cavities in mass production.

Single Cell Coupon Cavity

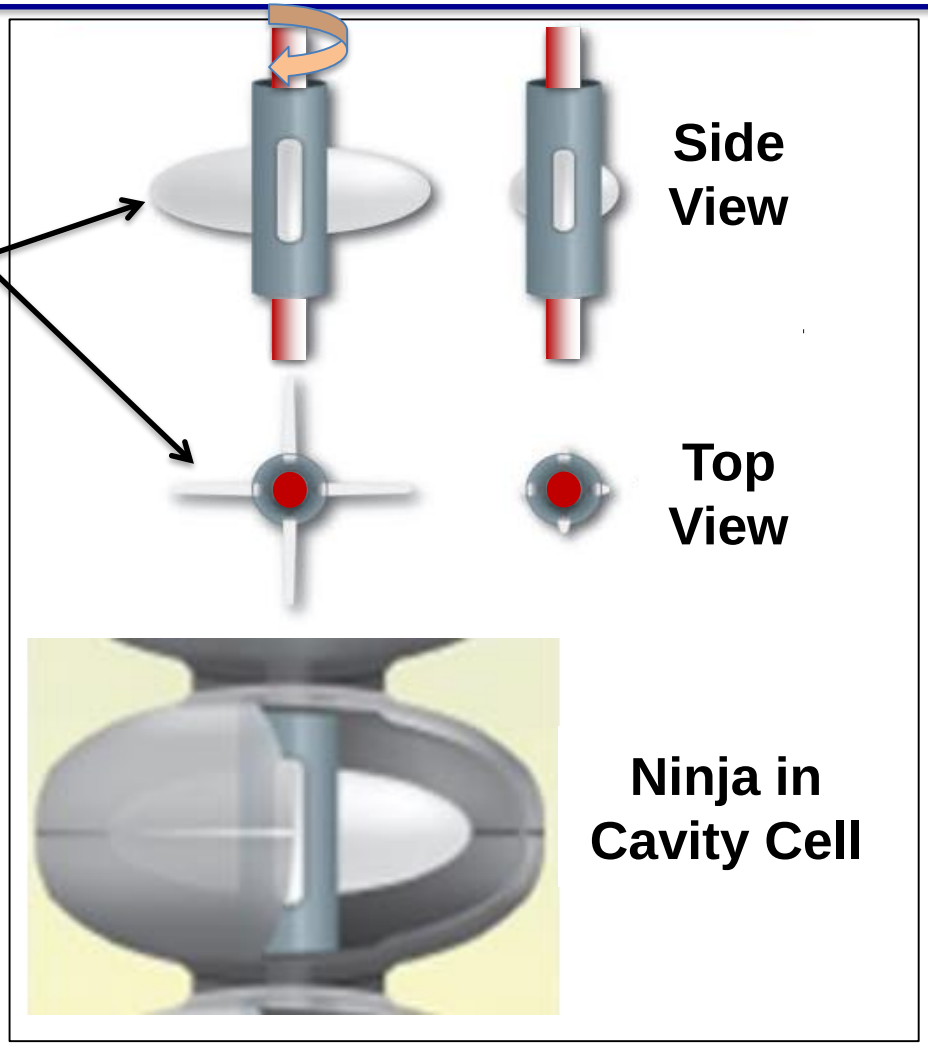


1–Cell Coupon Cavity for Parameter Study



- The cavity contains 6 coupons at the beam pipes, irises, and equator.
- An EP current can be measured for individual coupons.
- Coupon surfaces are analyzed with several surface analytical tools.
- The cavity is having 4 view ports on the top iris, bottom iris, and equator for light introduction and in-situ observation.

Ninja Cathode



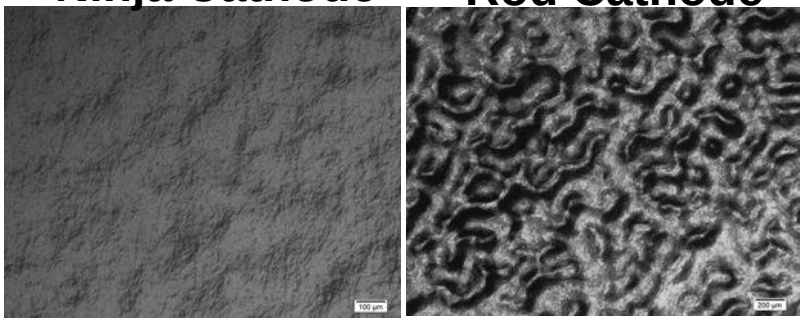
- Ninja cathode was developed for the acid agitation.
- The wings are either insulating or metallic/partially metallic which act as a cathode.

EP with Rod and Ninja Cathode (Al Wings)

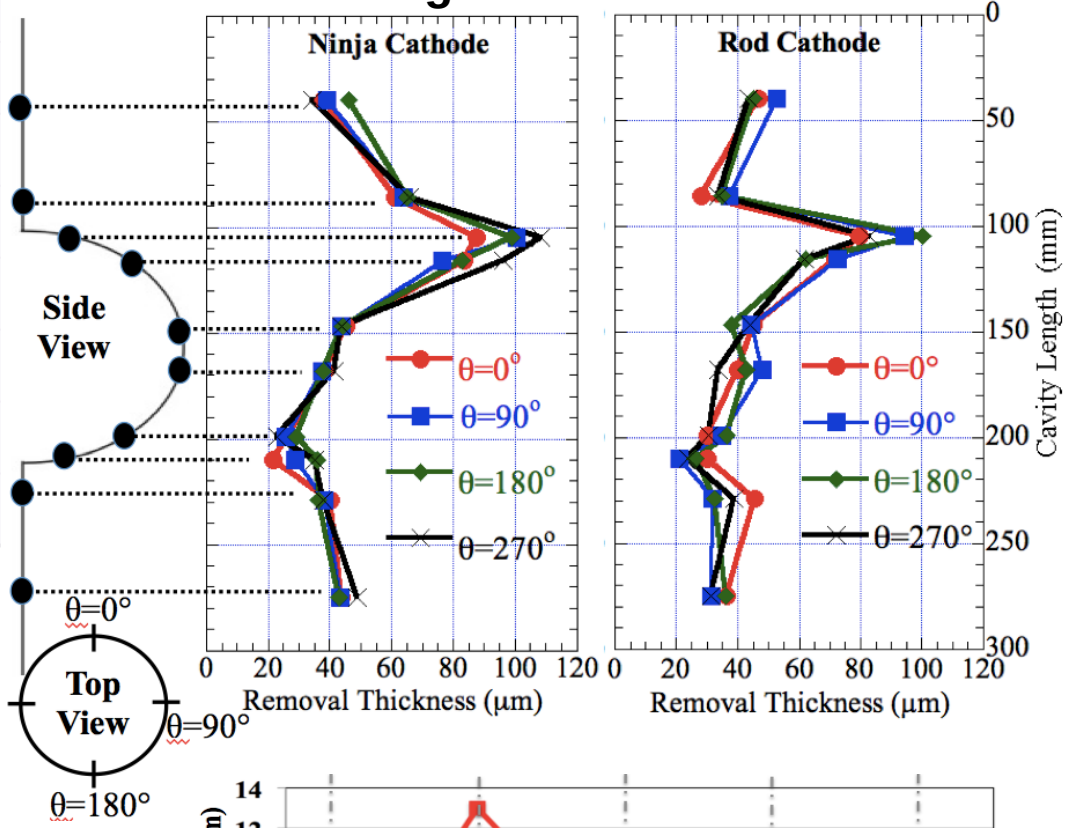
Parameter	Value
H_2SO_4:HF	9:1
Electrolyte Flow Direction	Bottom to Top
Flow Rate	5 L/min
Cathode Rotation Speed	1 rpm
Applied Voltage	~9 V
EP Current Density	25-30 mA/cm^2
Target Removal Thickness	50 µm
Cavity Surface Temperature	~25 °C

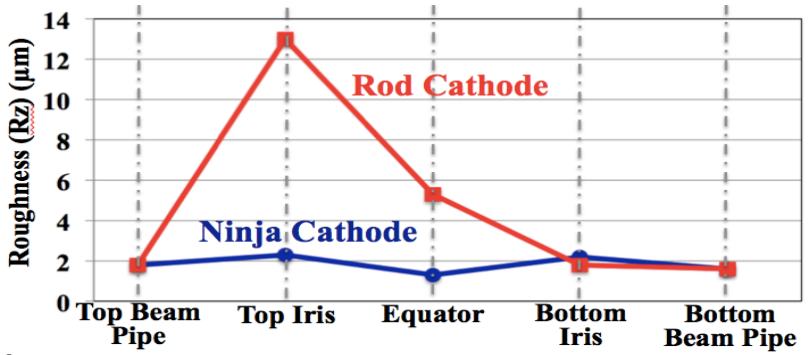
Upper Iris Coupon

Ninja Cathode **Rod Cathode**



Ninja Cathode- Al Wings **Rod Cathode**

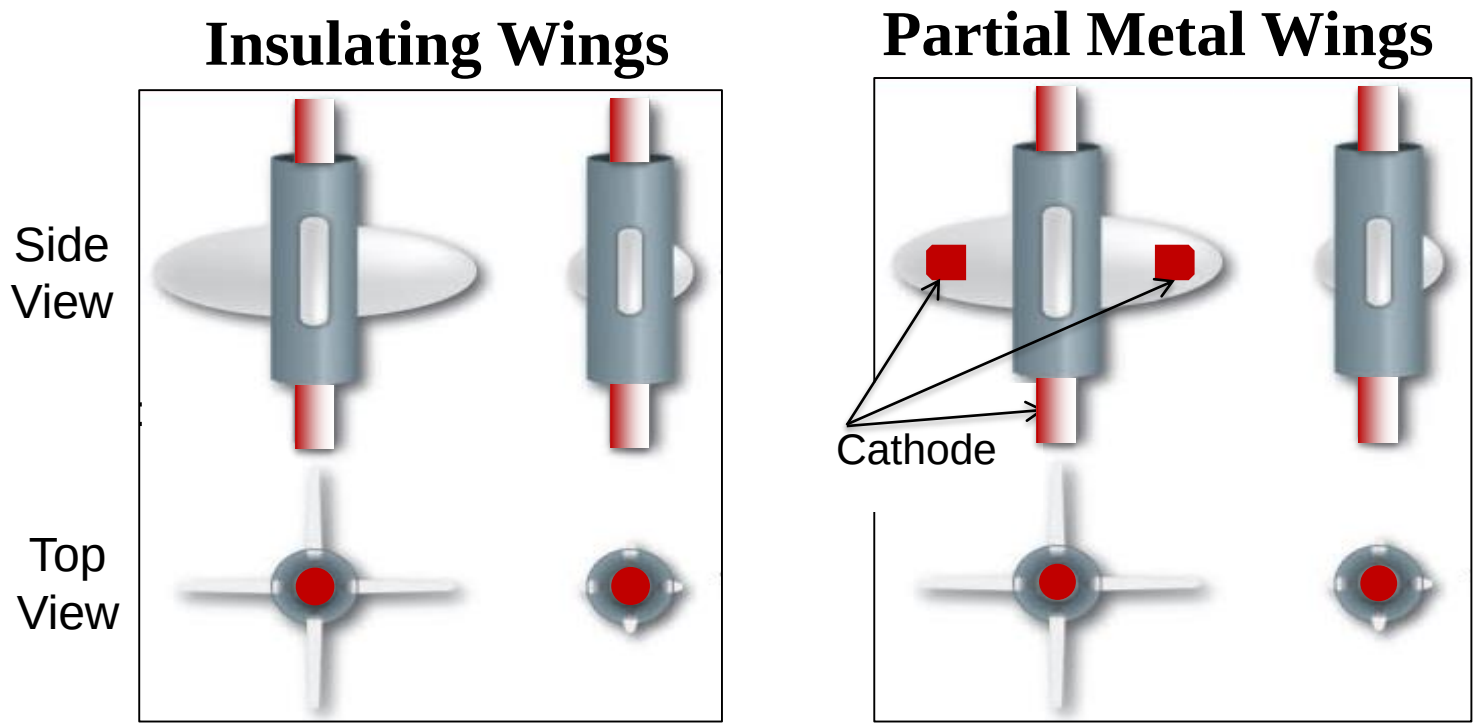




- Ninja Cathode (Al wings) results in:
  - Smooth surface
  - Asymmetric removal similar as rod cathode

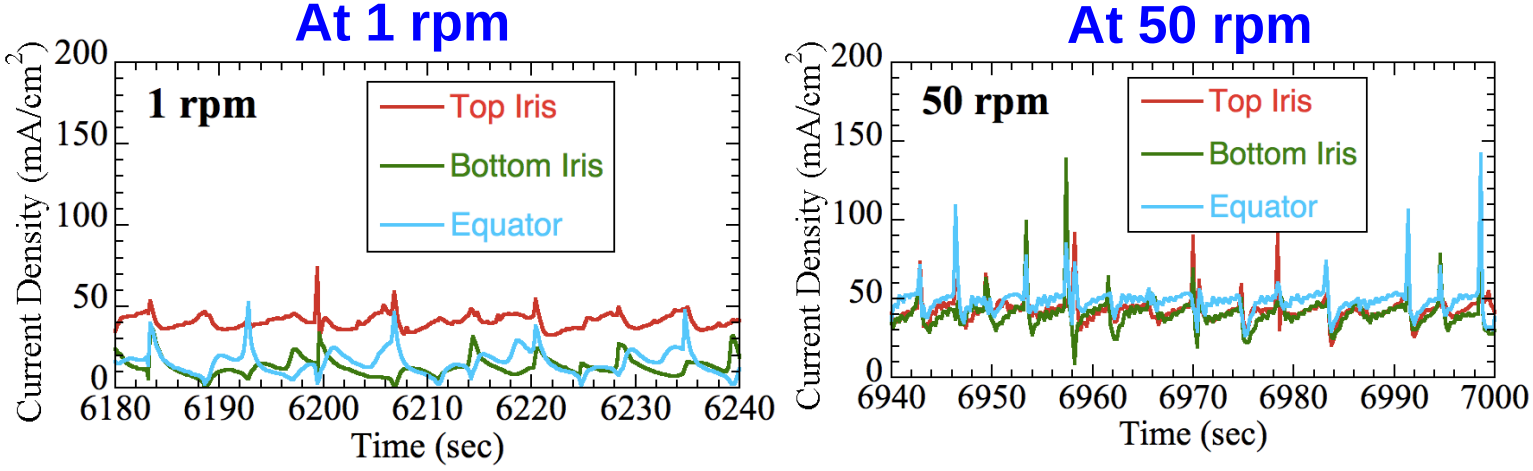
Improvement in Ninja Cathode

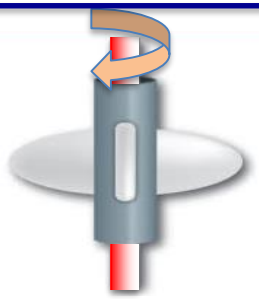
- Al wings were replaced with insulating and partial metallic wings to reduce direct impact of H_2 gas bubbles on the top iris surface.

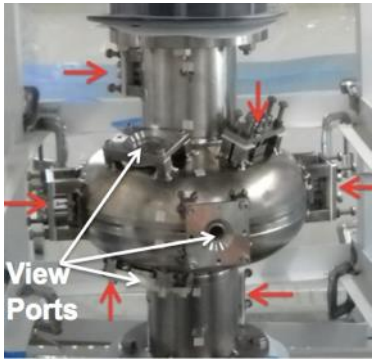


Effect of Stirring in VEP

Coupon currents: Ninja cathode with insulating wings



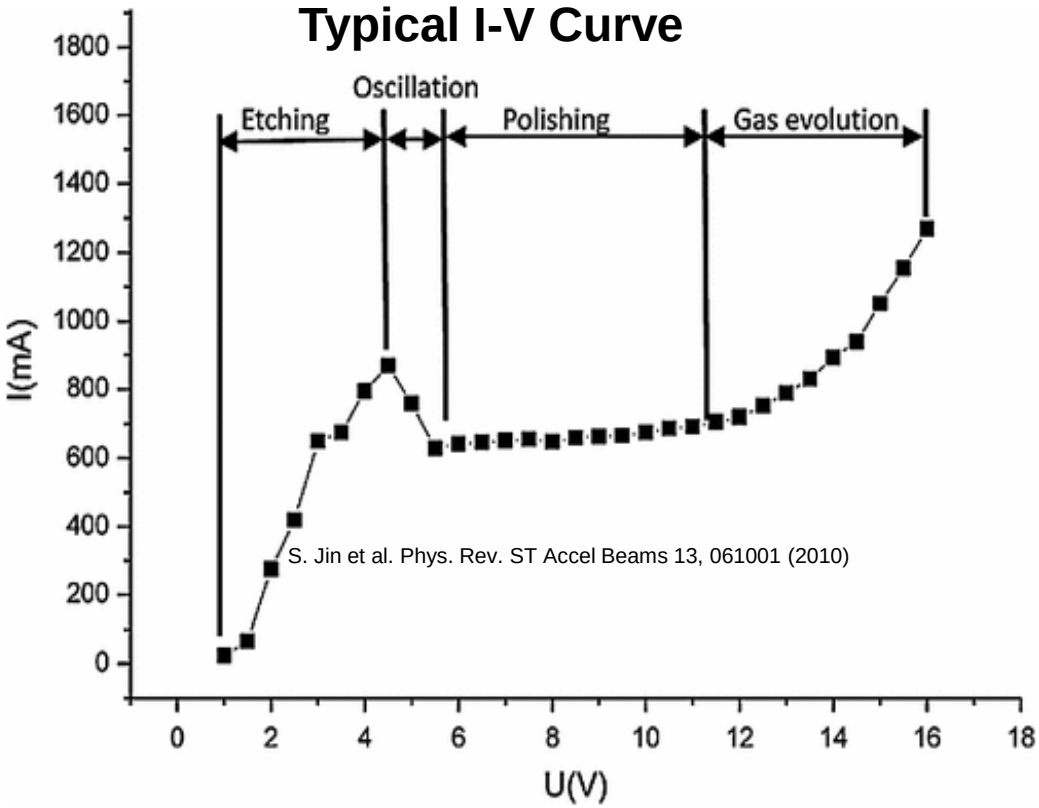




- Similar coupon currents in the cavity cell were obtained at 50 rpm.
- 1 rpm: Accumulation of H_2 bubbles on the top iris surface, non-uniform acid flow at Nb surface
- 50 rpm: Wings displaced the accumulated bubbles, acid flow might be uniform in the cell

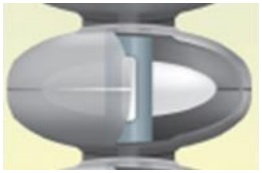
Coupon

Typical I-V Characteristic

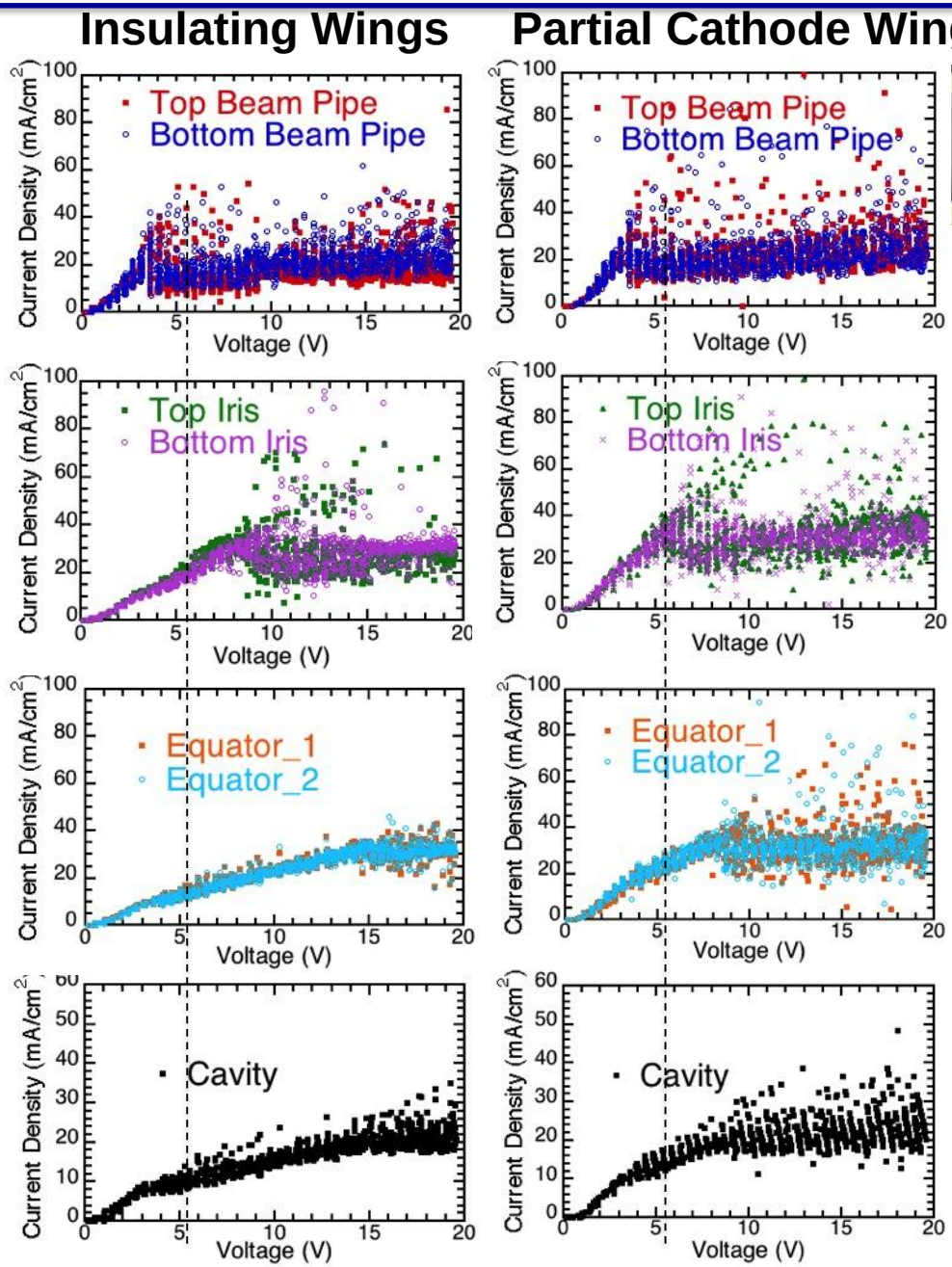


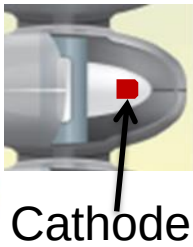
- An I-V curve gives information about phenomenon occurs at Nb surface in different voltage ranges.
- A voltage lying in the polishing region needs to be applied for EP.

Effect of Partial Cathode Wings



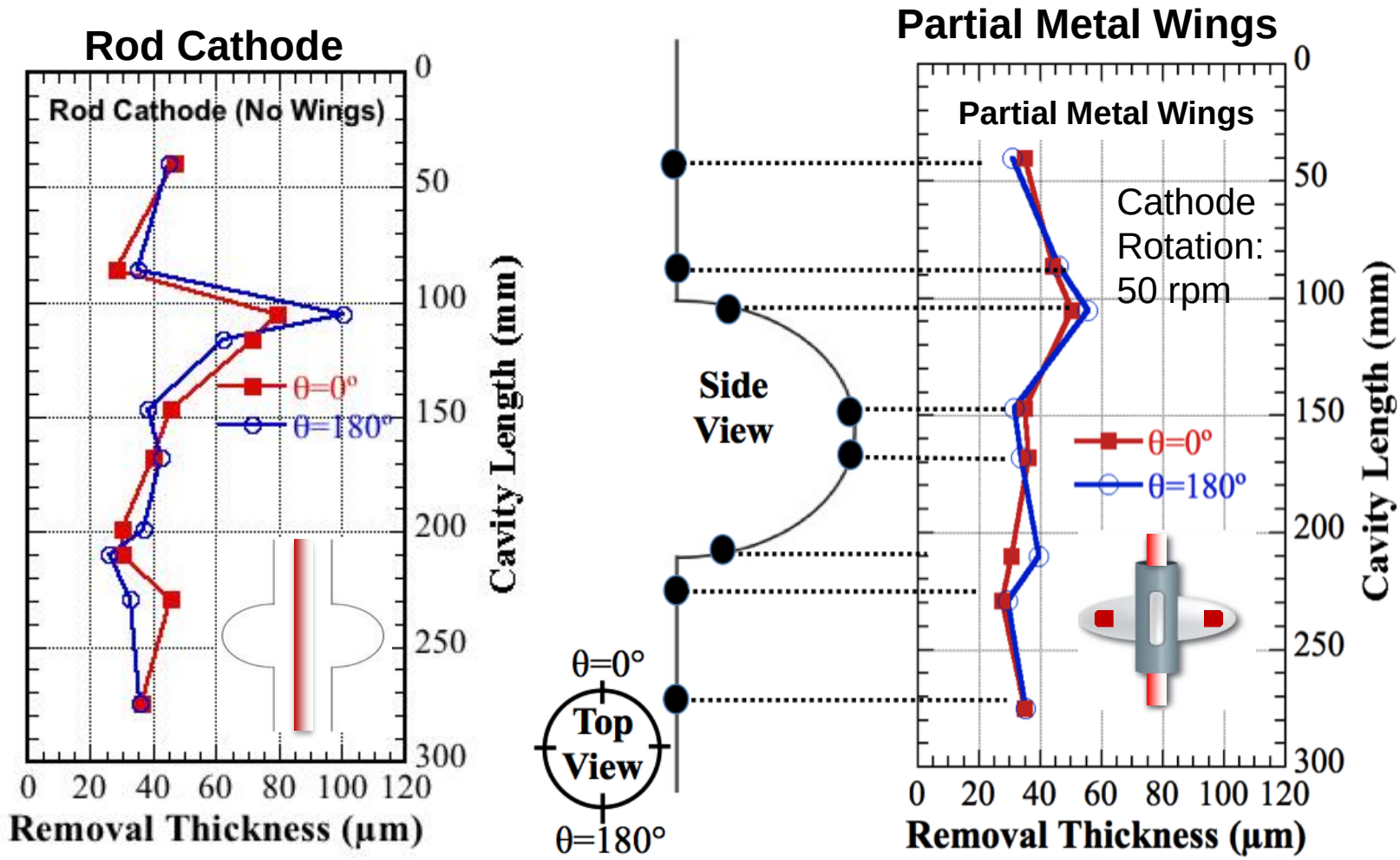
- I-V curves obtained at 50 rpm.
- Cathode screening by H_2 bubbles and a larger anode-cathode distance reduced ion transportation and electric field at the equator.
- **Wing cathode enhanced ion transportation and electric field on equator surface.**





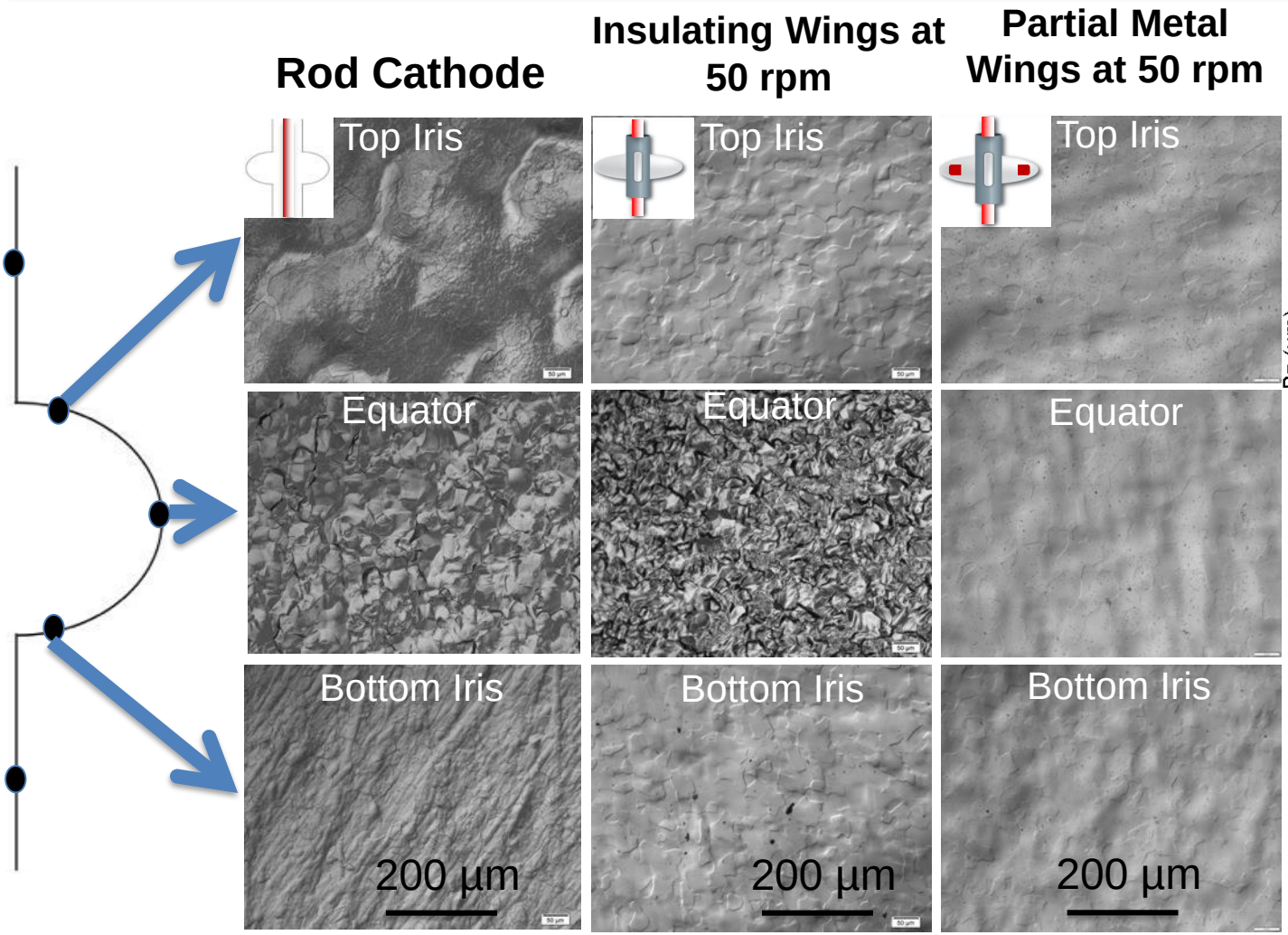
Removal Thickness W/O and W/ Wings

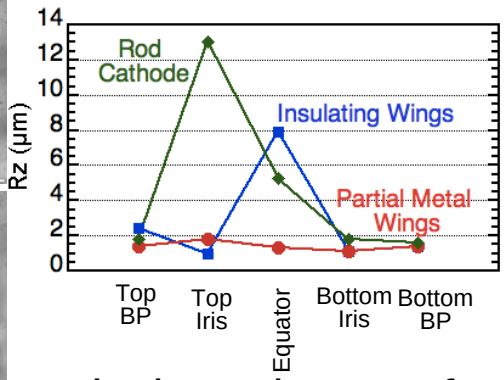
✧ Removal thickness was measured with ultrasonic thickness gauge.



✧ Ninja wings are effective as a stirrer to minimize longitudinal asymmetry in Nb removal.

Surfaces of Coupons



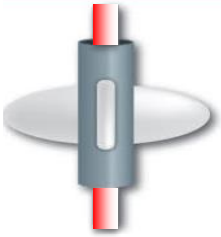


Typical roughness of coupons before VEPs: Rz ~4 µm

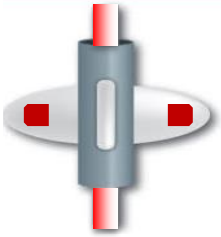
- The rough equator surface with the rod cathode and insulating wings might be due to Nb removal in the etching region.
- The Ninja cathode with partial metal wings resulted in a smooth surface of the equator.

What We Learned

- Ninja cathode with Insulating Wings:
  - Cannot be used since it resulted in rough equator surface.

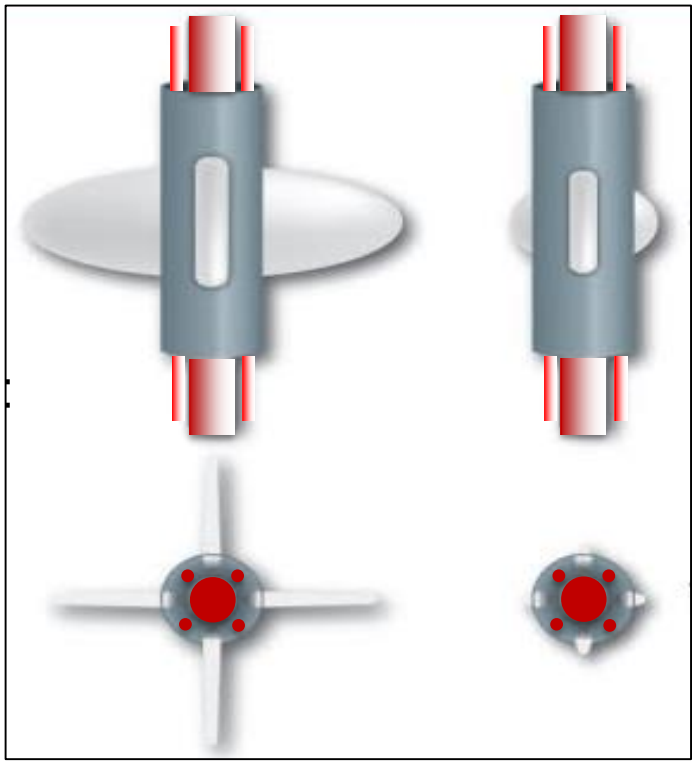


- Ninja cathode with Partial Metal Wings:
  - May not be appropriate for VEP of a 9-cell cavity because bubbles generating on the wings will finally accumulate in the upper cells of the cavity.



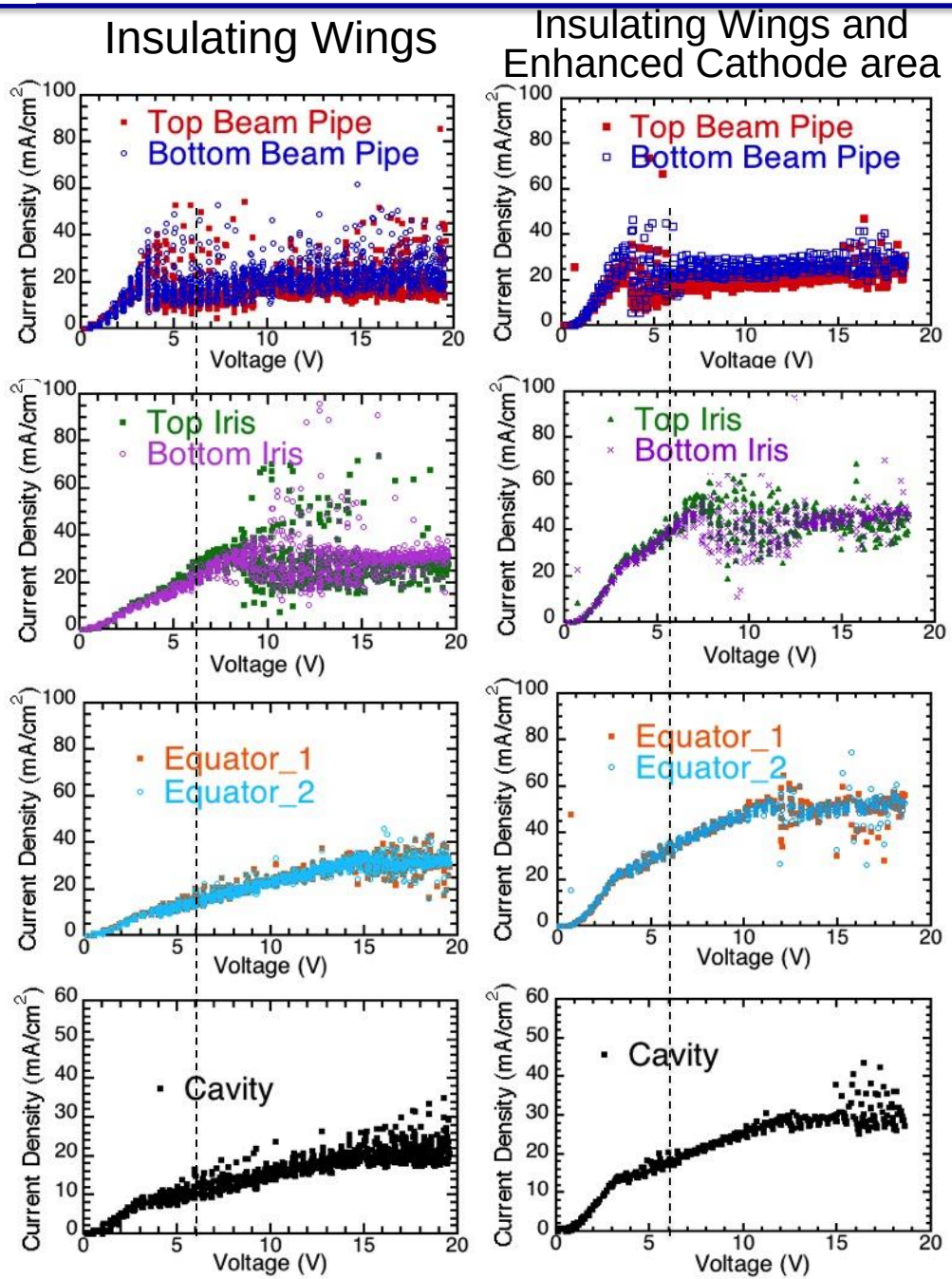
The problem of cathode screening by H_2 bubbles should be solved.

Ninja with Enhanced Cathode Area



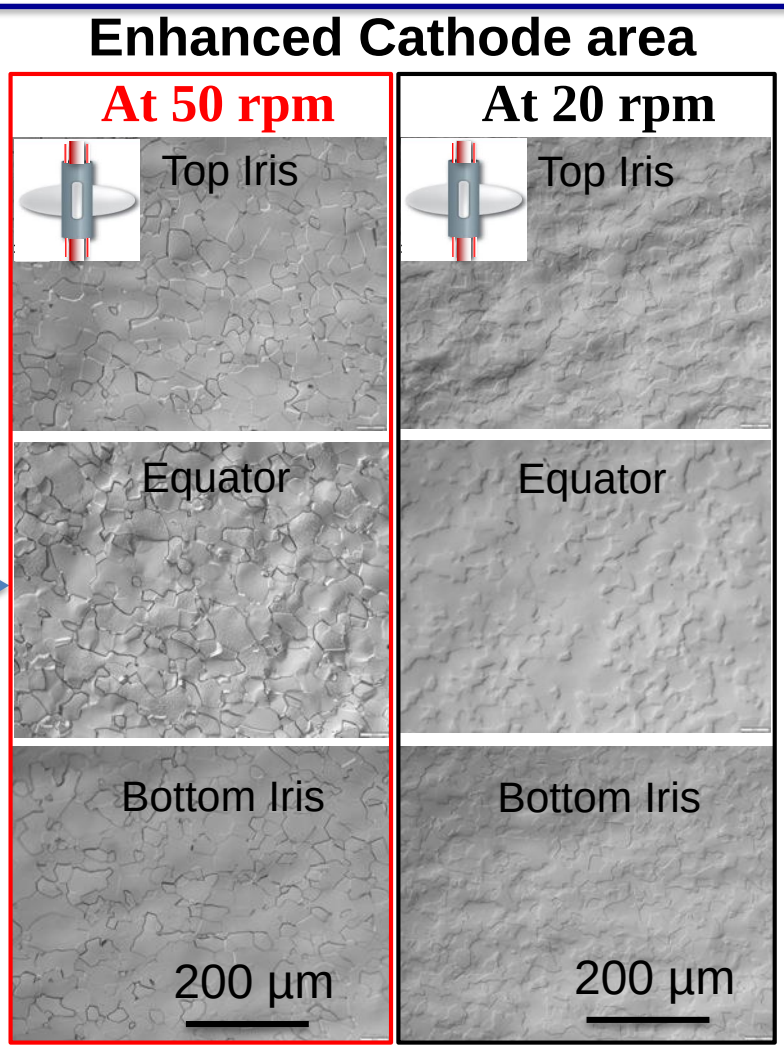
- Cathode surface area was enhanced to reduce the screening effect.
- The cathode was covered well with a meshed sheet to trap H_2 bubbles and guide them along the cathode.

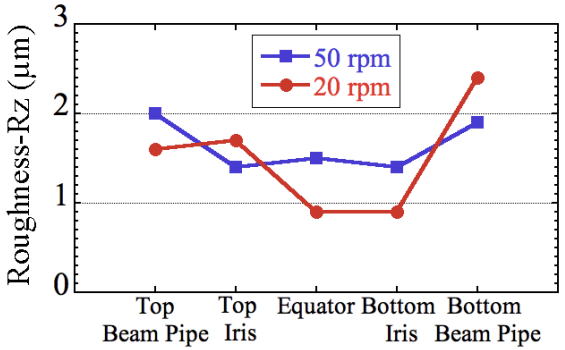
Effect of Enhanced Cathode Area

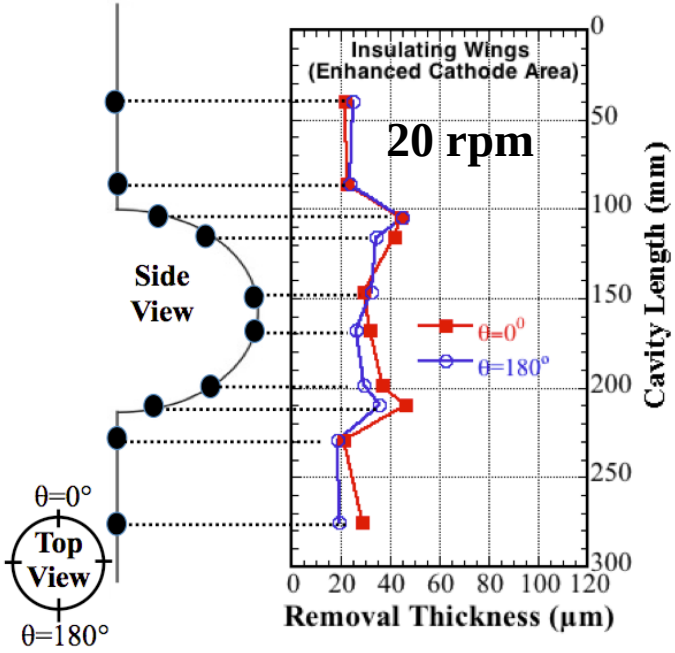


- EP plateaus for the equator coupons were obtained with the Ninja having larger cathode surface area.

Coupon Surfaces and Removal







- ✧ The Ninja cathode resulted in a smooth surface of the entire cavity.
- ✧ Almost symmetric removal was obtained due to bubble guide and uniform acid flow in cavity cell.

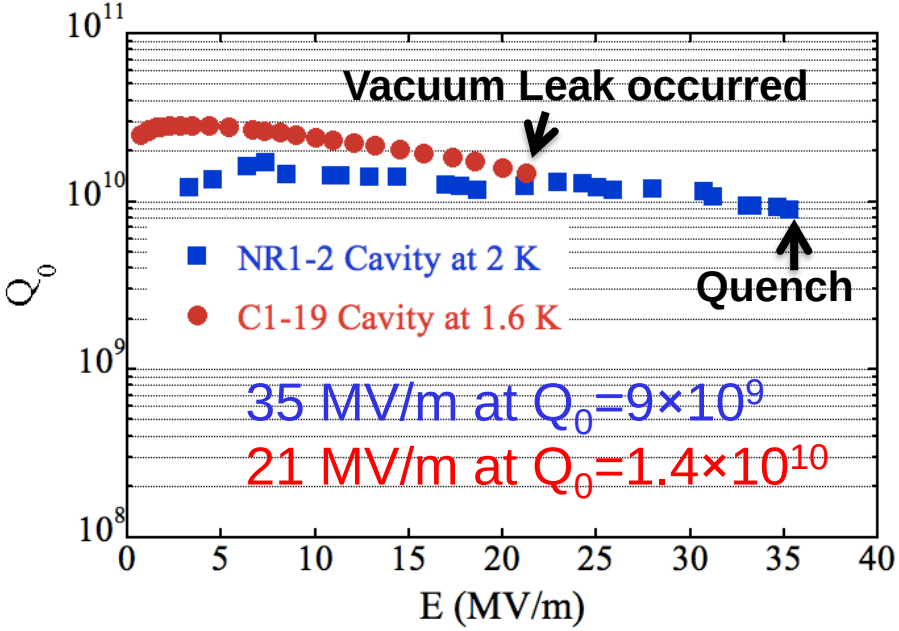
A Ninja cathode with enhanced area has been fabricated for 9-cell cavities.

Vertical Test Results

- Two single-cell cavities (NR1-2 and C1-19) were VEPed with the Ninja cathodes and tested in vertical cryostats.

NR1-2 Cavity (Cornell Cavity)

- **Pre-treatment**: Tumbling, BCP, degassing at 800 °C
- **Cathode**: Ninja cathodes (partial metal wings and enhanced area) with the VEP setup at Cornell University
- **VEP**: VEP with each cathode (20+20 μm removal)
- **Ninja rotation speed**: 50 rpm
- **VT**: Performed at 2K at Cornell after 120 °C baking

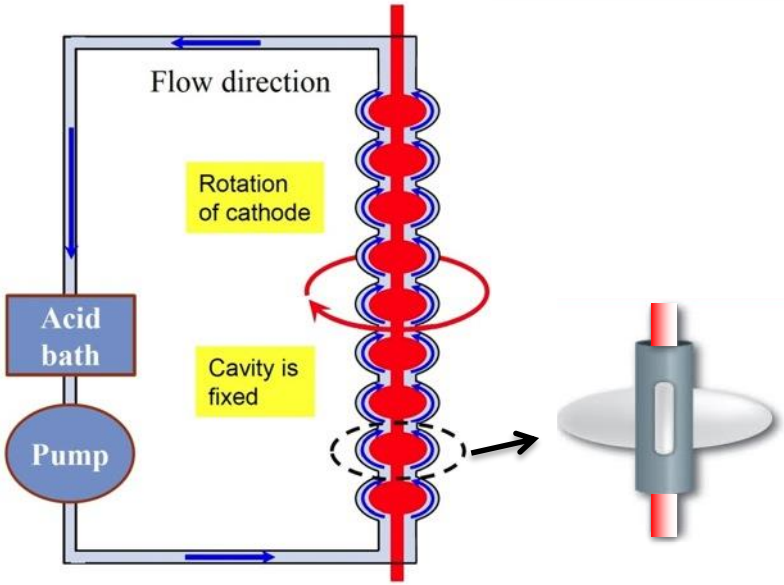


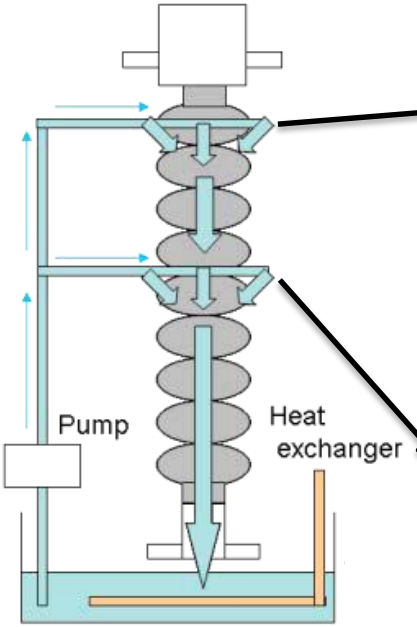
C1-19 Cavity (Saclay Cavity)

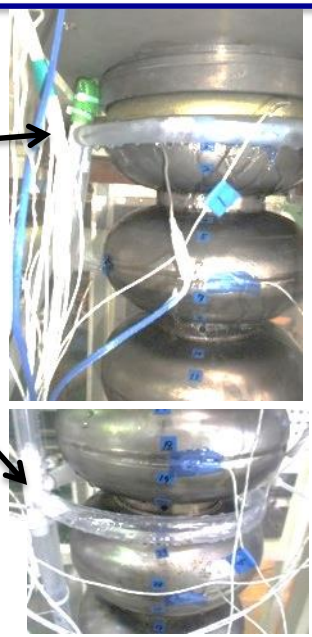
- **Pre-treatment**: BCP
- **Cathode**: Ninja cathode (enhanced area) with the Marui's VEP setup
- **VEP**: Two VEP for 31 and 55 μm removal, degassing at 750°C and final VEP for 11 μm removal
- **Ninja rotation speed**: 30 rpm
- **VT**: Performed at 1.6K at Saclay

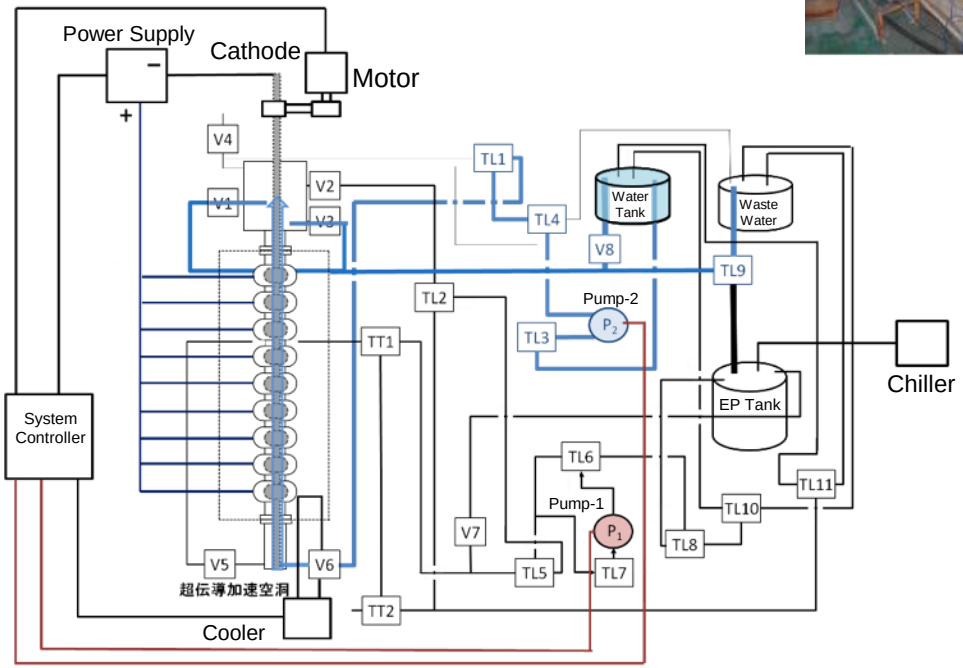
The both cavities showed good performance in the vertical tests.

9-Cell VEP Experiment



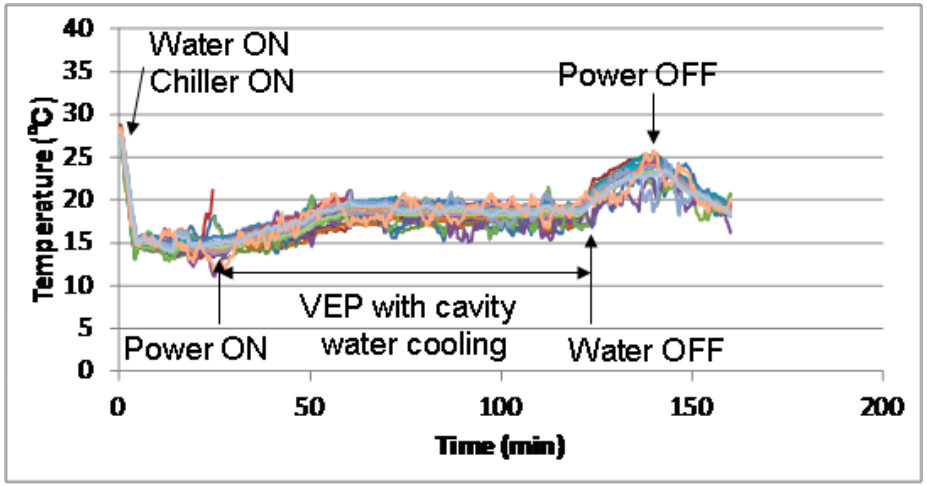


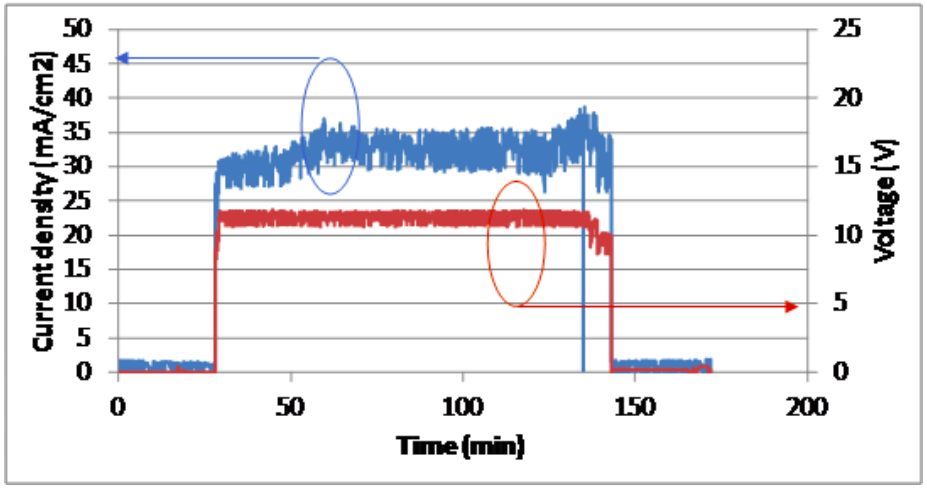


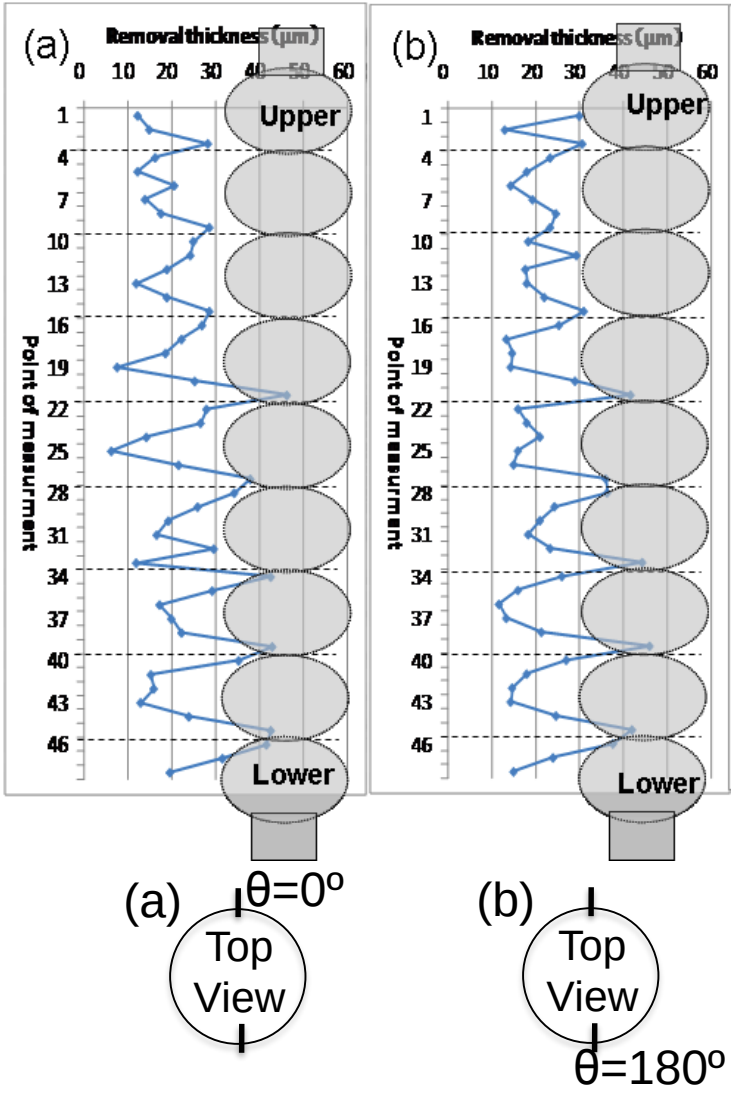


Parameter	Value
H_2SO_4:HF	9:1
Electrolyte Flow Direction	Bottom to Top
Flow Rate	5 L/min
Cathode Rotation Speed	50 rpm
Applied Voltage	~11 V
EP Current Density	30-35 mA/cm^2
Cavity Surface Temperature	~ 20 °C

VEP of 9-Cell Cavity with Ninja Cathode (Al Wings: Old Version)



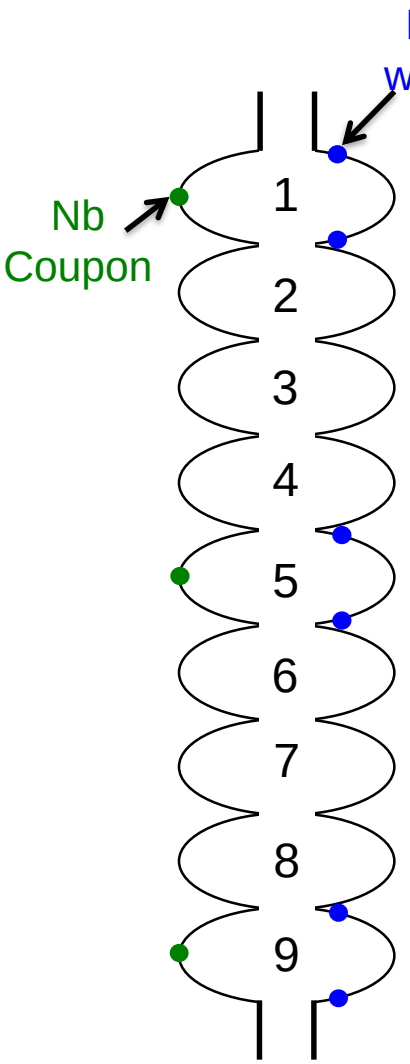




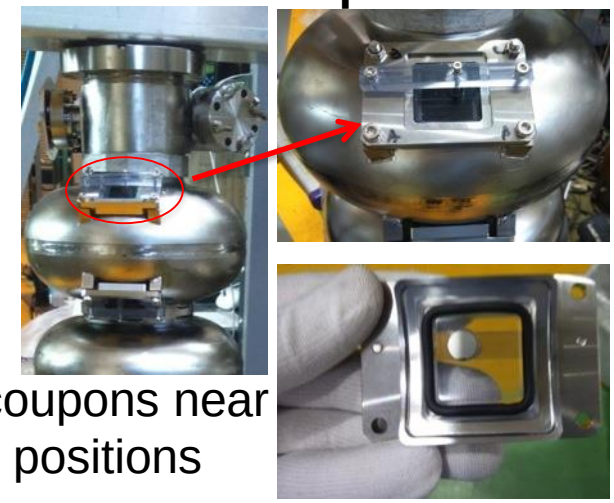
- Removal thickness at iris is around 2-3 times larger than that at the equator.

9-Cell Coupon Cavity

- The world's first 9-cell coupon cavity was fabricated to optimize VEP parameters.

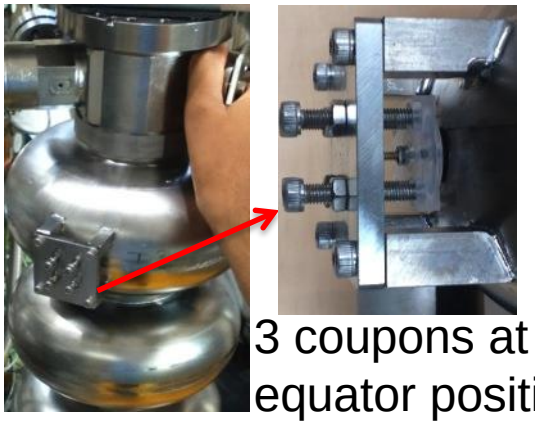


Coupon with Viewport near Iris



6 coupons near iris positions

Equator Coupon



3 coupons at the equator positions

Coupon Cavity at VEP Stand

Currently, we are optimizing VEP parameters using the coupon cavity and the modified Ninja cathode (Insulating wings and large surface area).

Future Work

- The 9-cell VEP facility is being improved for better control of VEP condition.
- The 9-cell Ninja cathode is under testing with 9-cell coupon cavity to investigate VEP parameters.
- Optimized VEP parameters will be applied to a 9-cell cavity at Marui and the cavity will be tested in a vertical cryostat at KEK.
- Additionally, VEP setup (compatible with the Ninja cathode) for single cell cavity is under installation at Saclay (by October 2017).
- Single-cell cavities will be vertically electropolished and tested for evaluation of RF performance at Saclay.

Summary

- VEP setup and unique Ninja cathodes were developed for surface treatment of Nb cavities.
- VEP parameters and design of the Ninja cathode were optimized for single cell cavity.
- Smooth surface and symmetric removal of Nb along cavity length were obtained with the Ninja cathode.
- The Ninja cathodes and optimized VEP parameters were applied to two single-cell cavities which showed good performance in vertical tests performed at Cornell University and CEA-Saclay.
- The world's first 9-cell coupon cavity has been fabricated.
- Based on the VEP results of 1-cell cavity, the 9-cell Ninja cathode has been fabricated and is under testing with the 9-cell coupon cavity.

Conference Proceedings

- V. Chouhan et al., **THPP098**, LINAC2014.
- K. Nii et al., **MOPP108**, LINAC2014.
- K. Nii et al., **TUPP101**, LINAC2014.
- V. Chouhan et al., **MOPB105**, SRF2015.
- V. Chouhan et al., **THBA02**, SRF2015.
- K. Nii et al., **MOPB098**, SRF2015.
- V. Chouhan et al., **MOPLR037**, LINAC2016.
- S. Kato et al., **MOPLR038**, LINAC2016.
- K. Nii et al., **MOPLR039**, LINAC2016.

Thank You

Top Iris Viewports

Rod cathode

Ninja cathode-Al wings