



Suppression of field emission for the SRF cavities at KEK

TTC Meeting
12/06/2023

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for the iCASA SRF team

High Energy Accelerator Research Organization (KEK)

Contents



- Introduction
- Clean room survey
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- Assembly work planning, documentation, and analysis
- Further measures to reduce field emission
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- Summary

Motivation

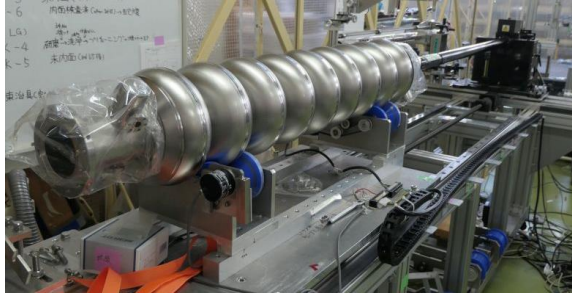
- Our R&D goal: Achieve as high as possible quality factors Q_0 and maximal accelerating voltages E_{acc} within 1.3 GHz superconducting radio frequency (SRF) cavities



Example Workflow of Cavity Treatment before Test



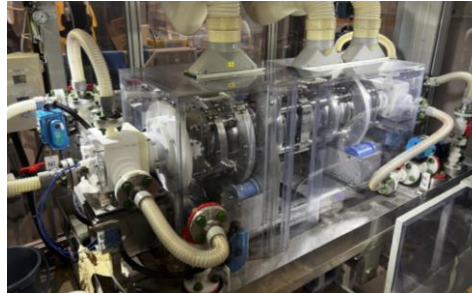
Inspection



Annealing



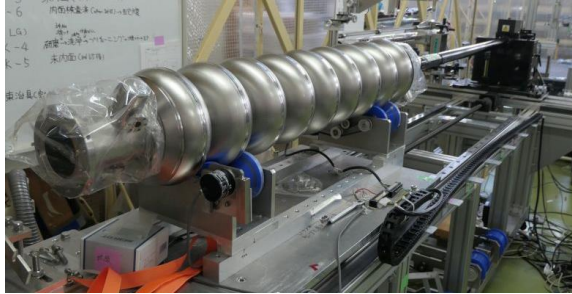
Bulk Electro Polishing



High Pressure Rinsing



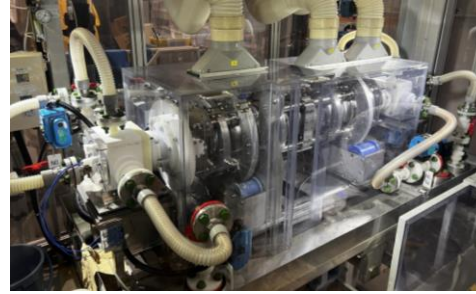
Inspection / Grinding



Tuning / Straightening



Electro Polishing



High Pressure Rinsing



Assembly



Baking

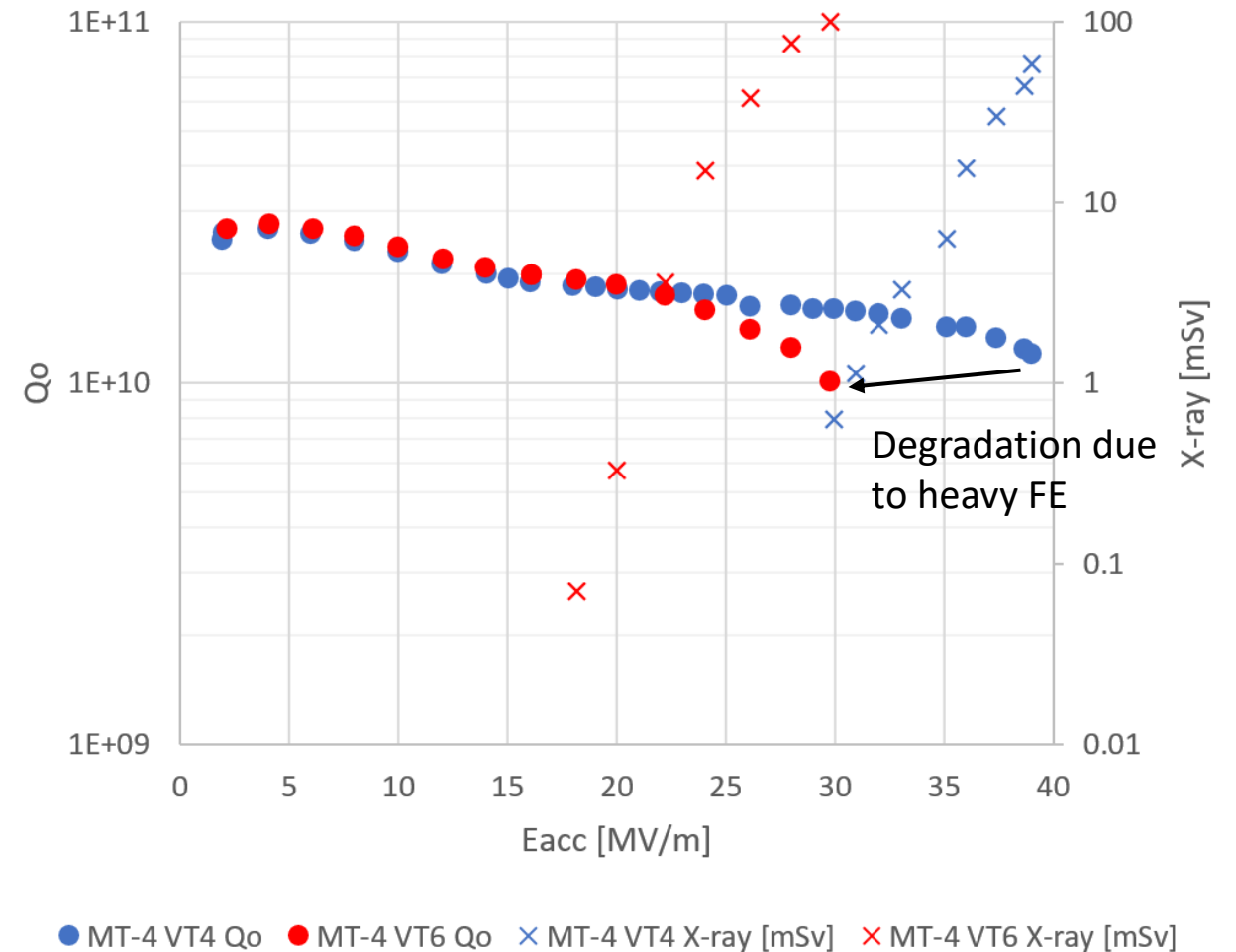


Vertical Test



Motivation

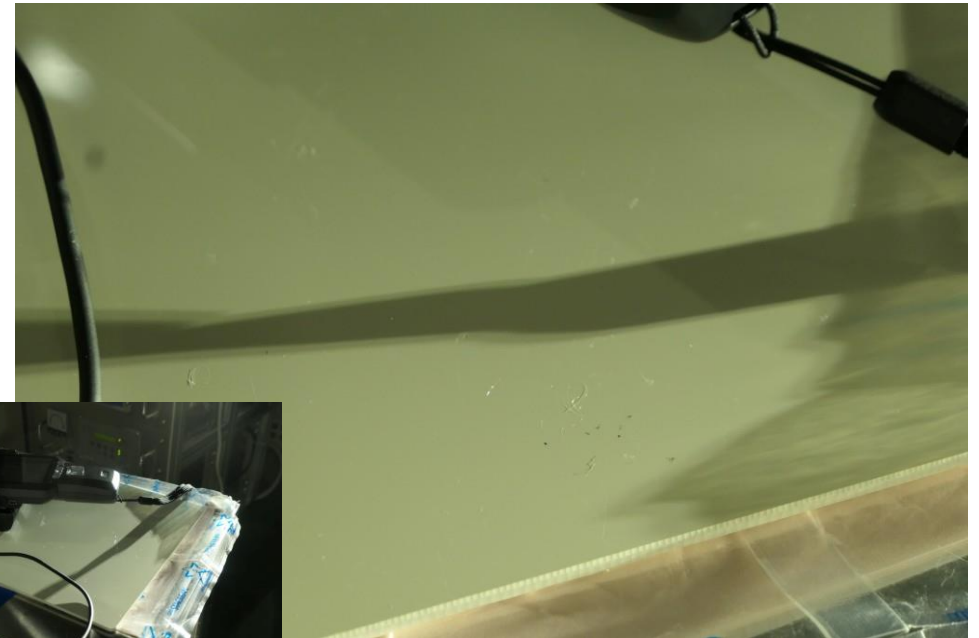
- Since field emission (FE) degrades the cavity performance, it has to be avoided
- Thus, pollution of the inner cavity surface with particulates has to be avoided
- Sources of particulates:
 - Environment
 - Generation during assembly process
 → We have to understand both



Clean Room Survey using Spotlight



- Turned off all ambient lighting in STF class 1000 clean room and class 10 clean room (C10CR)
- Used spotlight to illuminate surfaces in C1000CR



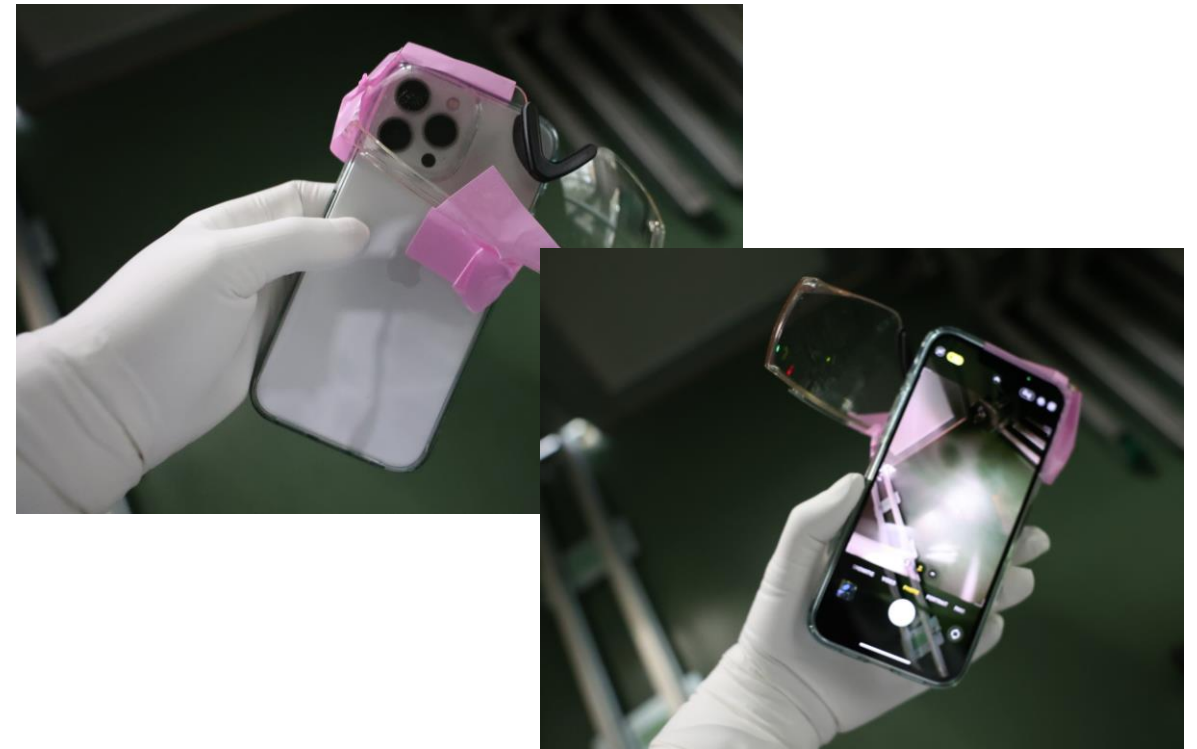
Clean Room Survey using D Light



- Turned off all ambient lighting in STF and COI C1000CRs and C10CRs
- Used D light to illuminate surfaces



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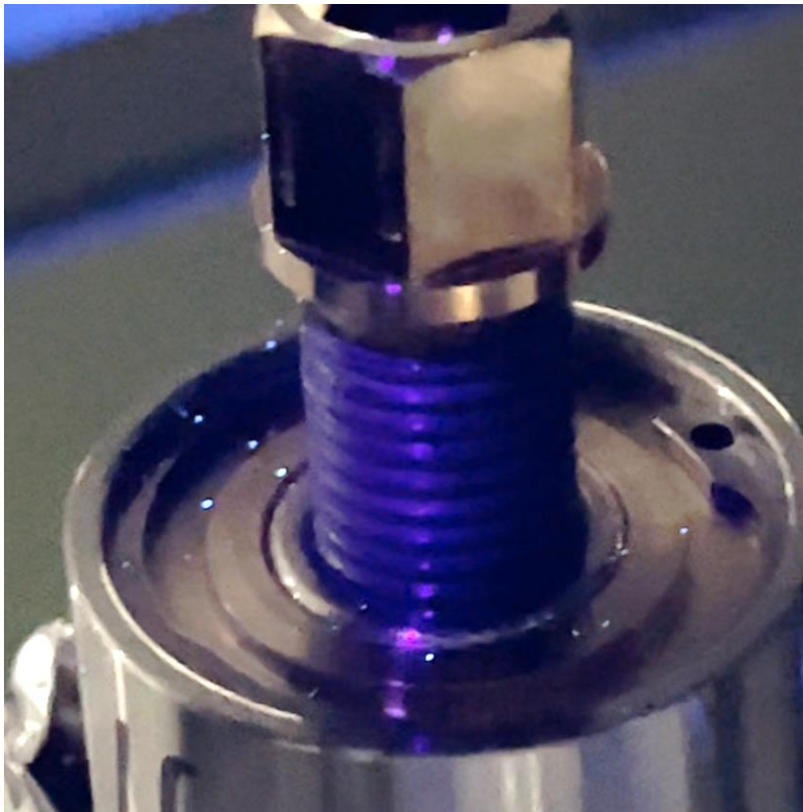


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Checking other Surfaces with Cleaning (Air Blowing)

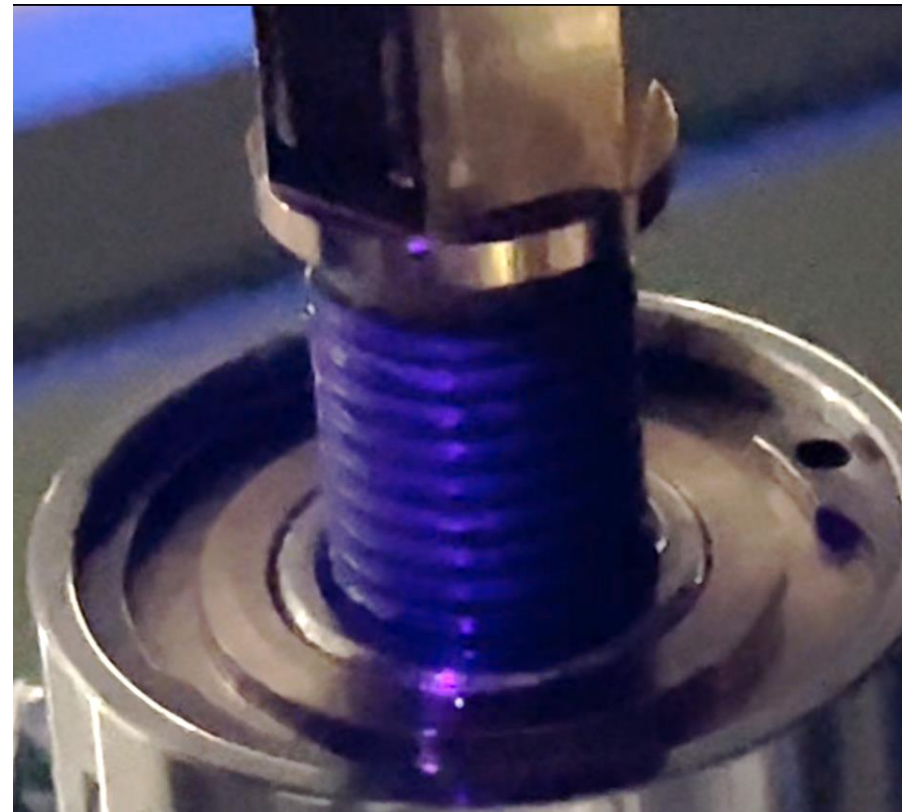


- Sample surface: valve of pumping station (ion pump)
- Initial situation



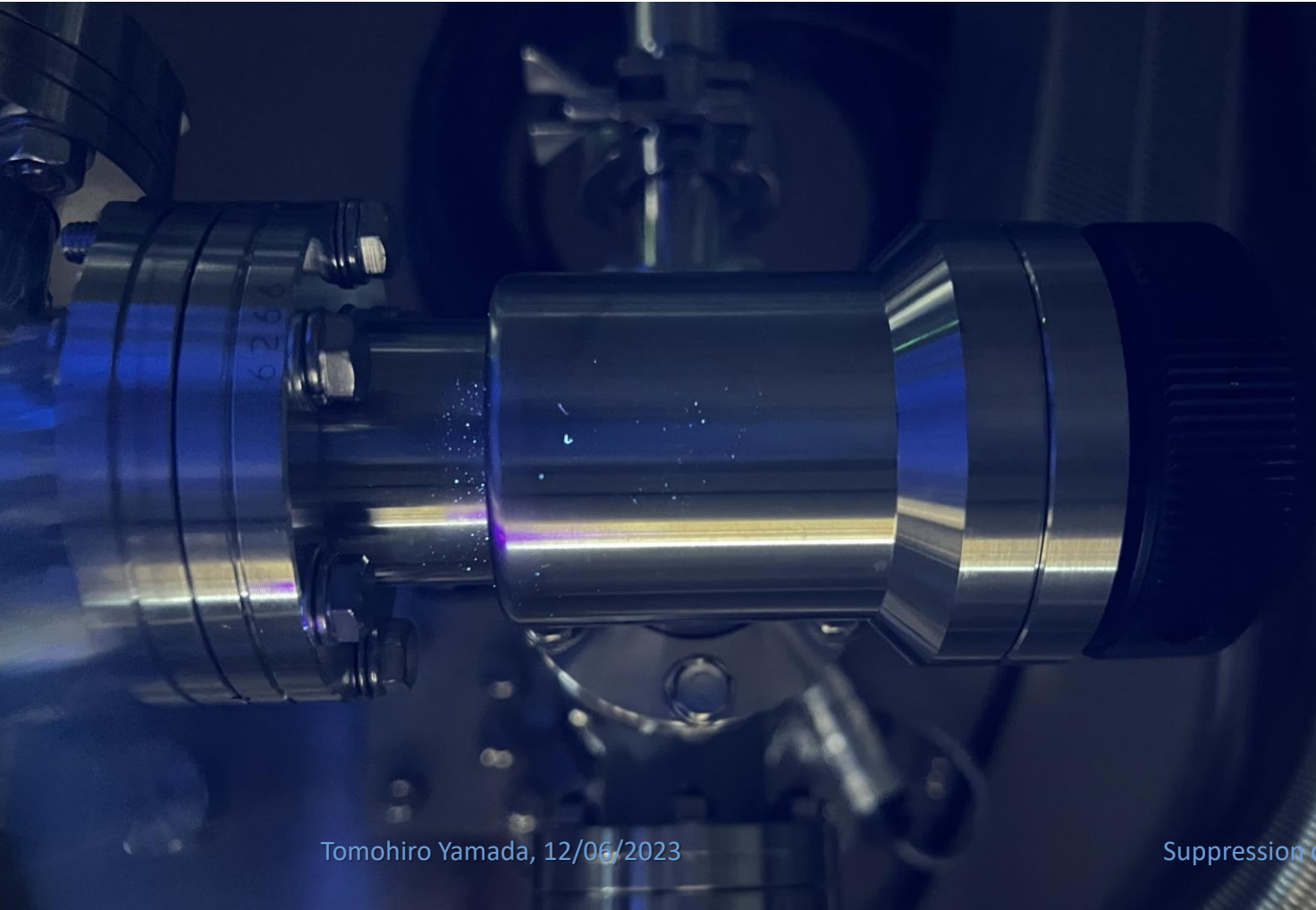
Tomohiro Yamada, 12/06/2023

Final situation after air blowing

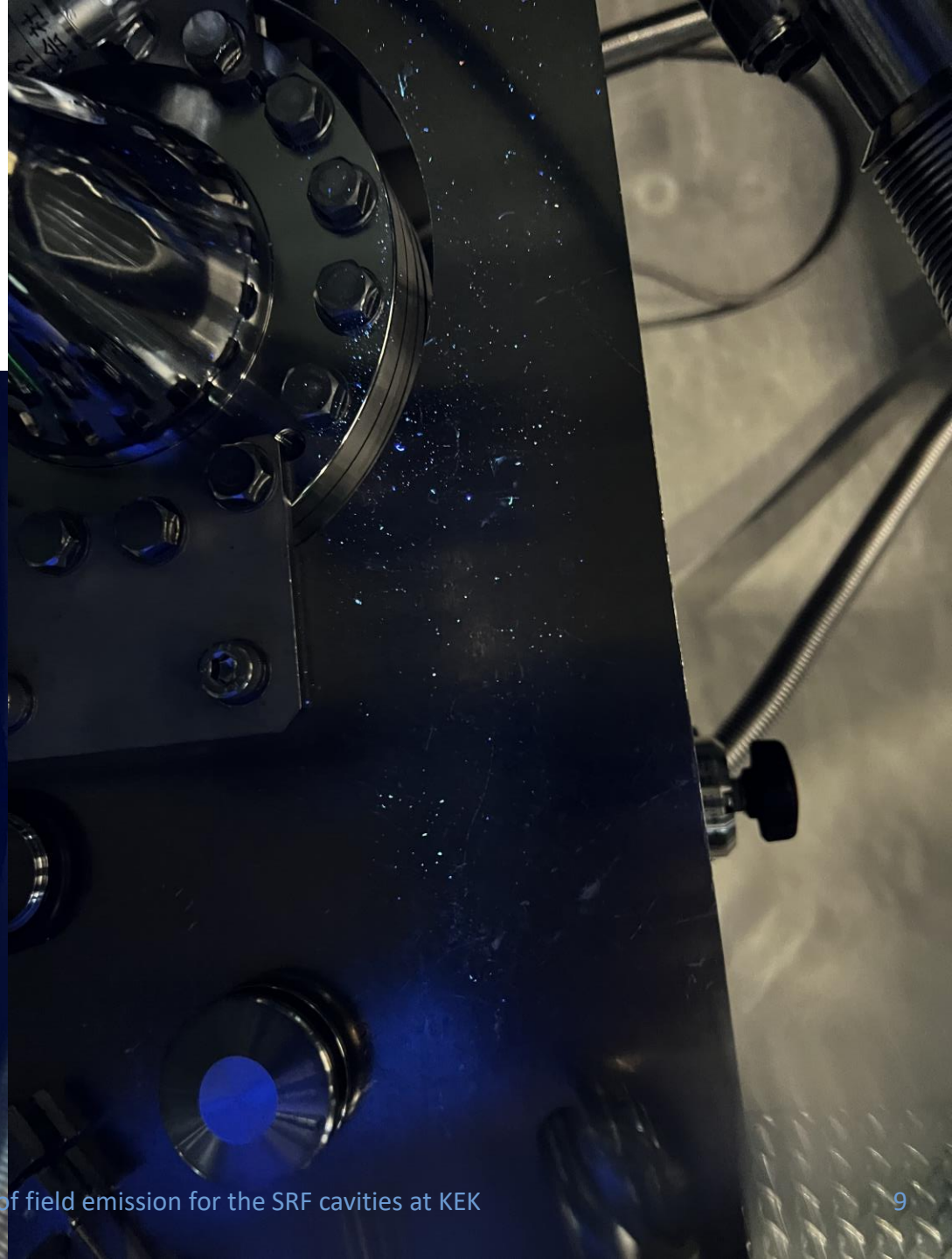


Suppression of field emission for the SRF cavities at KEK

COI C1000CR – Pumping Station

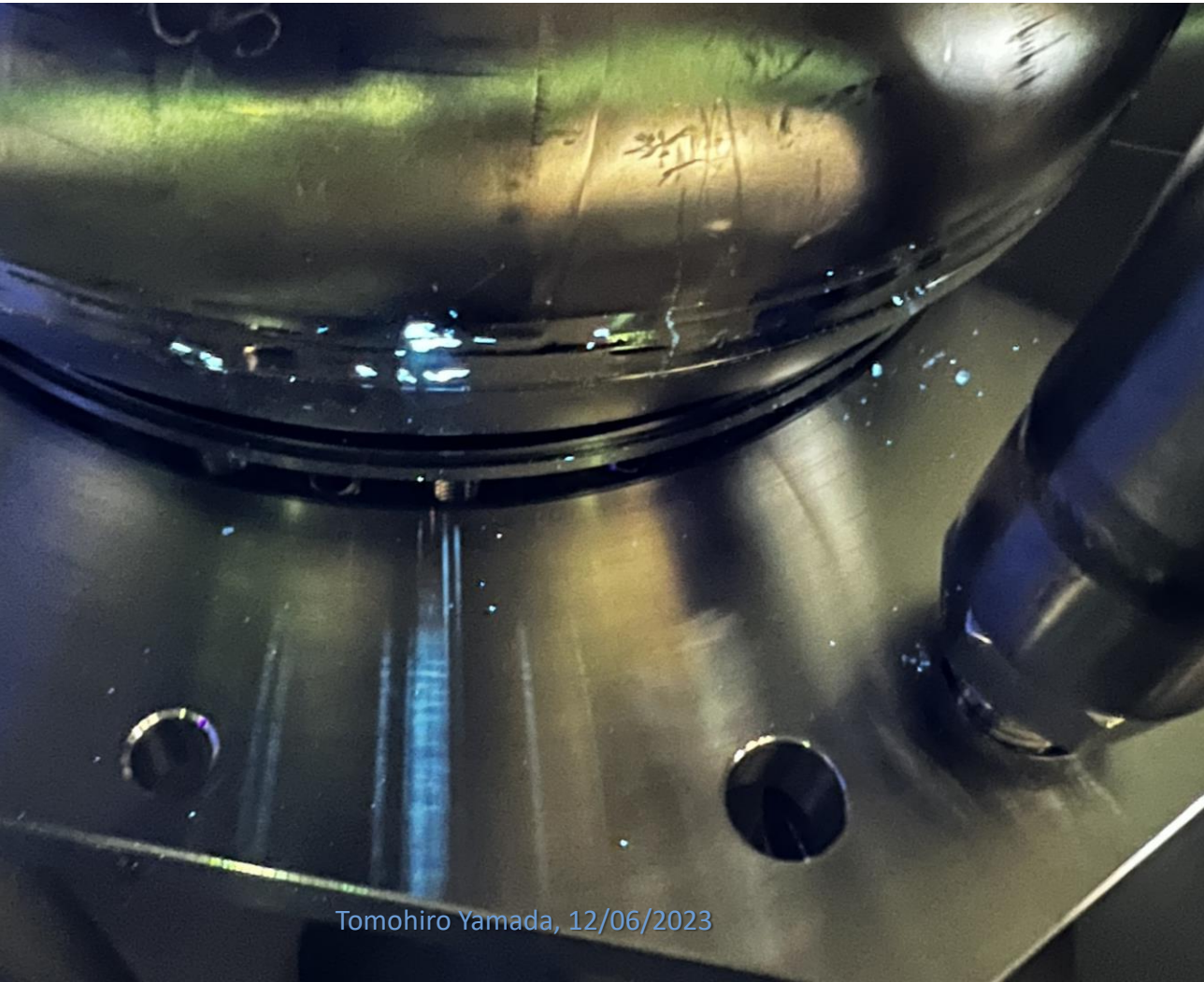


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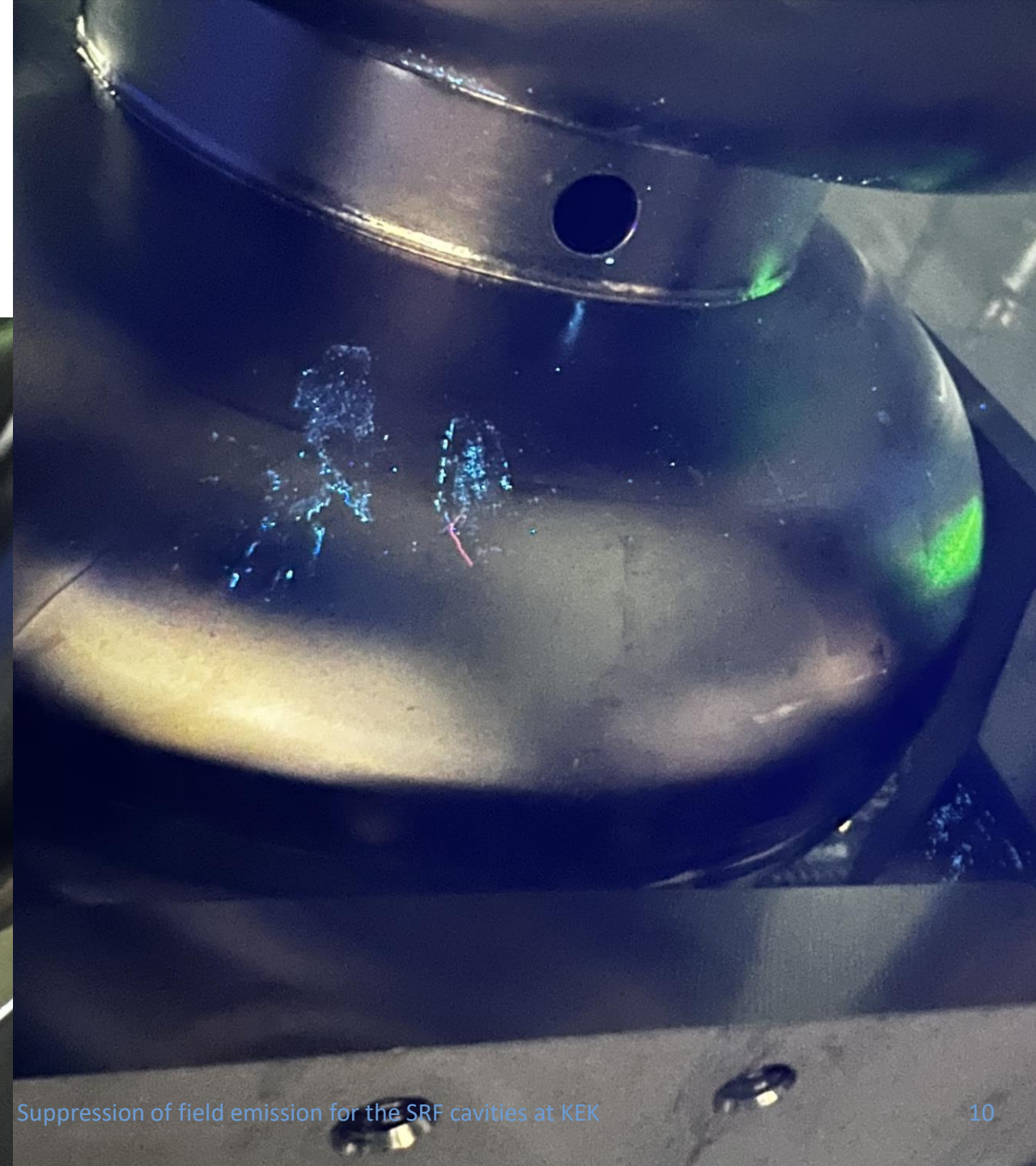


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COI C1000CR – Cavity Stored in the CR

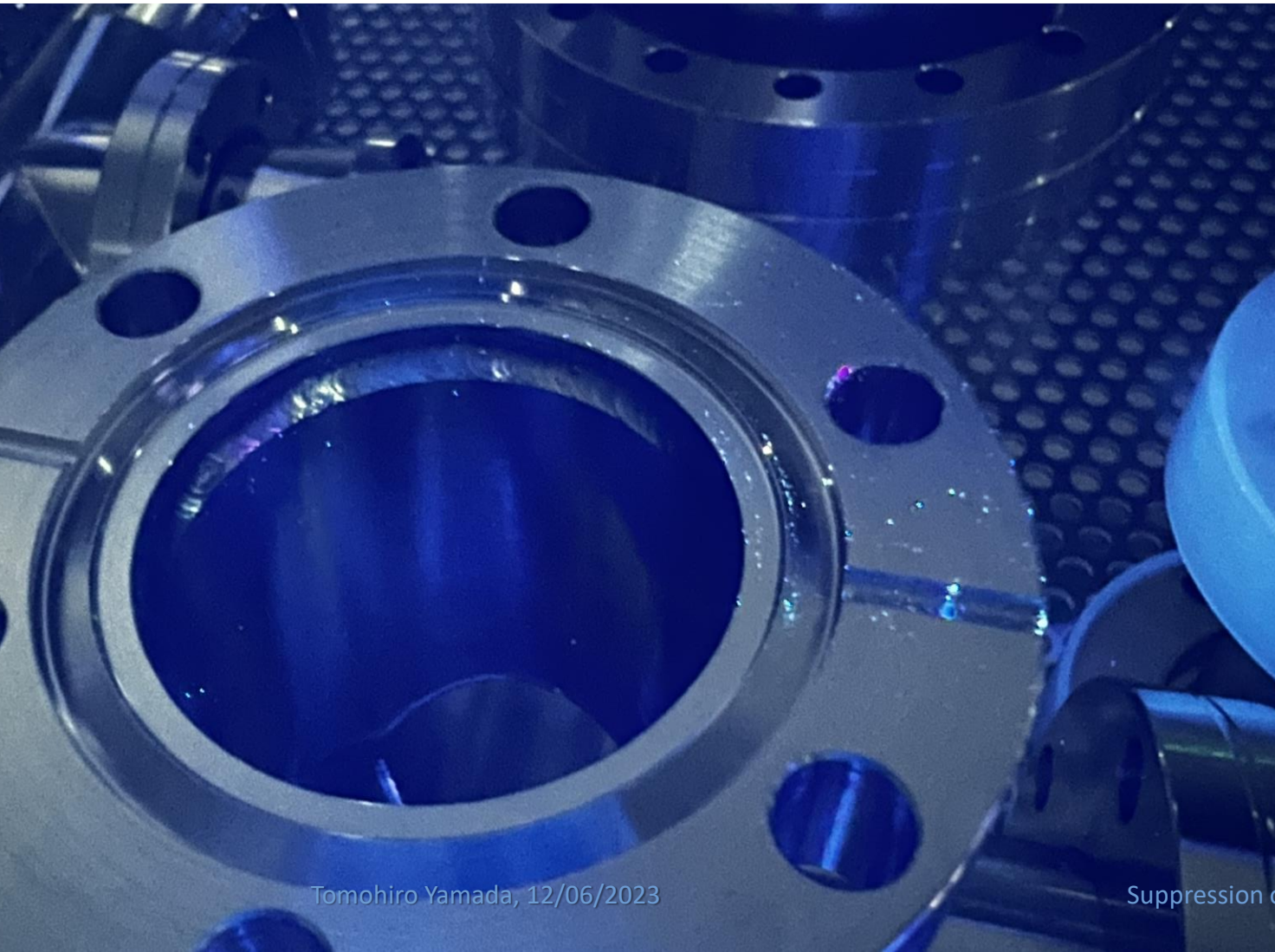


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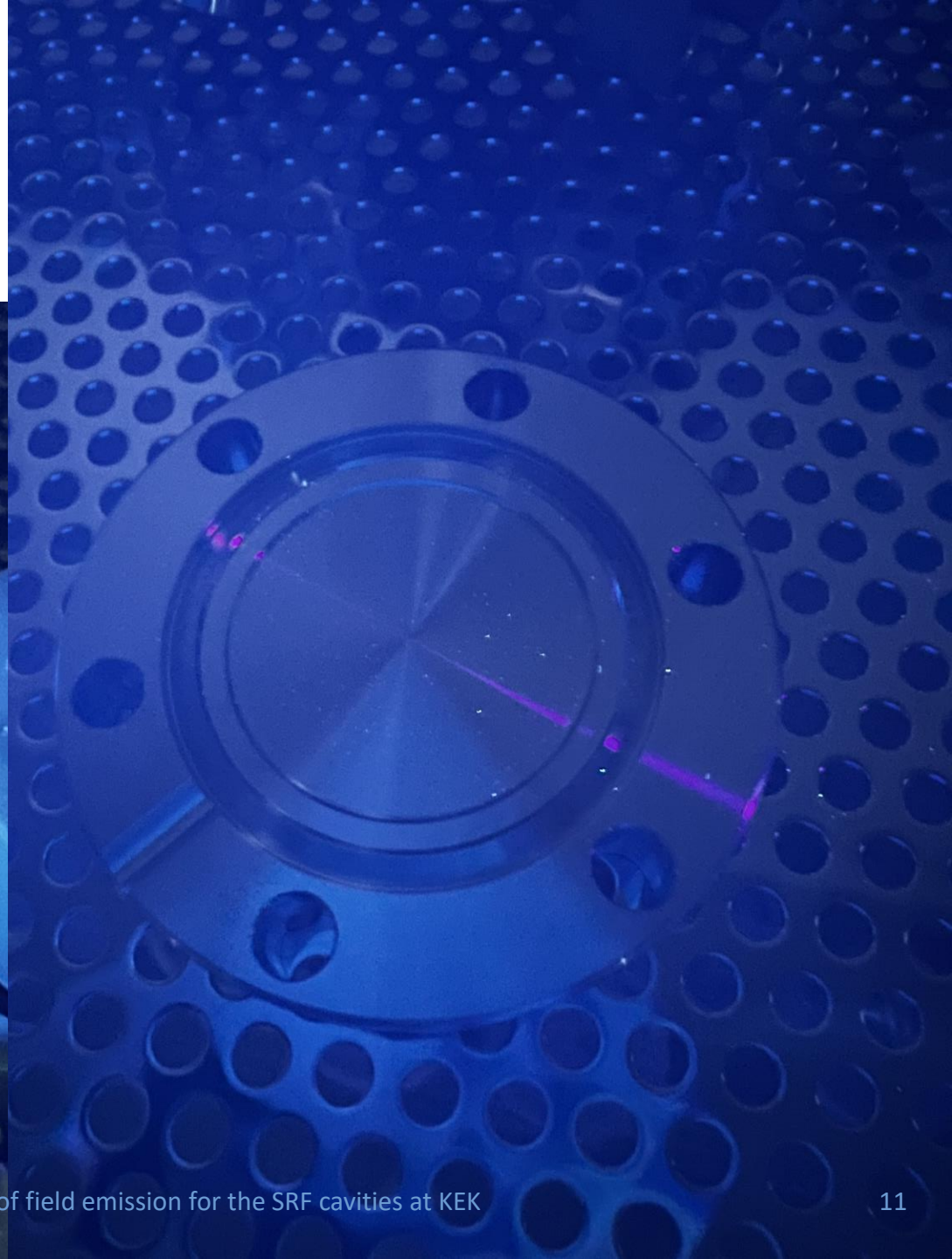


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COI C1000CR – Items Stored in Shelf

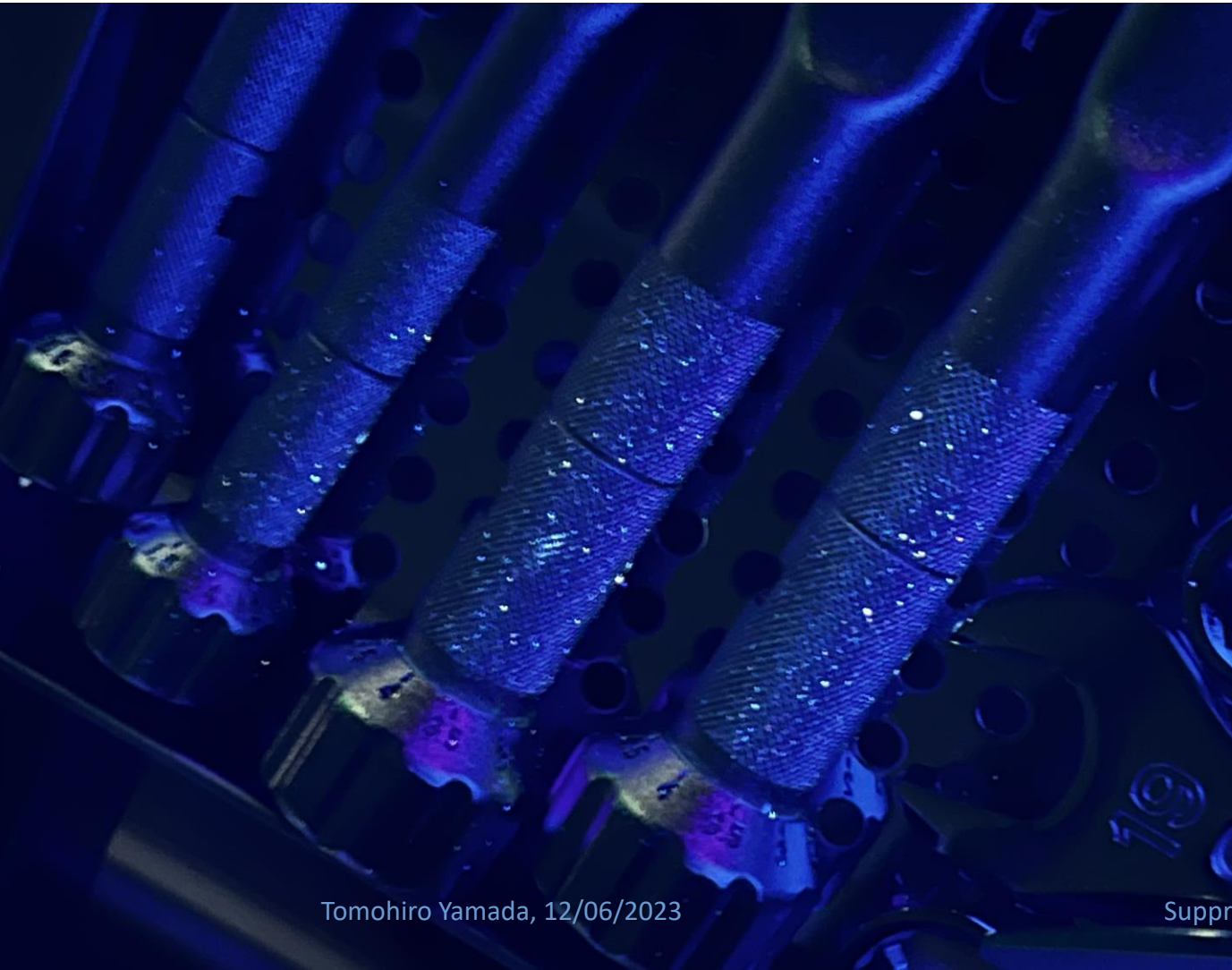


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Suppression of field emission for the SRF cavities at KEK

COI C10CR – Tray with Tools



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STF C1000CR - Window of Air Lock between C1000CR and C10CR

Before cleaning

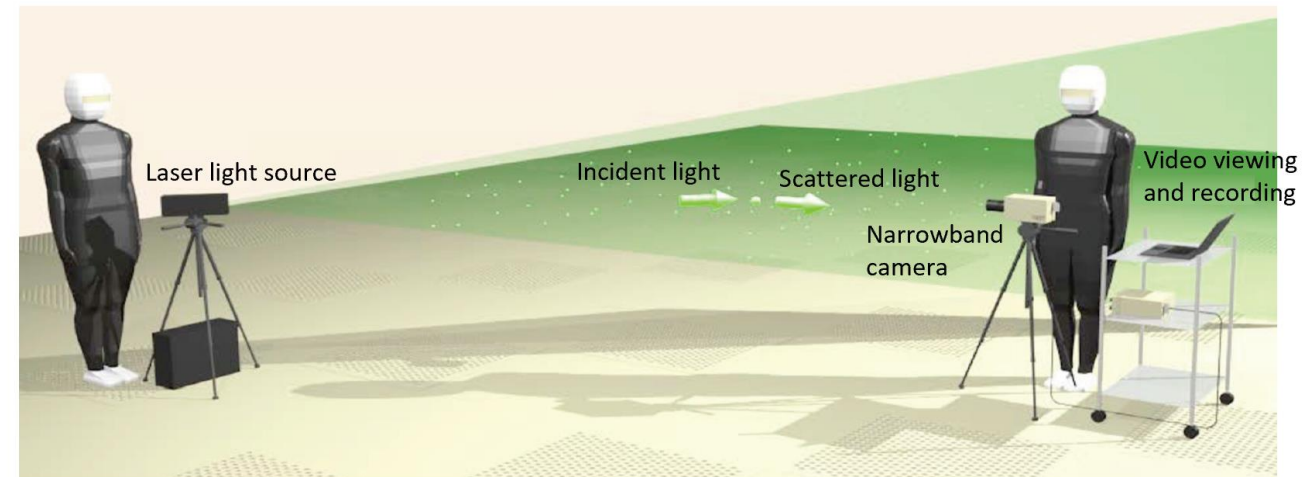


After cleaning

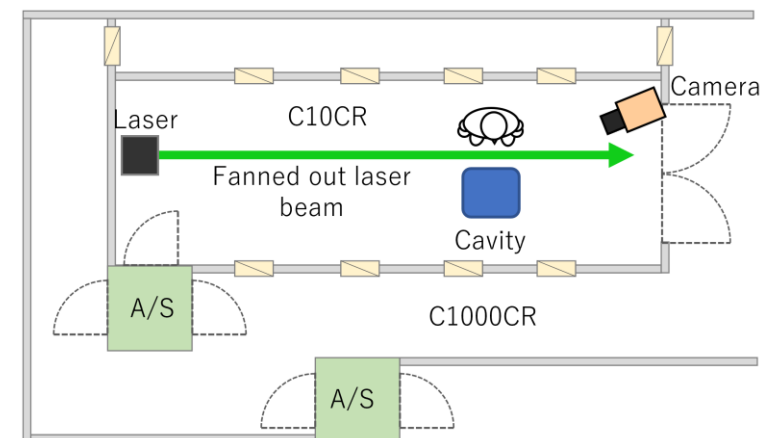
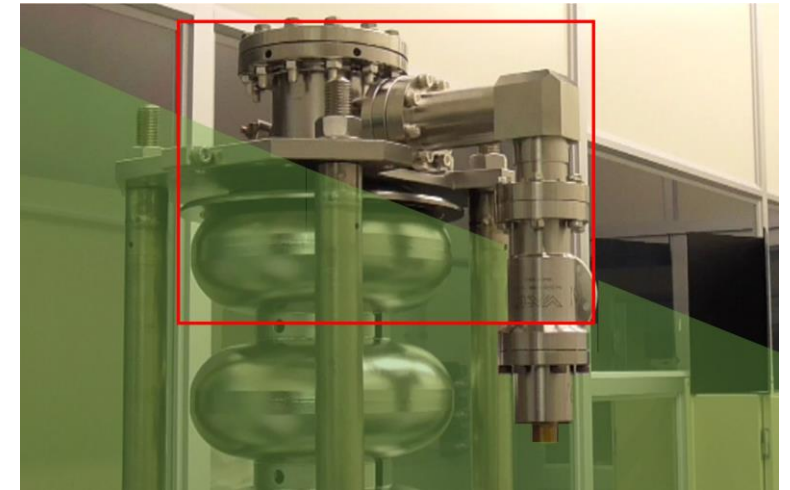


Study Particulates created during the Assembly

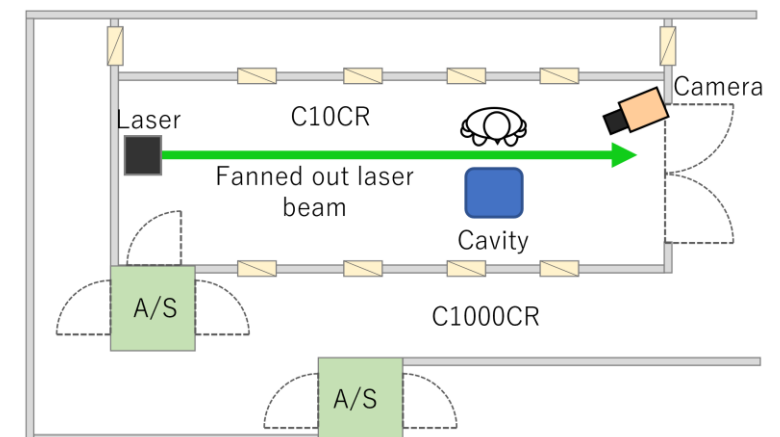
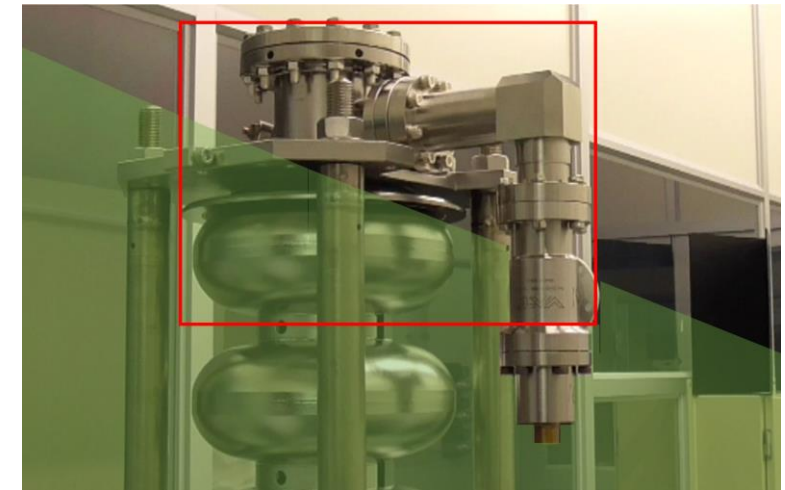
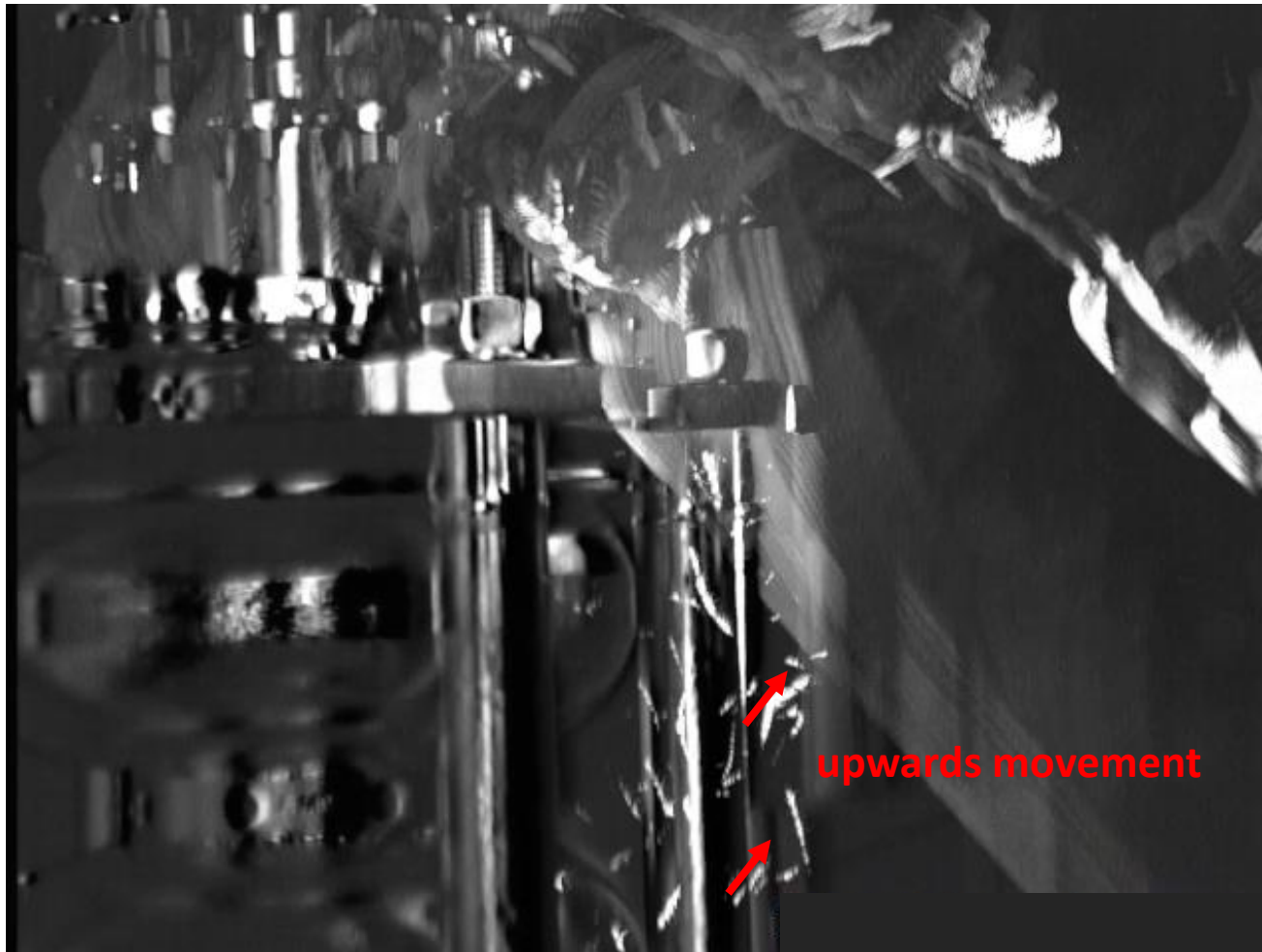
- Study performed together with SHIN NIPPON AIR TECHNOLOGIES CO.,LTD (SNK)
- Ambient lighting is turned off
- Green laser light is transmitted through the area of interest
- Laser light is scattered by particles
- Scattered light is recorded by a video camera



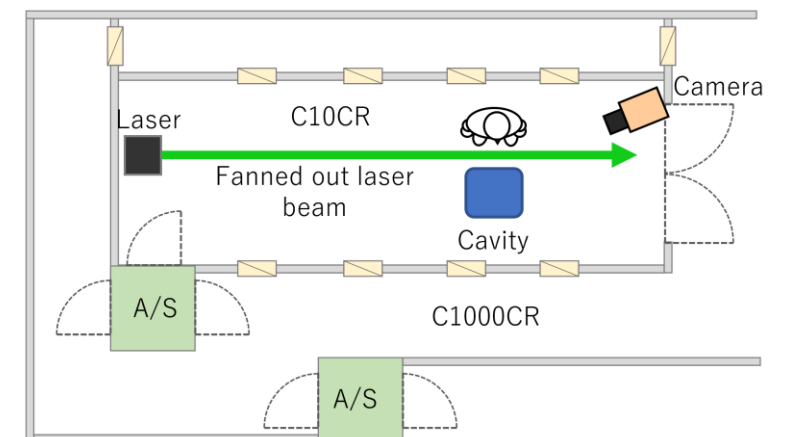
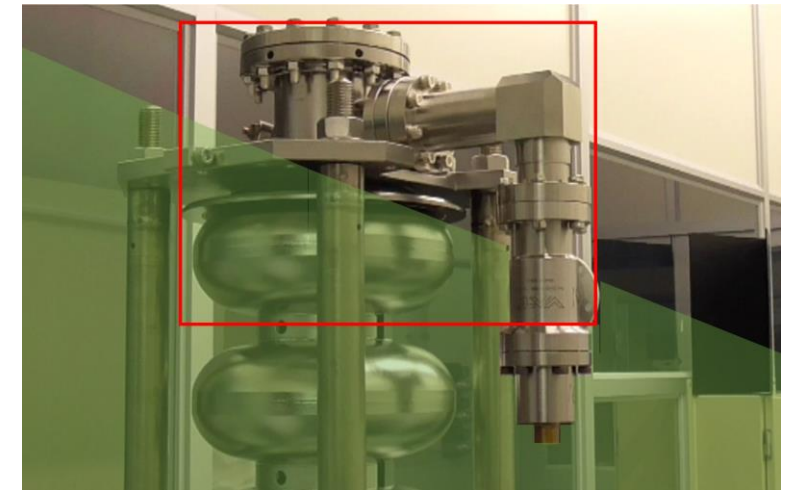
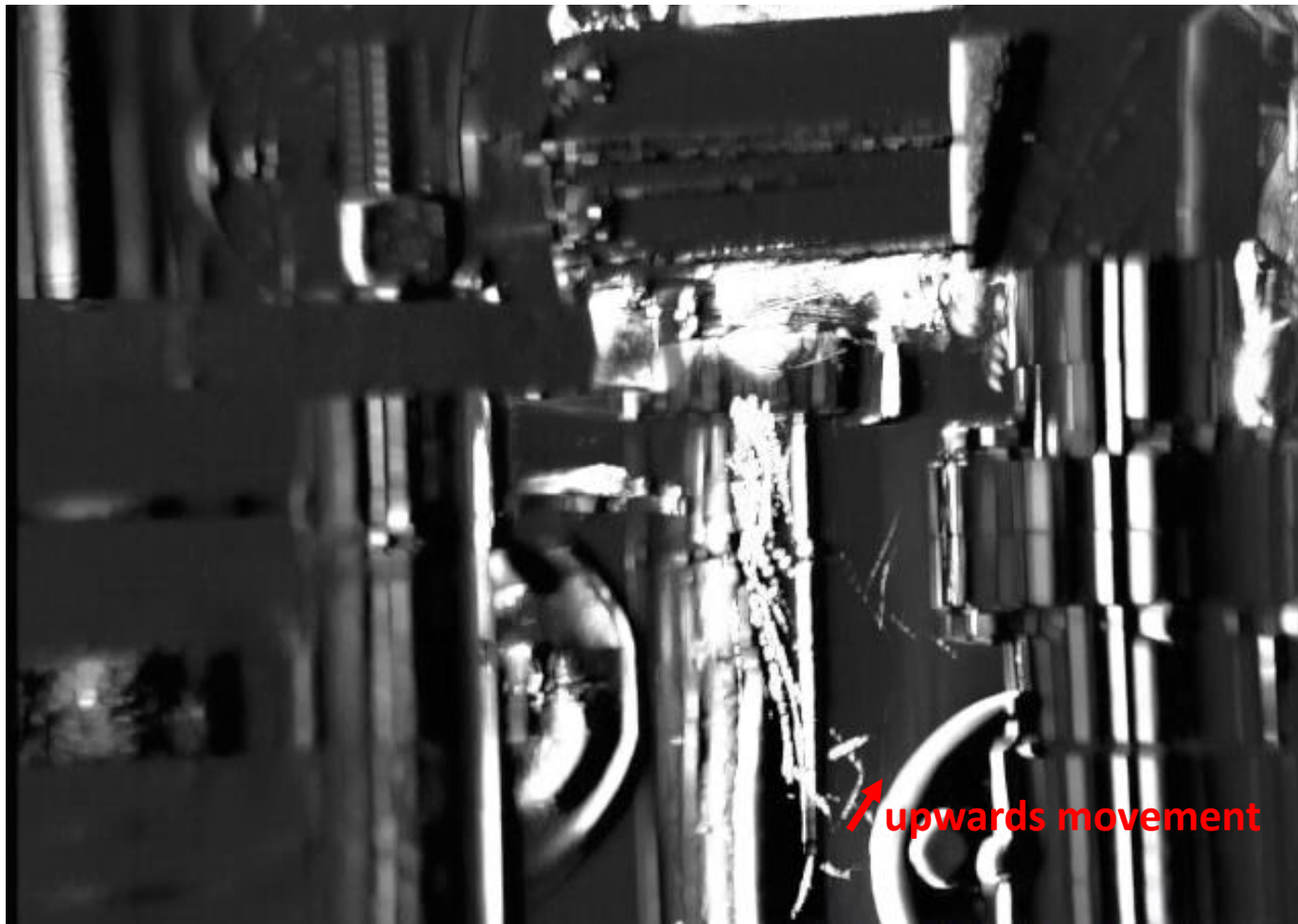
Clean blowing with ion gun and particle counter before assembly (15 s)



Release of bolts of blind flange using a hex key and hands (15 s)



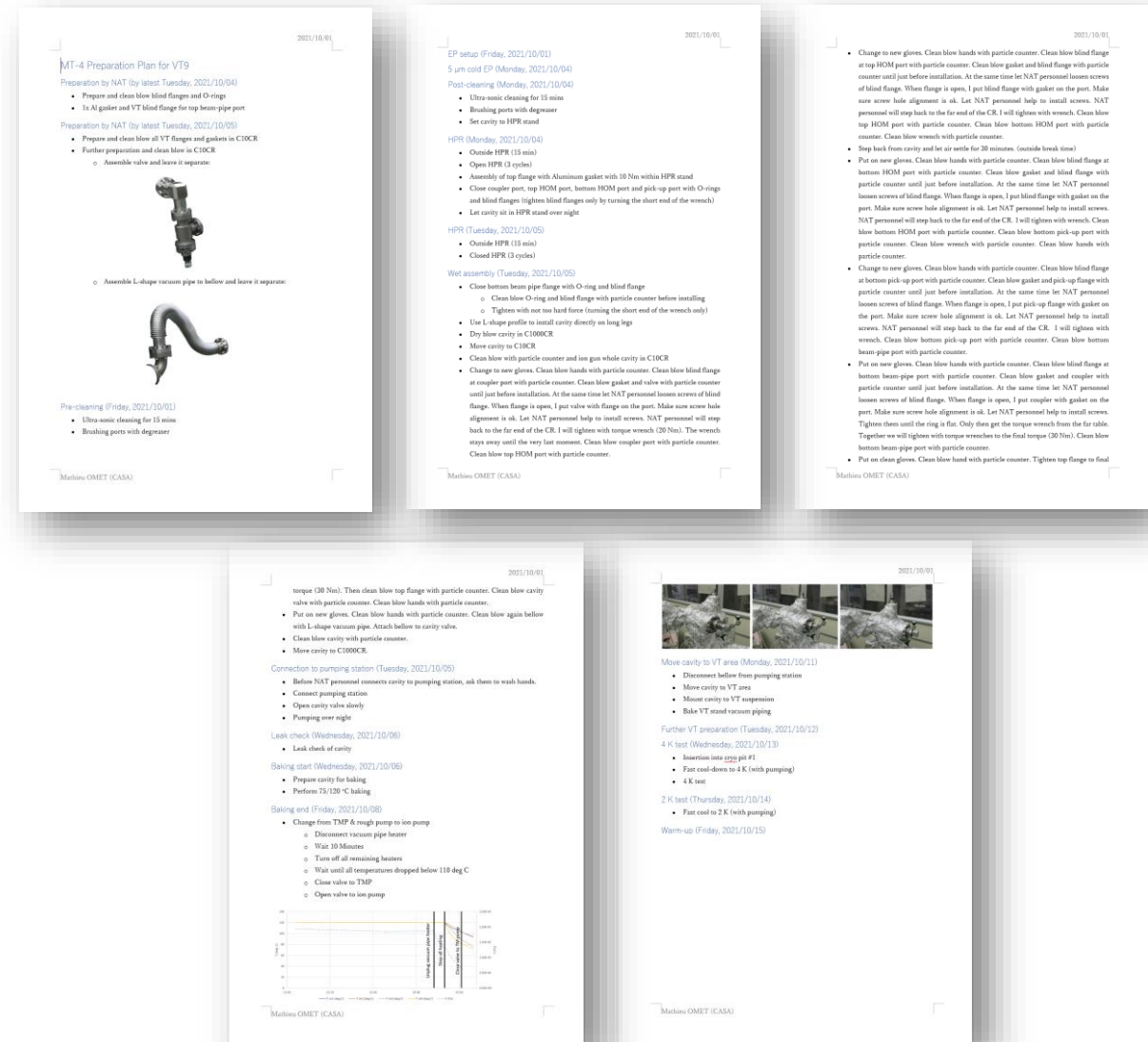
Tightening a bolt of the attachment using a hex key (20 s)



Work Plan for Assembly



- Detailed assembly procedure is described
- Written for every single assembly
- Discussed with supporting technical staff before the assembly
- Document is accessible during the assembly via tablet in the C1000CR



Documentation during Assembly with Head-mounted Camera



Picture courtesy of T. Dohmae

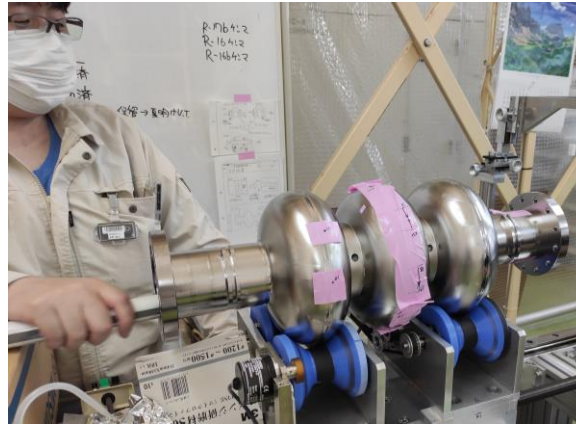
Analysis of Assembly Work



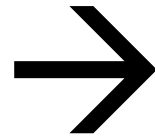
- After the assembly divergence from the work plan are noted down
- Recorded pictures and videos are shared with all group members via internal services (picture gallery, cloud storage, electronic logbook)
- A work report is compiled (typically a Power Point presentation) and discussed with all group members during the weekly group meeting
- The work reports are accessible on the internal meeting webpage

Further Measures to Suppress Field Emission

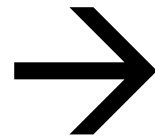
- Iris grinding of cavities



Example of iris grinding on 3-cell cavity
Picture courtesy of H. Araki



MT-4 (9-cell cavity)
1-2 iris, $\theta = 0$ deg.

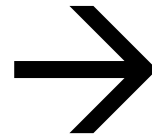


MT-4 (9-cell cavity)
3-4 iris, $\theta = 162$ deg.



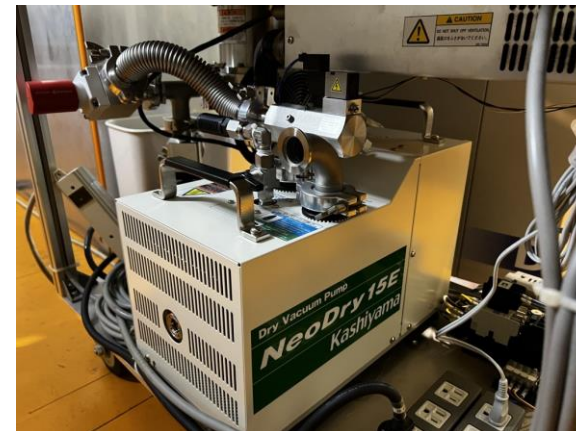
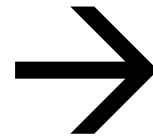
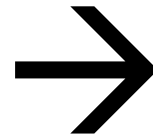
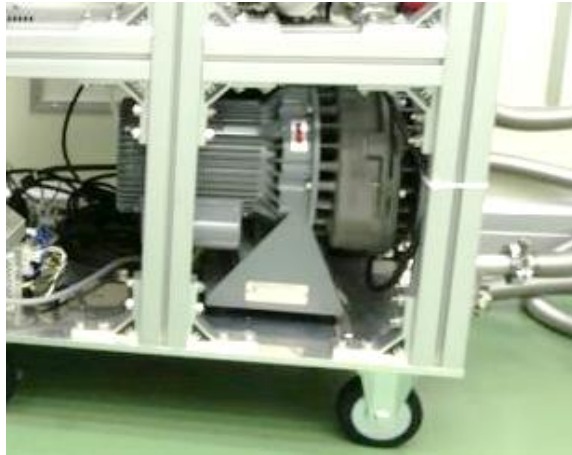
Further Measures to Suppress Field Emission

- Exchange ion gun from TOP GUN to KEYENCE SJ-L005G with filter



Further Measures to Suppress Field Emission

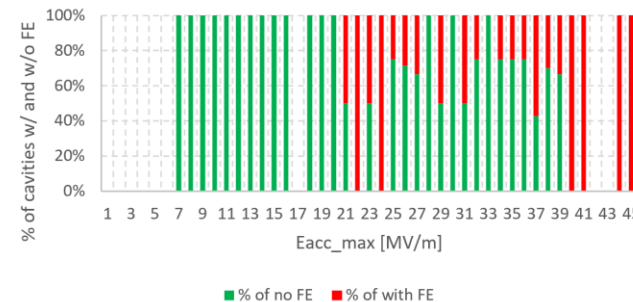
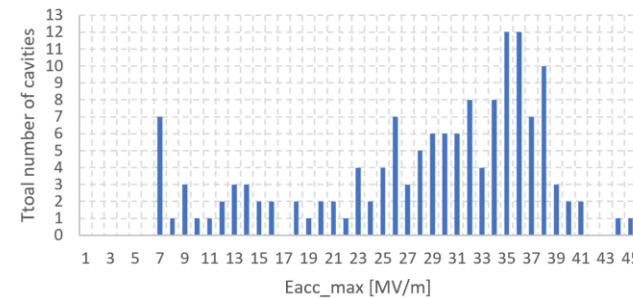
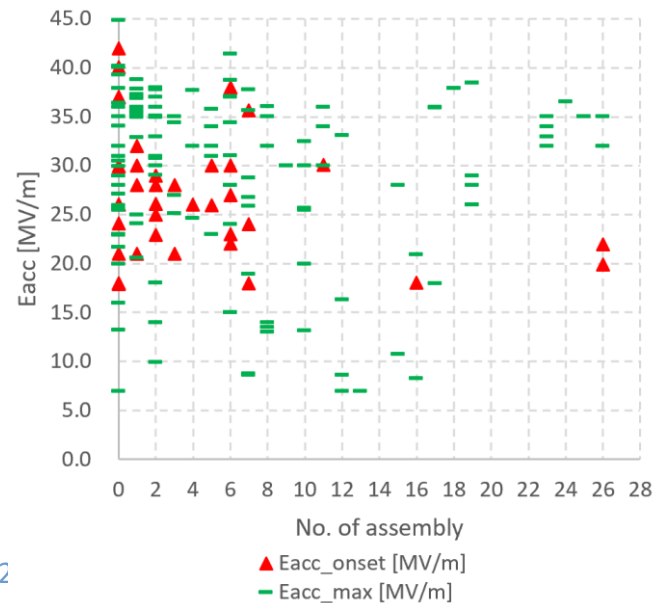
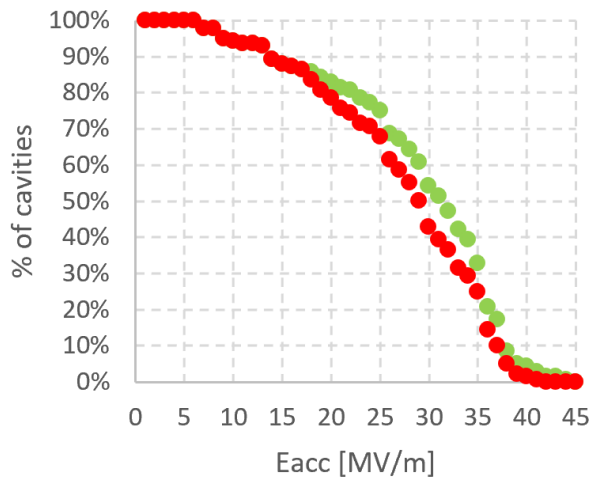
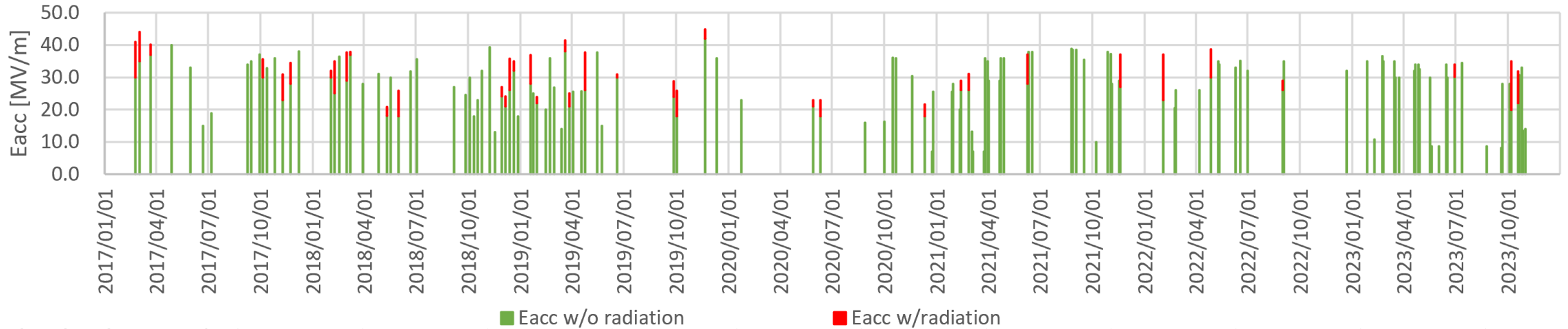
- Exchange the scroll pump with dry pump in clean room and at VT stand



History of Field Emission in single-cell Cavities



All Eacc_max and Eacc_onset (final π -mode at 2 K)

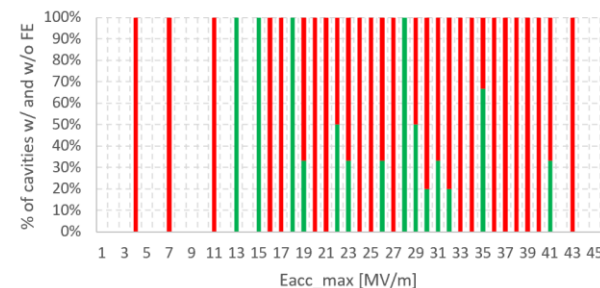
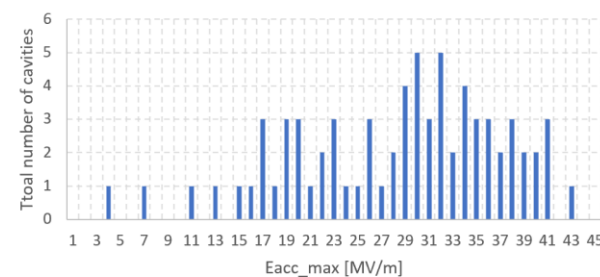
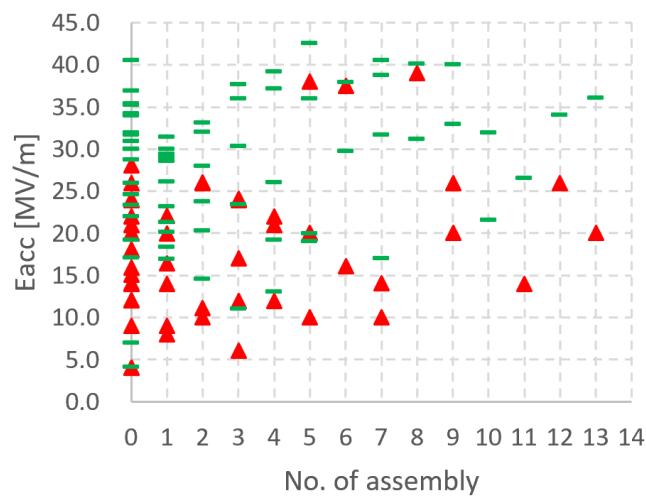
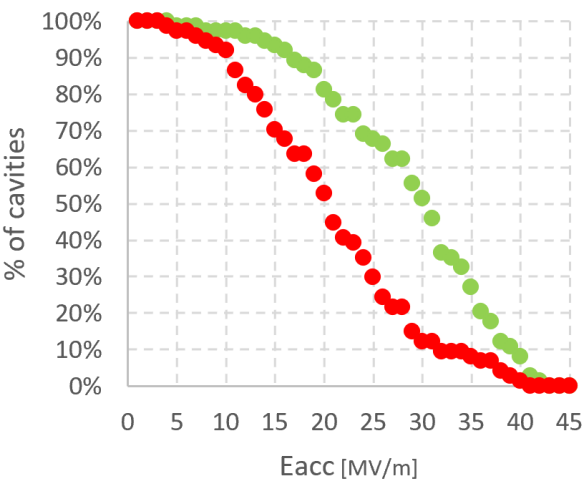
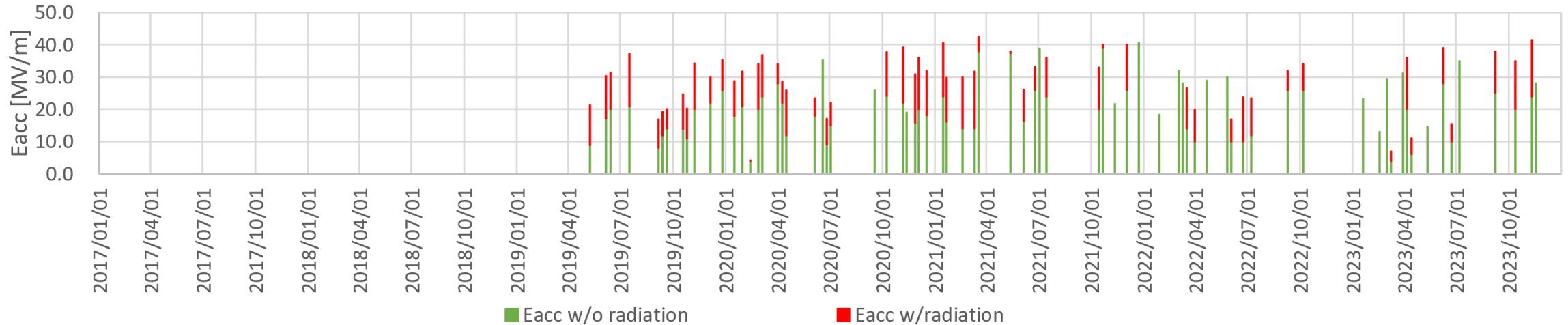


Number of VTs	142
VTs with radiation	40 (27.2%)
VTs w/o radiation	102 (71.8%)
Mean Eacc_onset	27.1 MV/m
Mean ratio (onset/max)	0.832

History of Field Emission in 9-cell Cavities



All Eacc_max and Eacc_onset (final π -mode at 2 K)



Number of VTs	74
VTs with radiation	56 (75.7%)
VTs w/o radiation	18 (24.3%)
Mean Eacc_onset	18.5 MV/m
Mean ratio (onset/max)	0.631

● % of cavities reaching this Eacc regardless of FE

● % of cavities reaching this Eacc w/o FE

▲ Eacc_onset [MV/m]

■ Eacc_max [MV/m]

2)

Su

at KEK

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Summary



- Clean room survey
 - Understanding of assembly environment
 - Spotlight / D light (more versatile)
 - Improvement possible by cleaning and/or not whirling up dust in certain corners
- Study on particles created during assembly
 - Understanding of particle creation and movement
 - Deduct rules for behavior during assembly (e.g. slow movement, clean up well after every assembly step, etc.)
- Assembly work planning, documentation, and analysis
 - Similar to a Plan, Do, Check, Act (PDCA) cycle, which is a well-established tool in quality management
 - Allows to easily share information among group members
- Further measures to reduce field emission
 - Iris grinding
 - Exchange of ion gun for assembly
 - Exchange of pump for rough pumping system
- Field emission statistics
- With on all points above, we are improving the quality of our assembly processes

- Thank you very much for your attention! Questions?