Efforts to improve the assembly work of SRF cavities in the clean room to suppress field emission

加速器学会

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Mathieu OMET
応用超伝導加速器イノベーションセンター
高エネルギー加速器研究機構

Contents

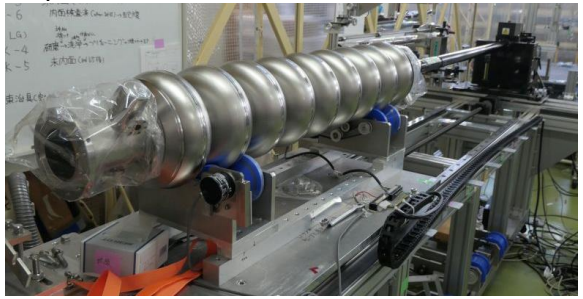
- Introduction
- Clean room survey
- Study on particle generation during assembly
- Assembly work planning, documentation, and analysis
- Further measures to reduce field emission
- FE statistics
- Summary

Motivation

- Our R&D goal: Achieve as high as possible quality factors Q0 and maximal accelerating voltages Eacc within 1.3 GHz superconducting radio frequency (SRF) cavities

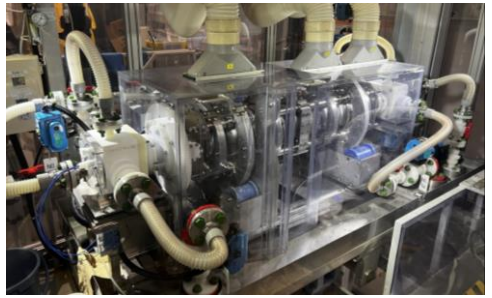
Example Workflow of Cavity Treatment before Test

Inspection



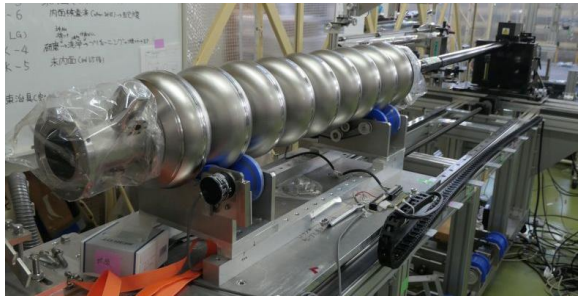
Annealing

Bulk Electro Polishing

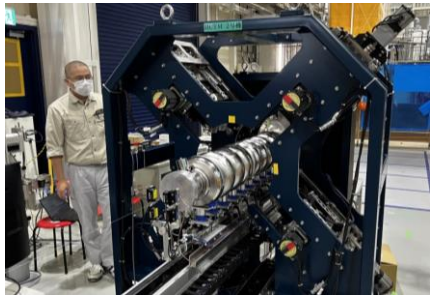


High Pressure Rinsing

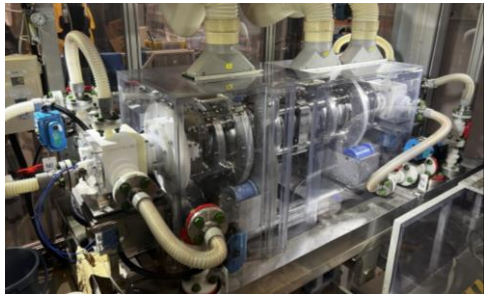
Inspection / Grinding



Tuning / Straightening



Electro Polishing



High Pressure Rinsing

Assembly

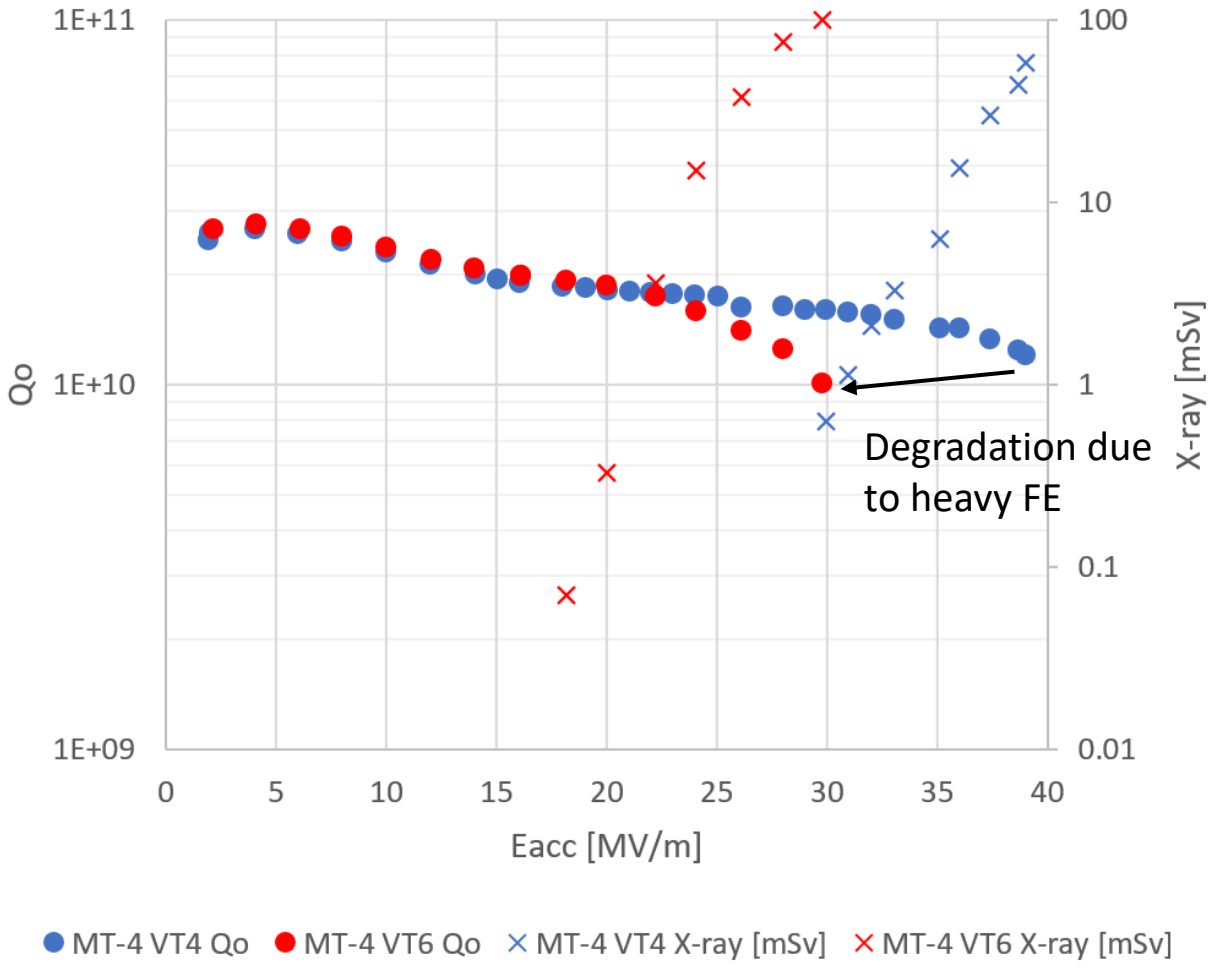
Baking

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

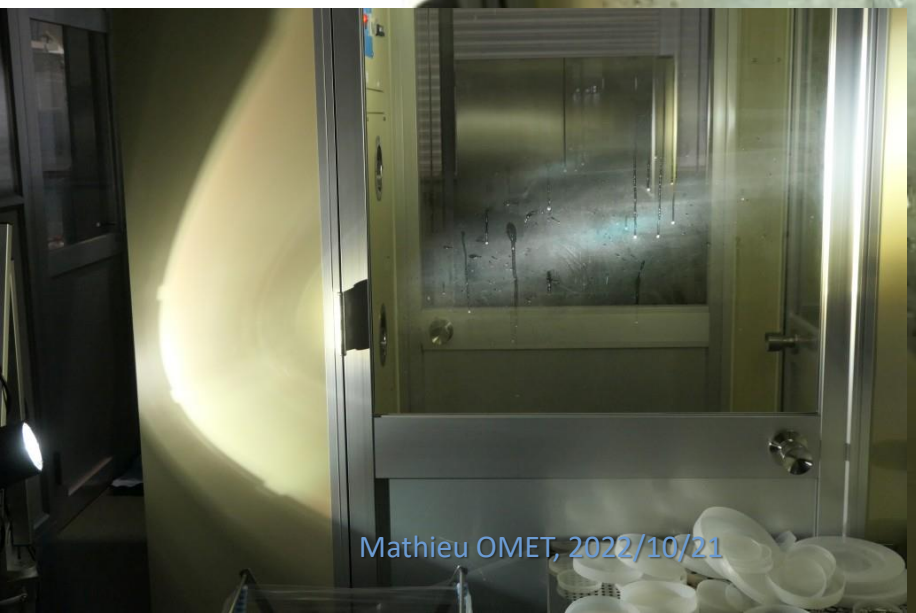


Clean Room Survey
Normal Light

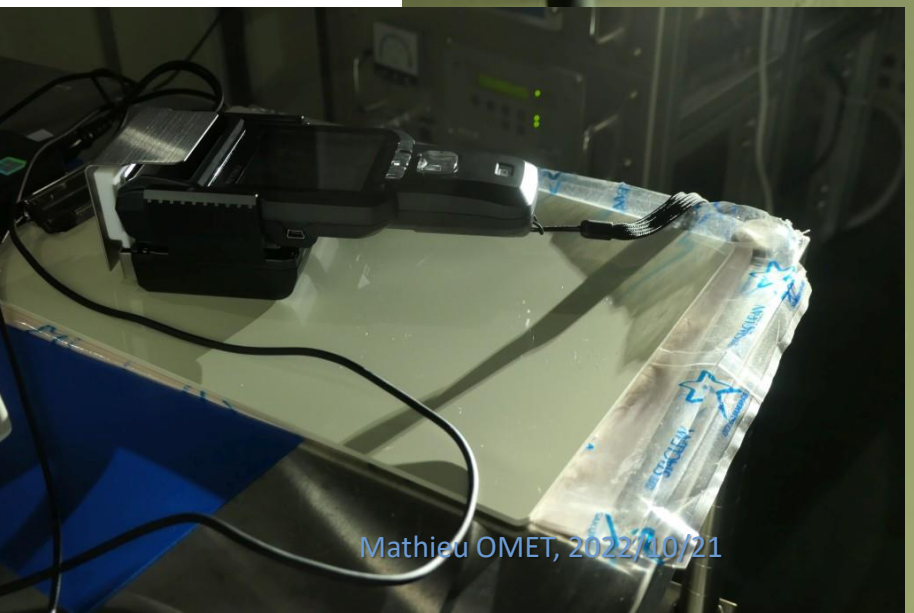
- Turned off all ambient lighting in STF class 1000 clean room (C1000CR) and class 10 clean room (C10CR)
- Used spotlight to illuminate surfaces in C1000CR

C10CR Airlock South Door

C10CR Airlock North Door

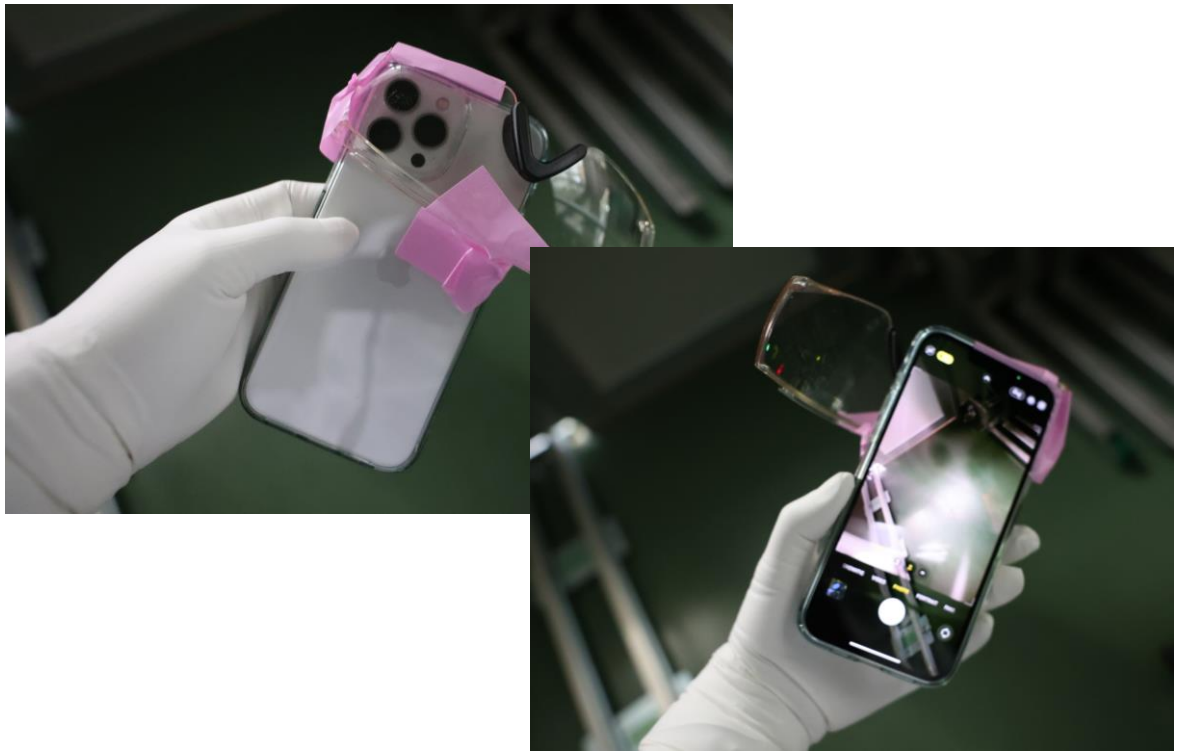


Dust and Fiber Particles on Table Beside Pumping Station

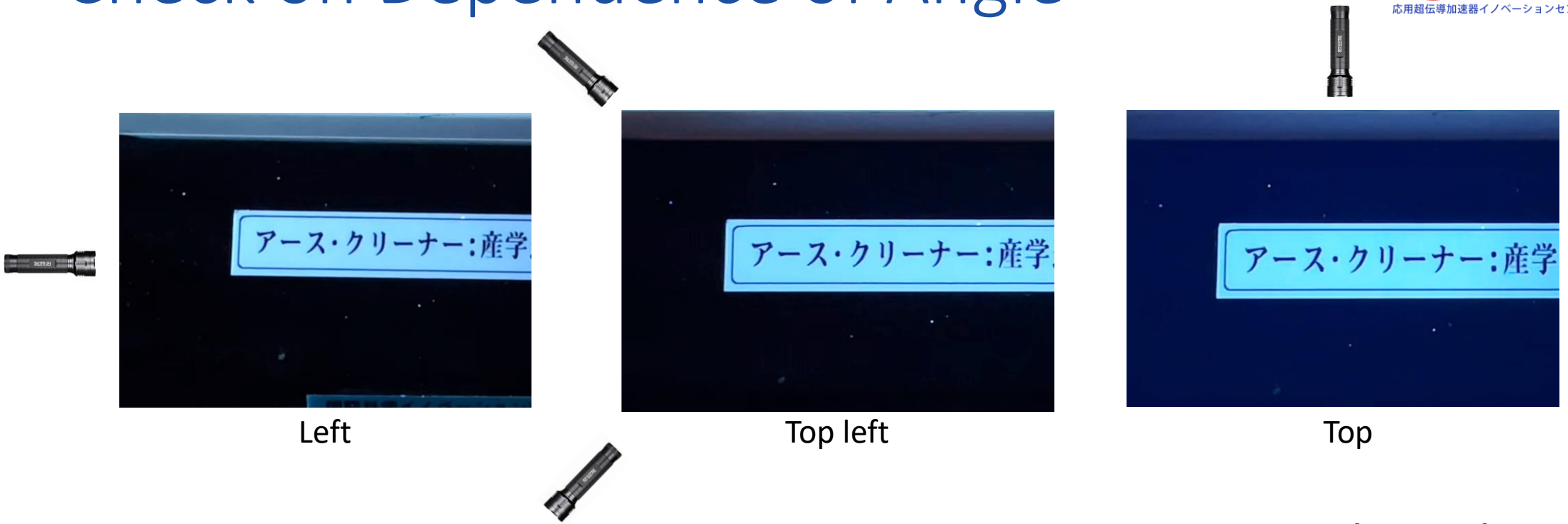


Clean Room Survey
D light

- Evaluate the capability of the D light to find dust in the clean room
- Evaluate the dust in the clean room using D light
- Light source used:



Check on Dependence of Angle



Left

Top left

Top

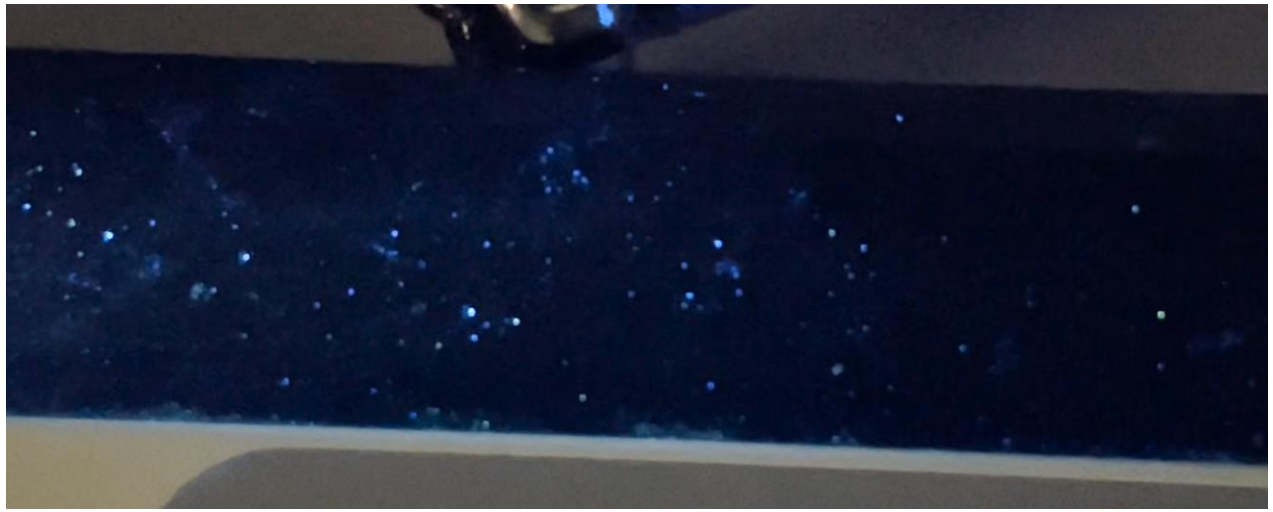
Top right

Right

- No dependence from left, top, right
- Little dependence when in direction or opposite direction of the camera

Confirm that we actually do see Dust

- Sample surface: housing of HELEN (Helium leak detector)
- Initial situation

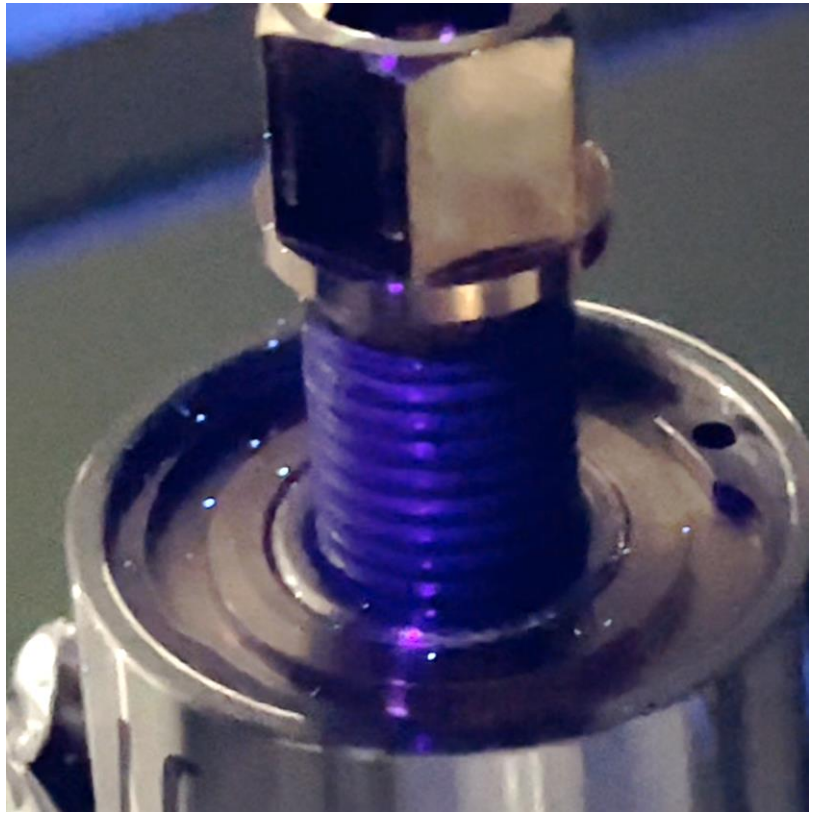


- Air blow, wipe with alcohol, air blow again
- Final situation

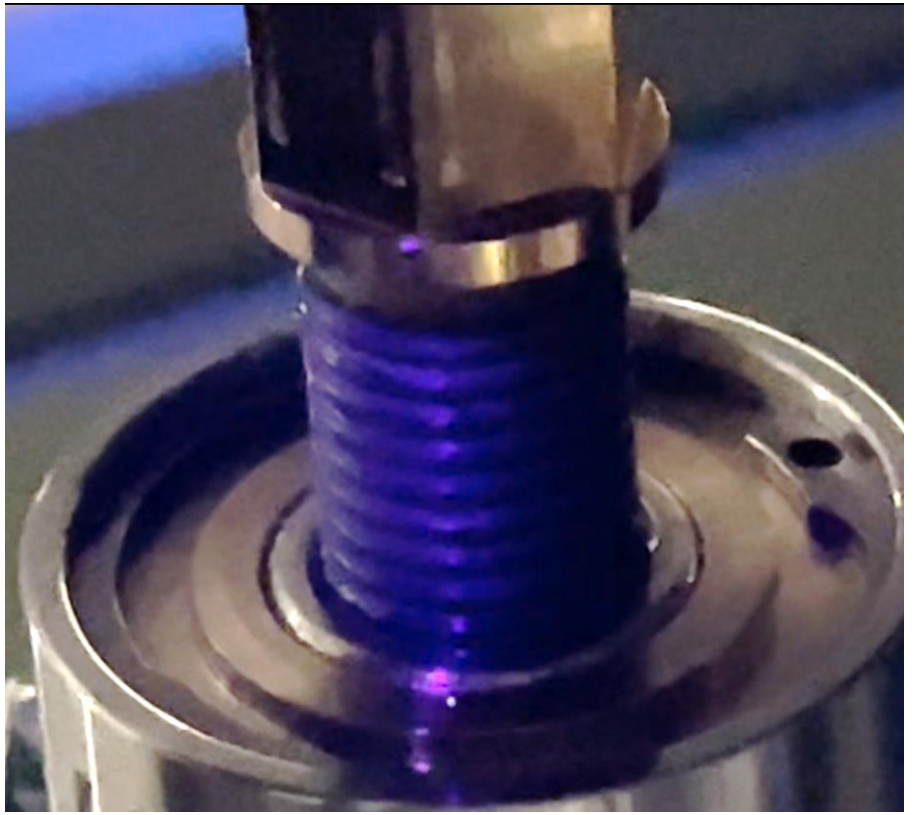
- A lot of dust was removed
- It is indeed dust we see

Checking other Surfaces with Cleaning (Air Blowing)

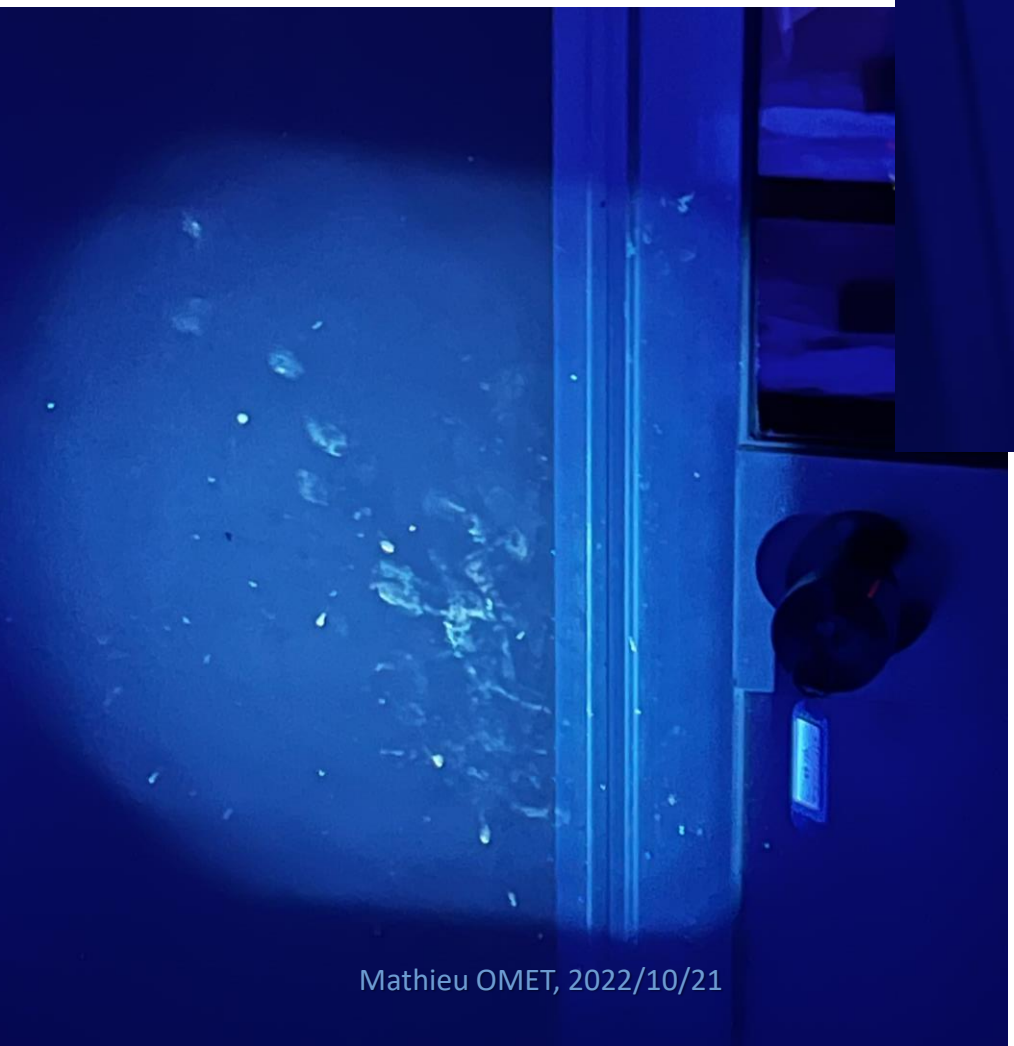
- Sample surface: valve of pumping station (ion pump)
- Initial situation

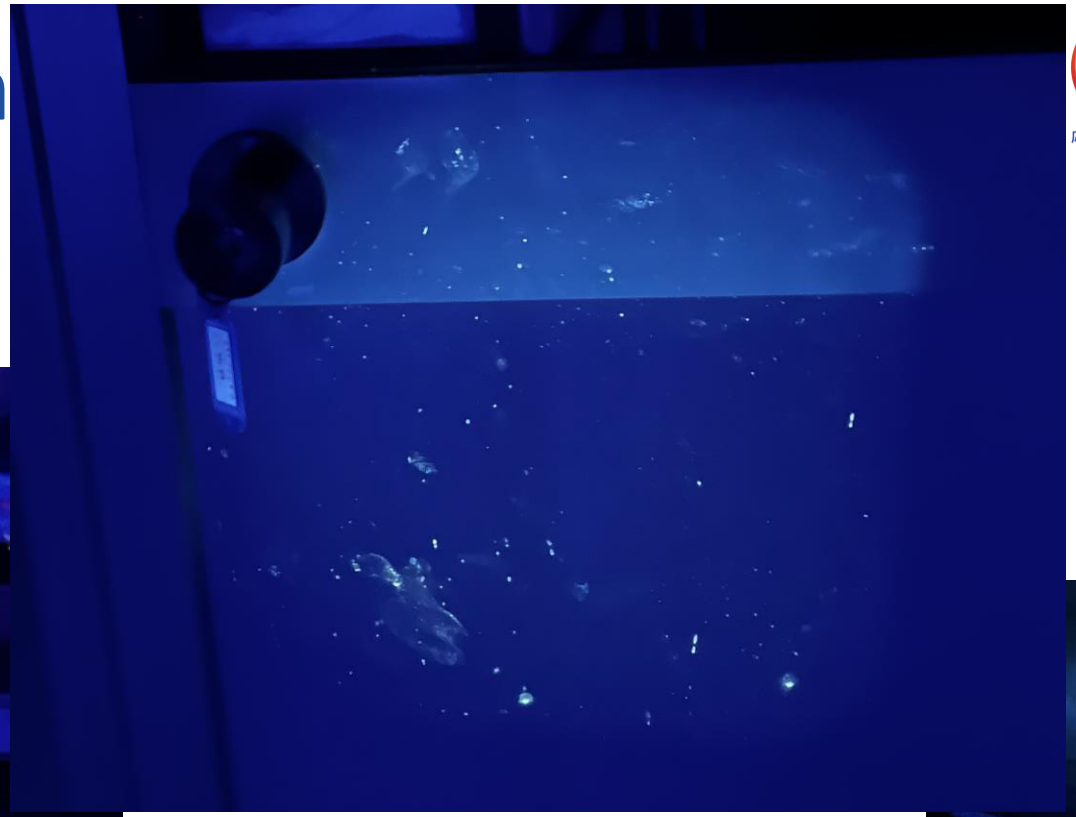


Final situation after air blowing

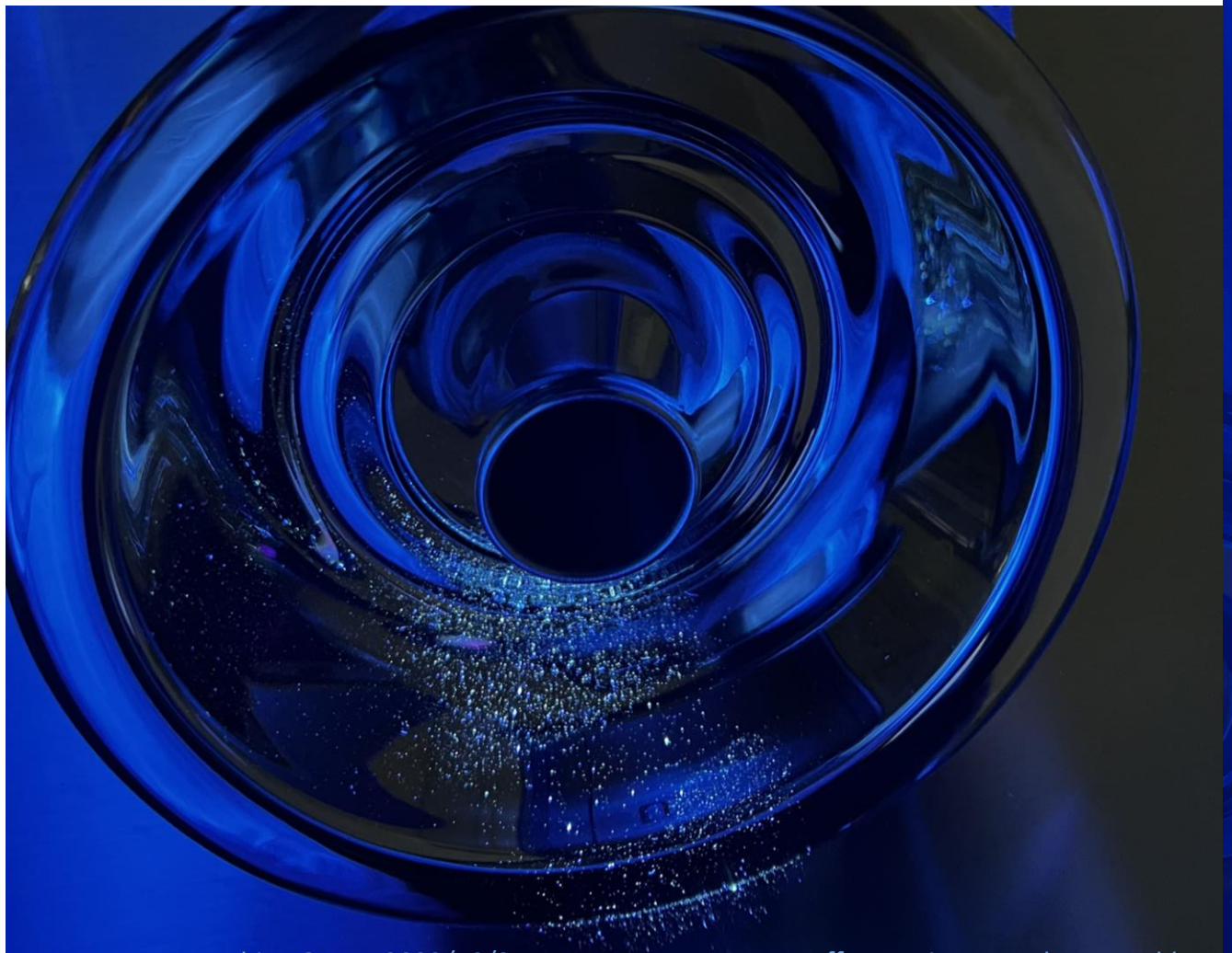


STF Changing Room Door to Air Lock

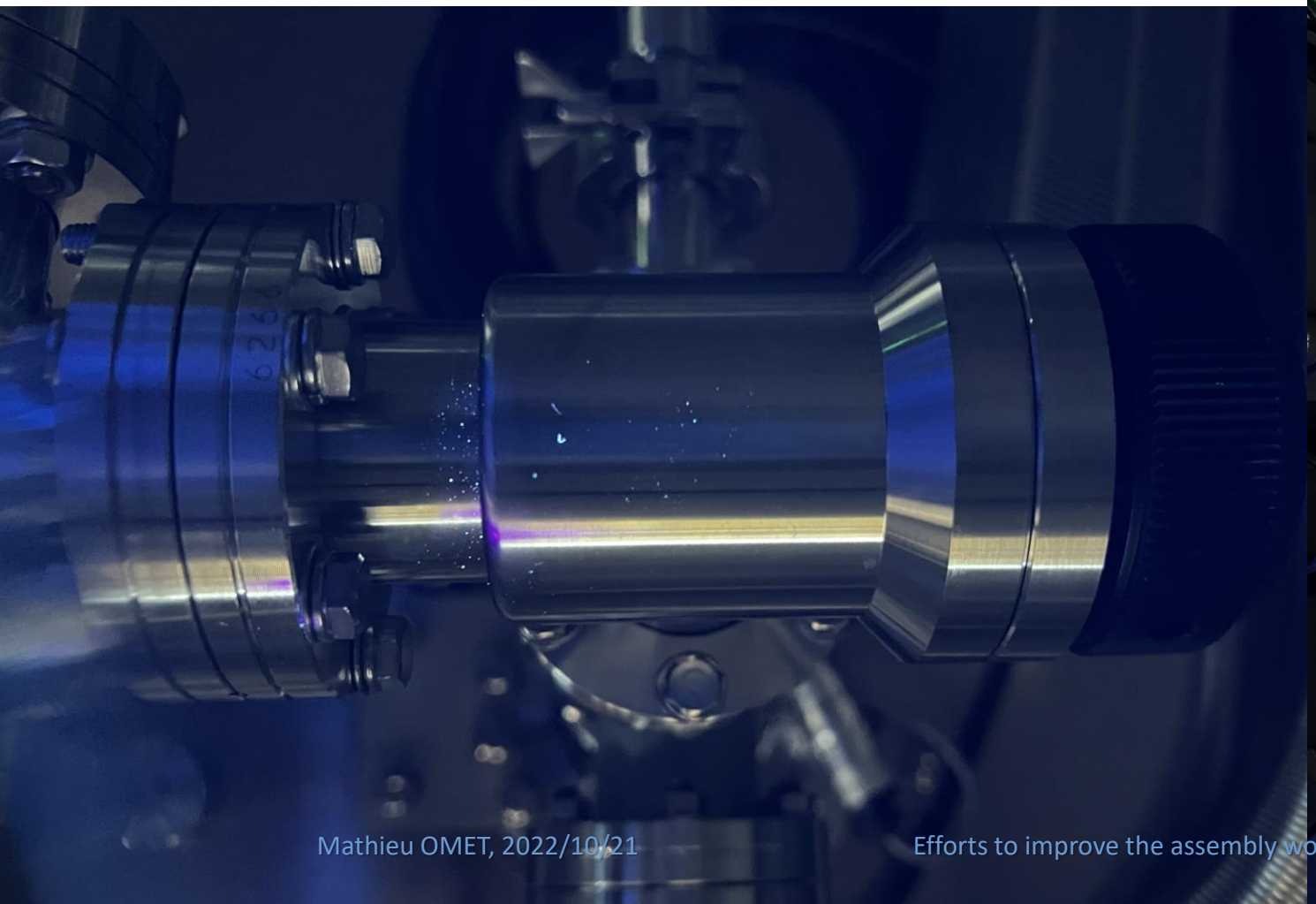


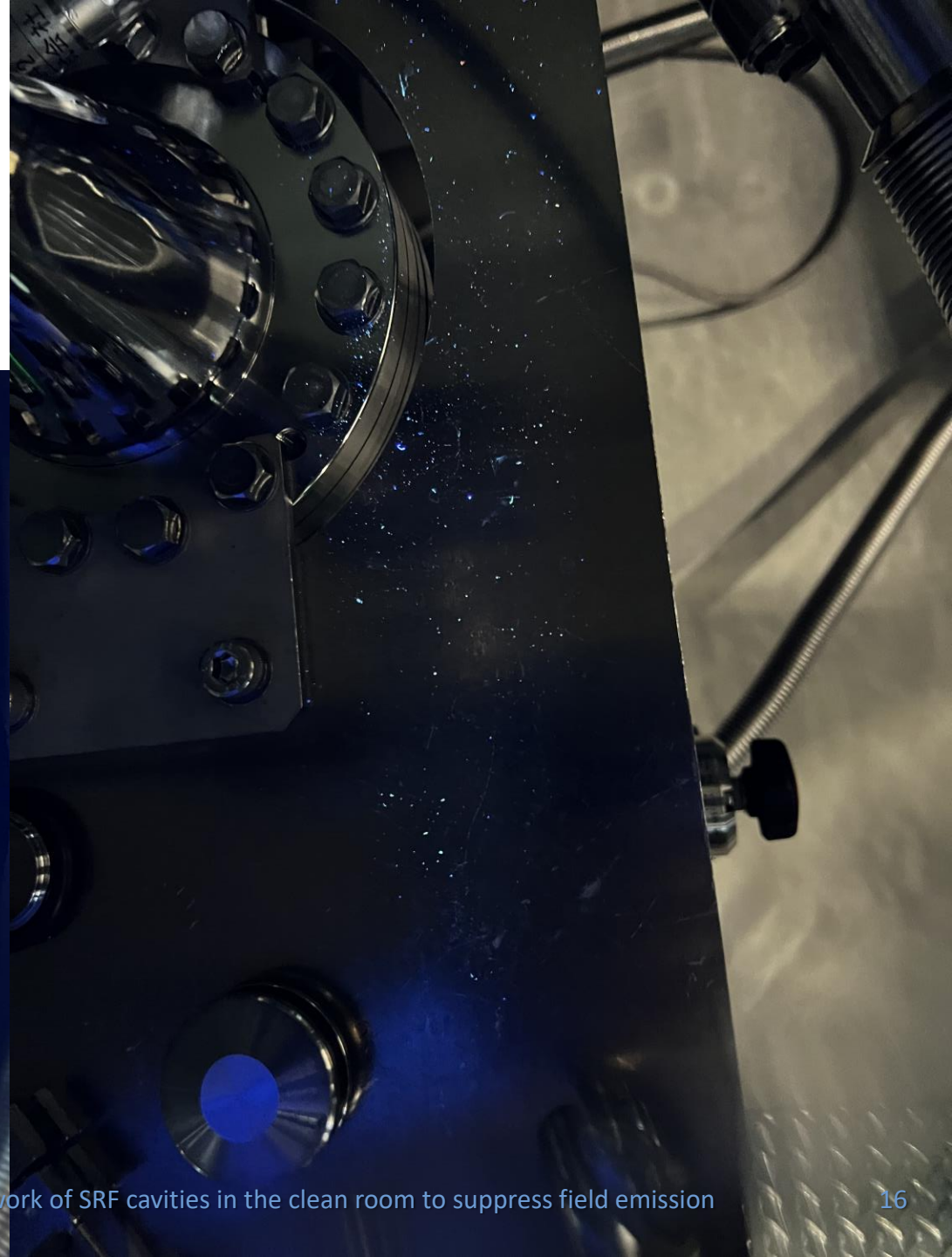


COI C1000CR – Air Lock

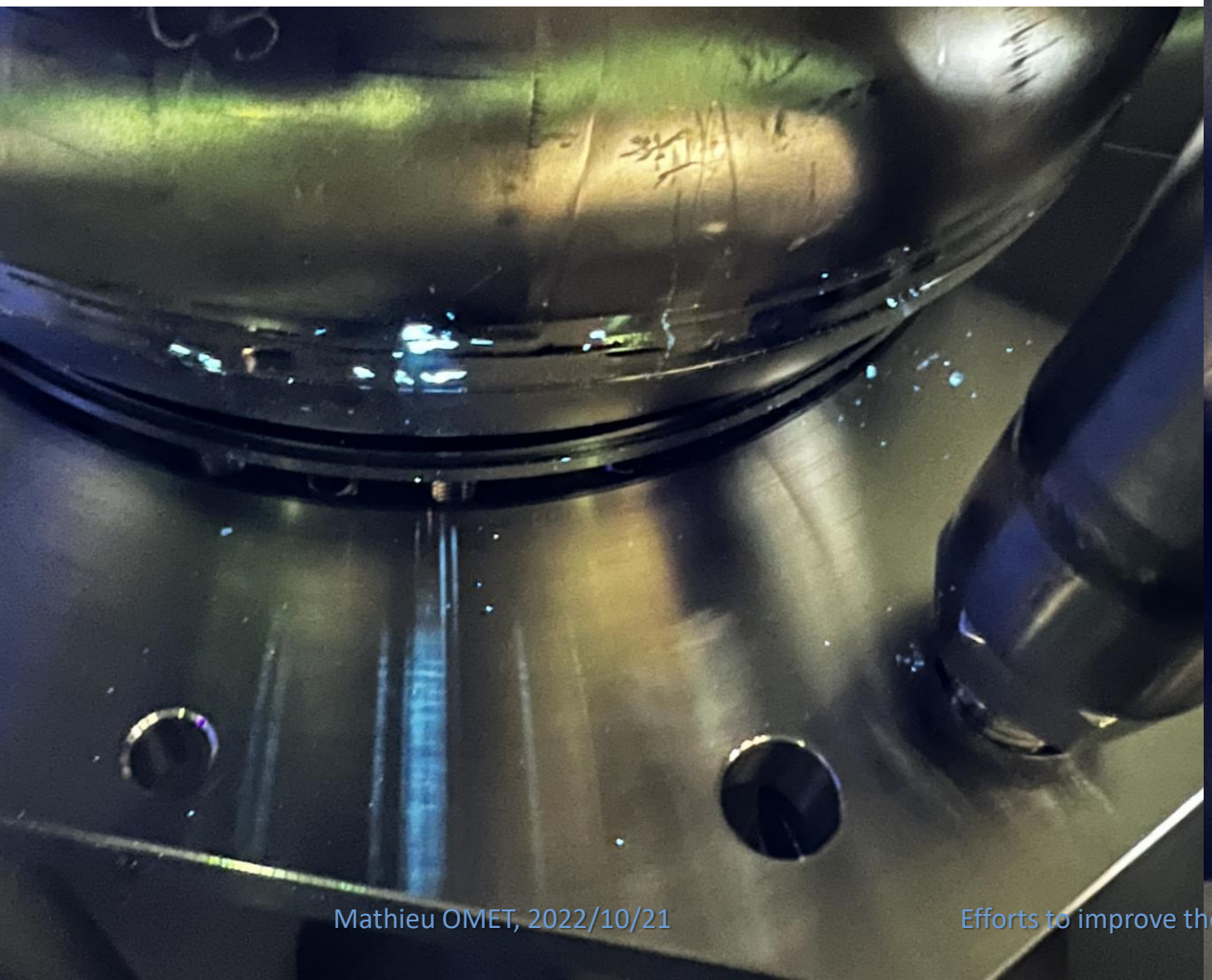


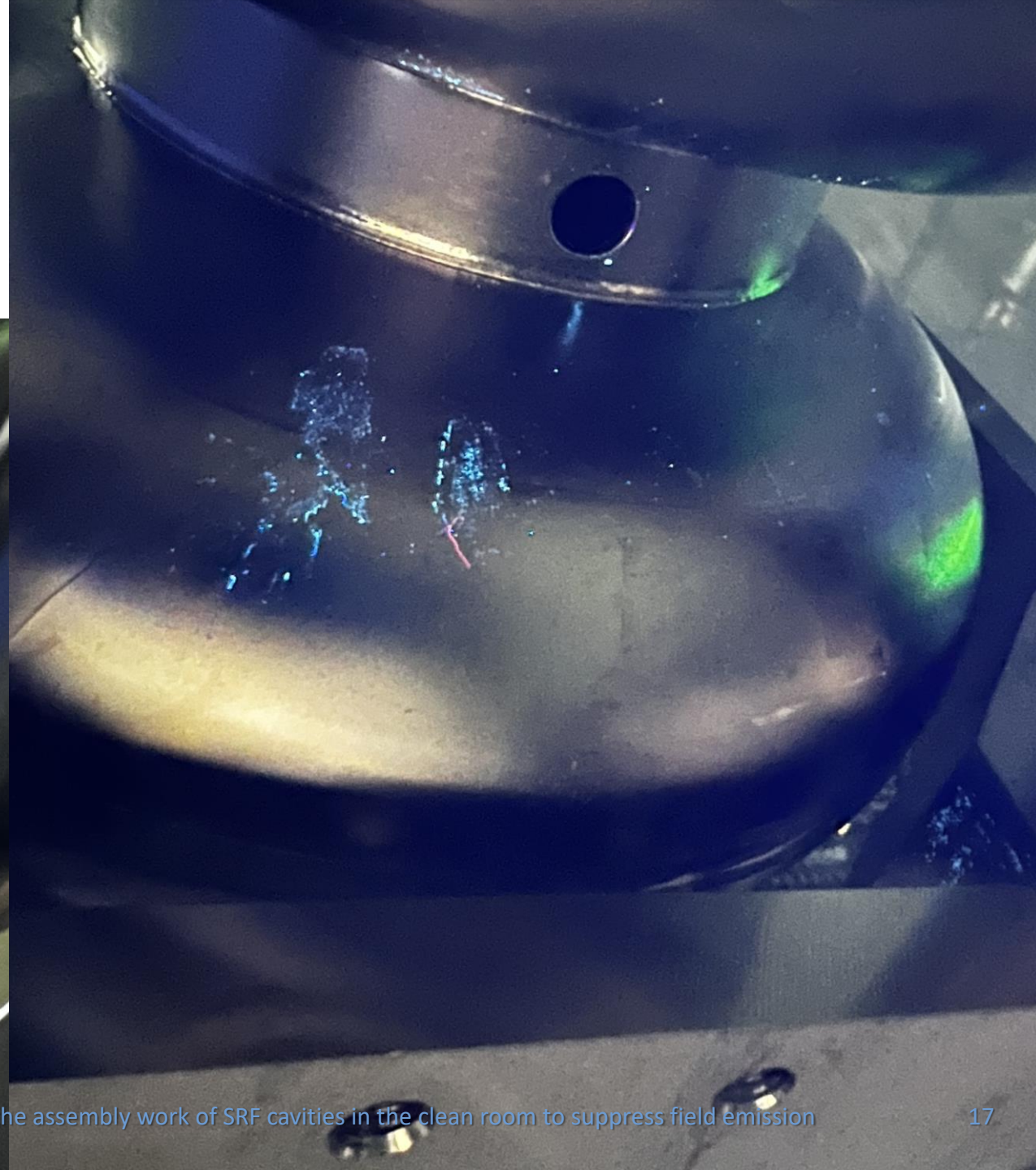
COI C1000CR – Pumping Station



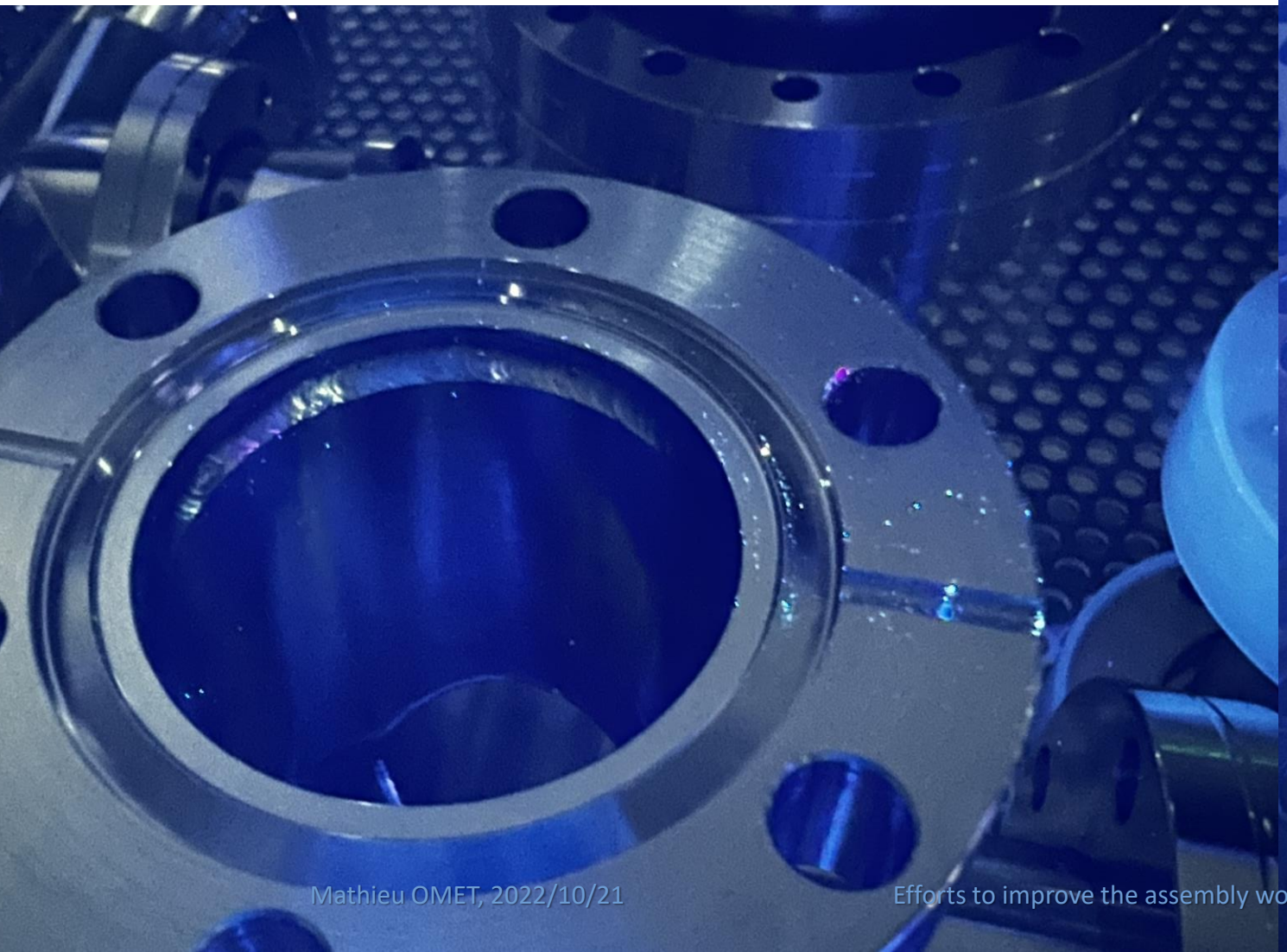


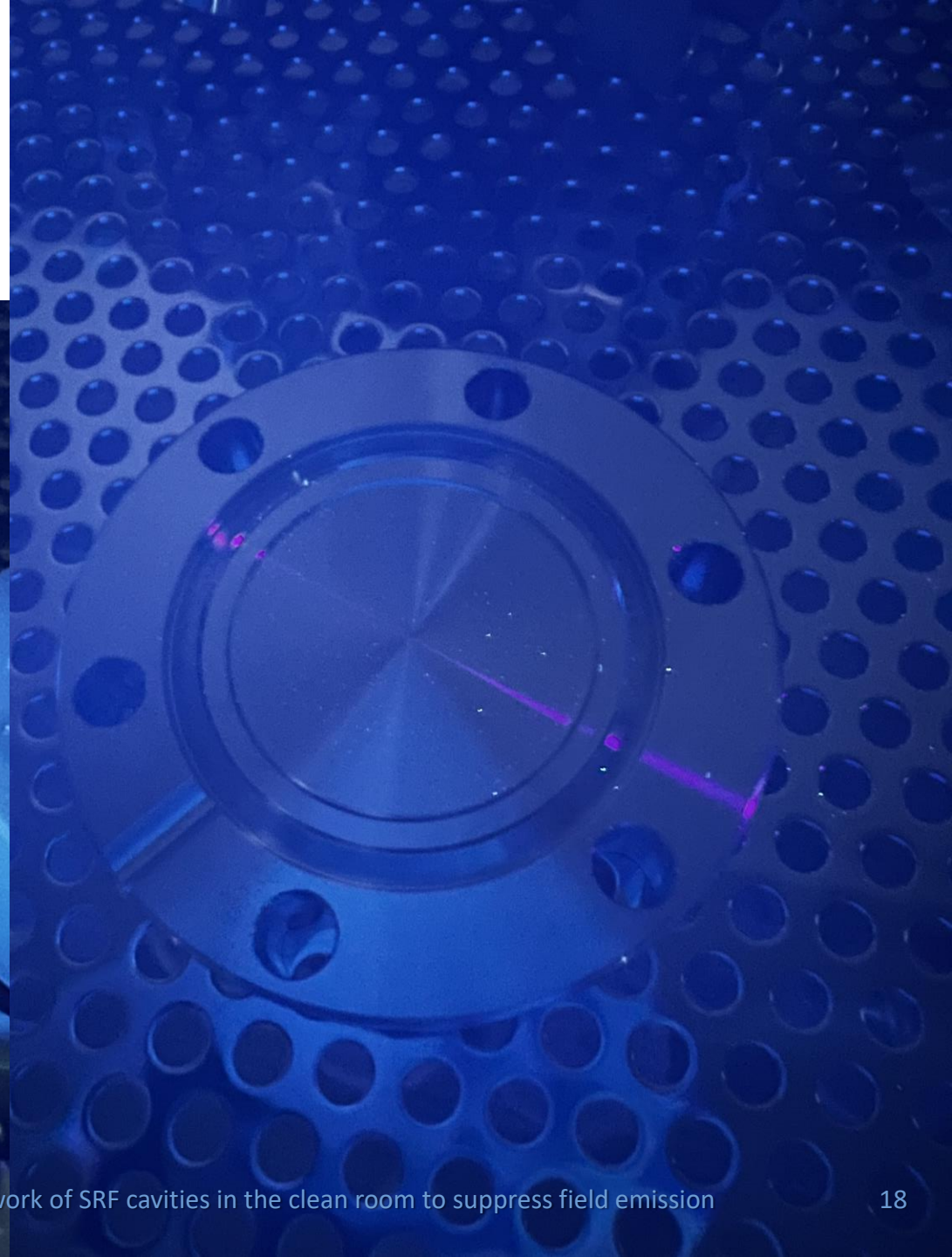
COI C1000CR – Cavity Stored in the CR





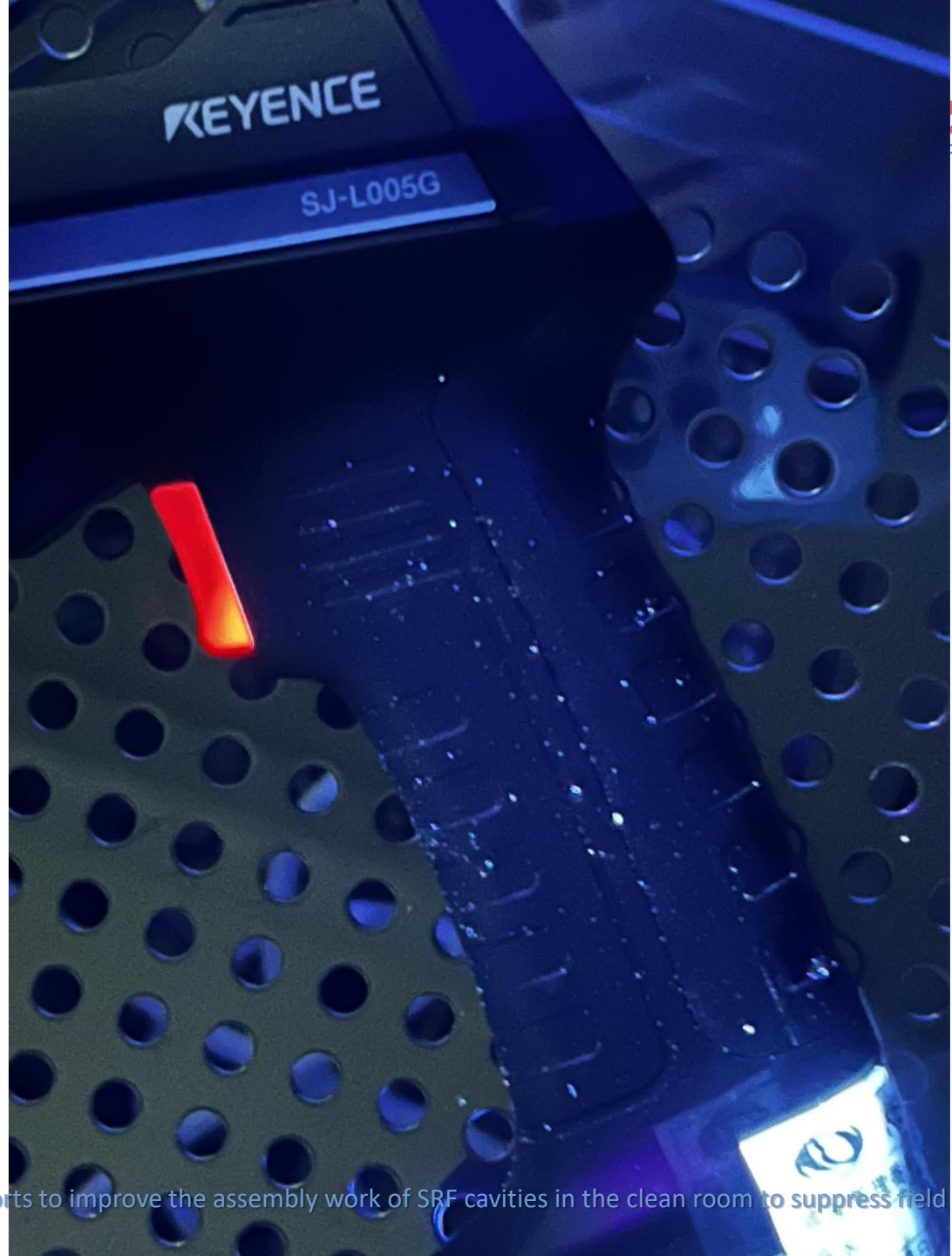
COI C1000CR – Items Stored in Shelf



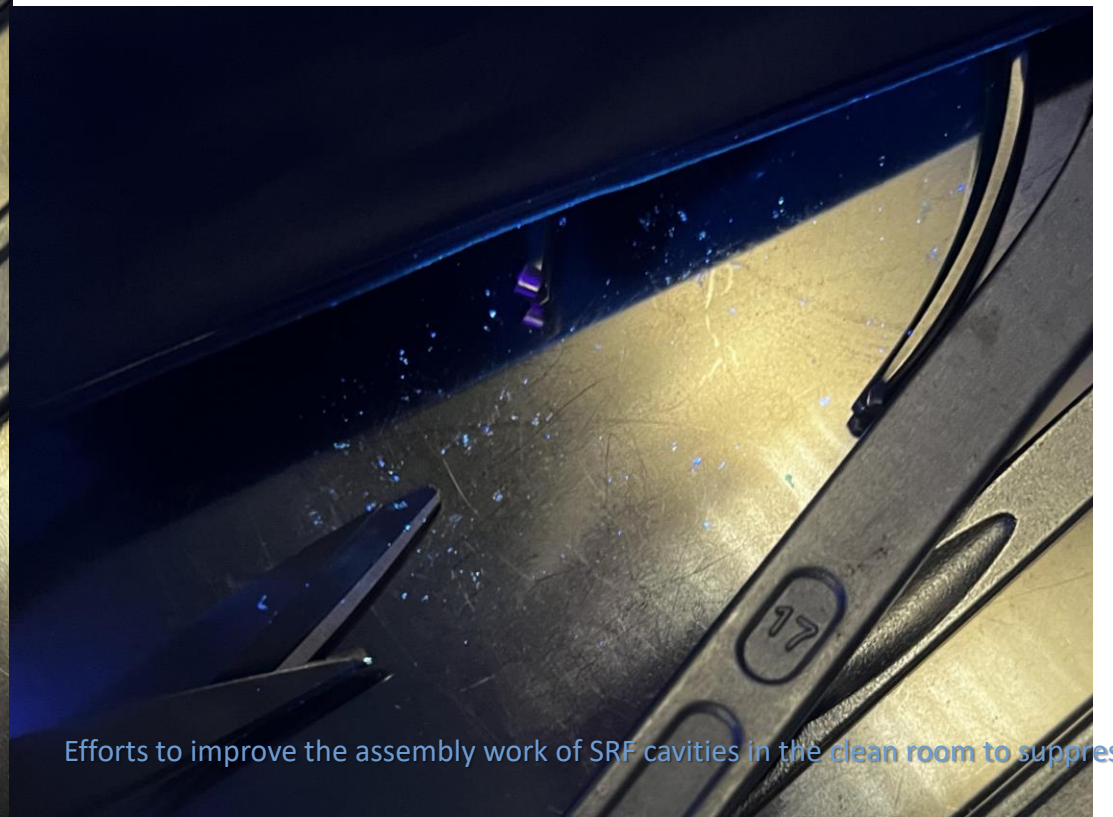


COI C1000CR – Items Stored in Shelf

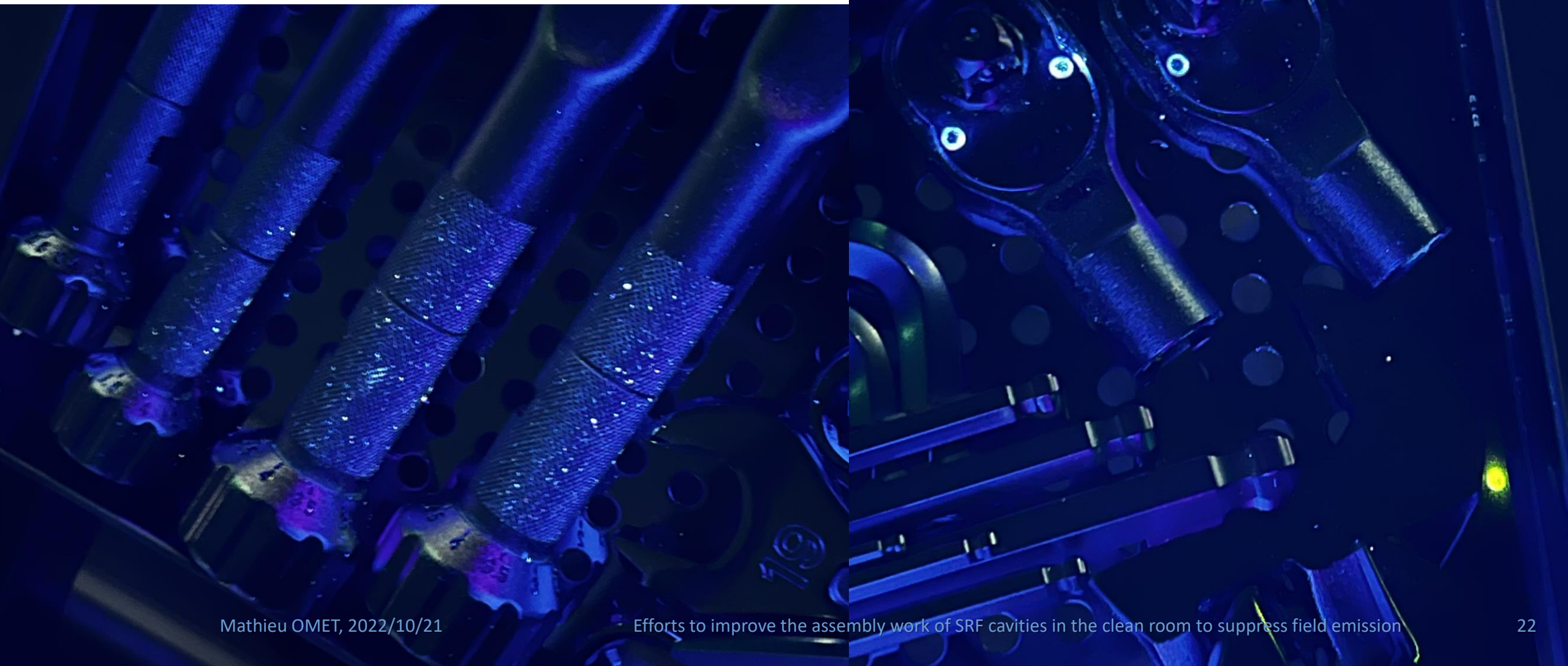
COI C10CR – Keyence Ion Gun



STF C1000CR – Tray with Tools



COI C10CR – Tray with Tools



STF C1000CR - Window of Air Lock between C1000CR and C10CR

Before cleaning

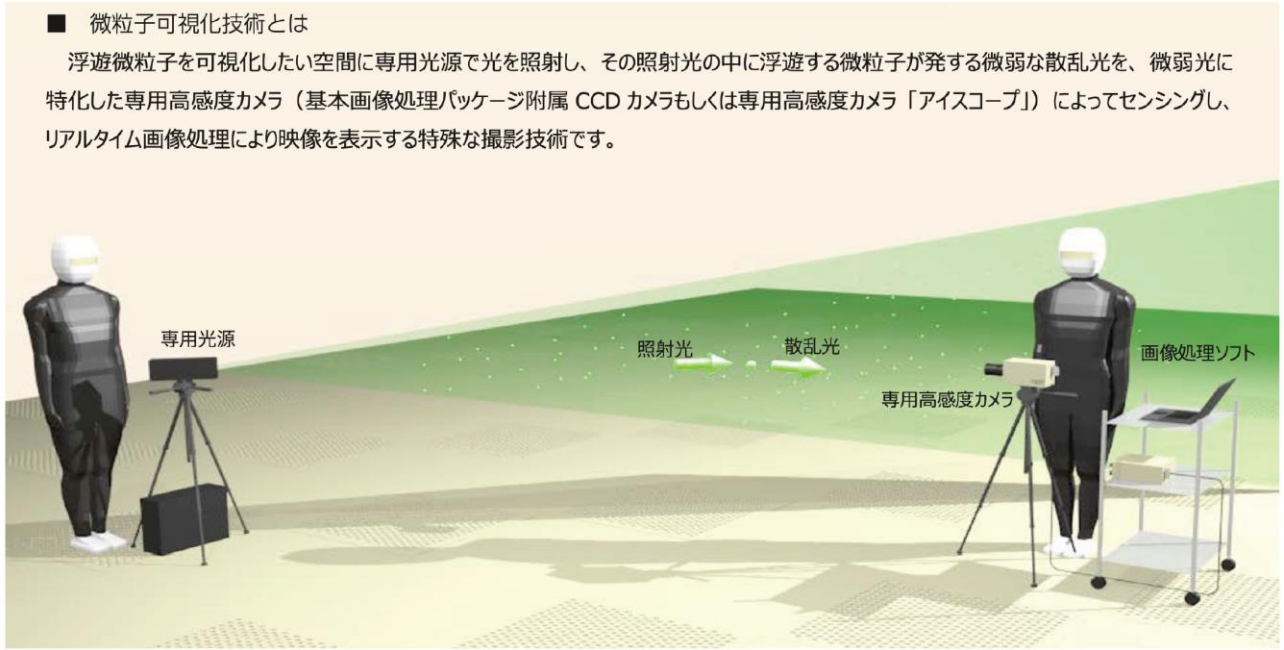
After cleaning

Conclusion of Clean Room Survey

- Using a spotlight or using D-light both allow a survey of dust and dirt on surfaces of the clean room
  - D-light is a bit more versatile
- In some areas cleaning was necessary and was applied
- It was not feasible to clean every last corner → avoid whirling up dust from there
  - Areas behind shelfs, which are used for storage
  - Torque wrenches
  - Etc.

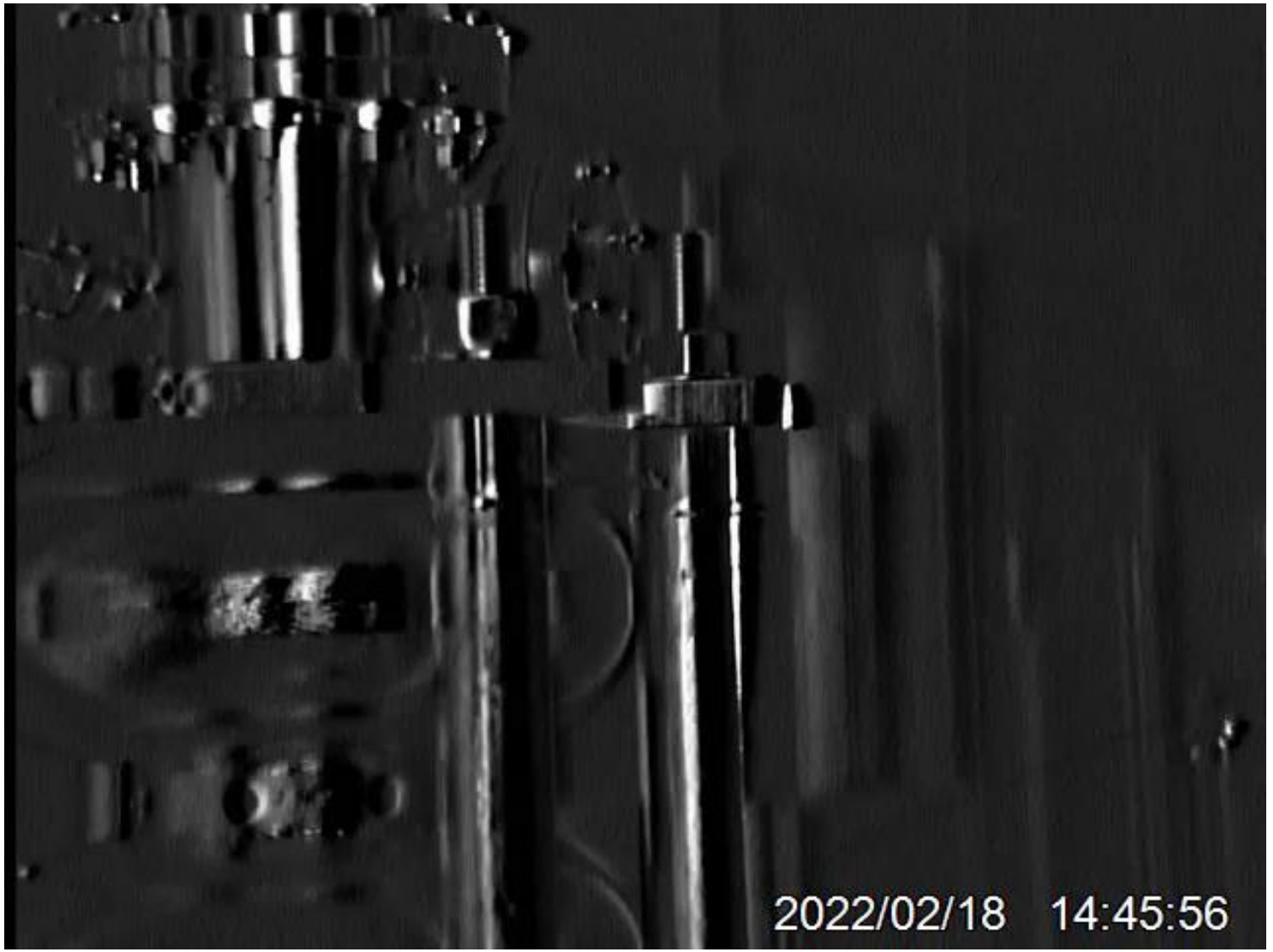
Study Particulates created during the Assembly

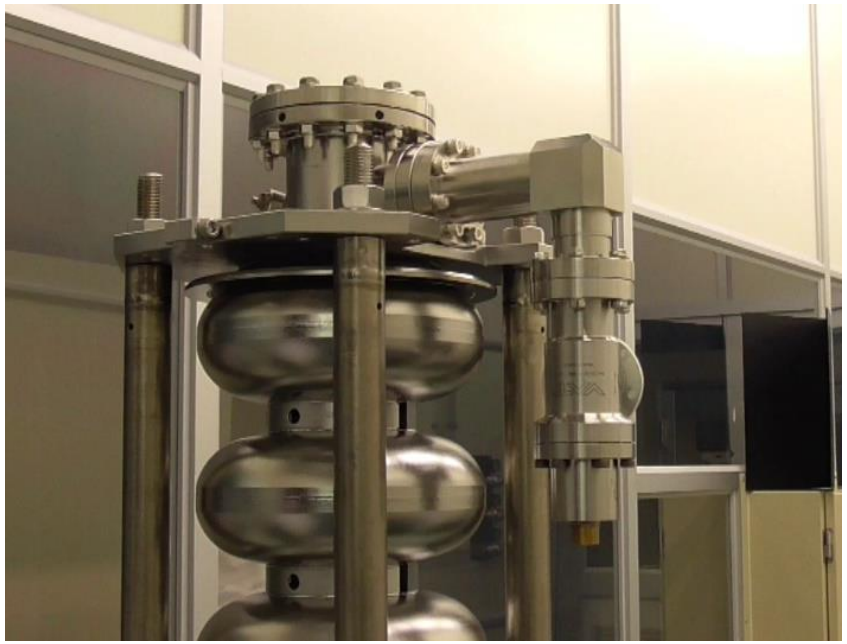
- Study performed together with SHIN NIPPON AIR TECHNOLOGIES CO.,LTD (SNK) 新日本空調株式会社
- Ambient lighting is turned off
- Green laser light is transmitted through the area of interest
- Laser light is scattered by particles
- Scattered light is recorded by a video camera

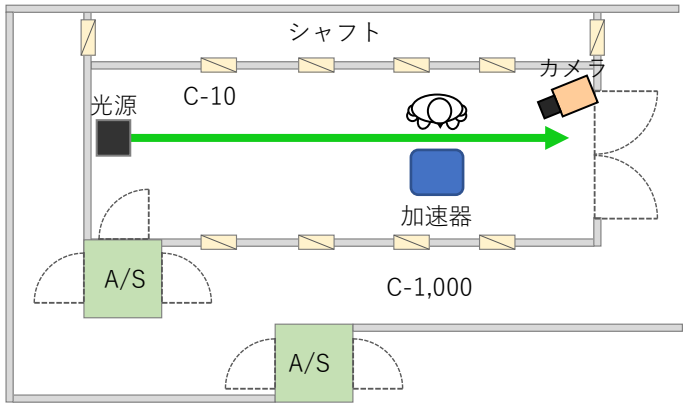


Masking of the Clean Room Windows

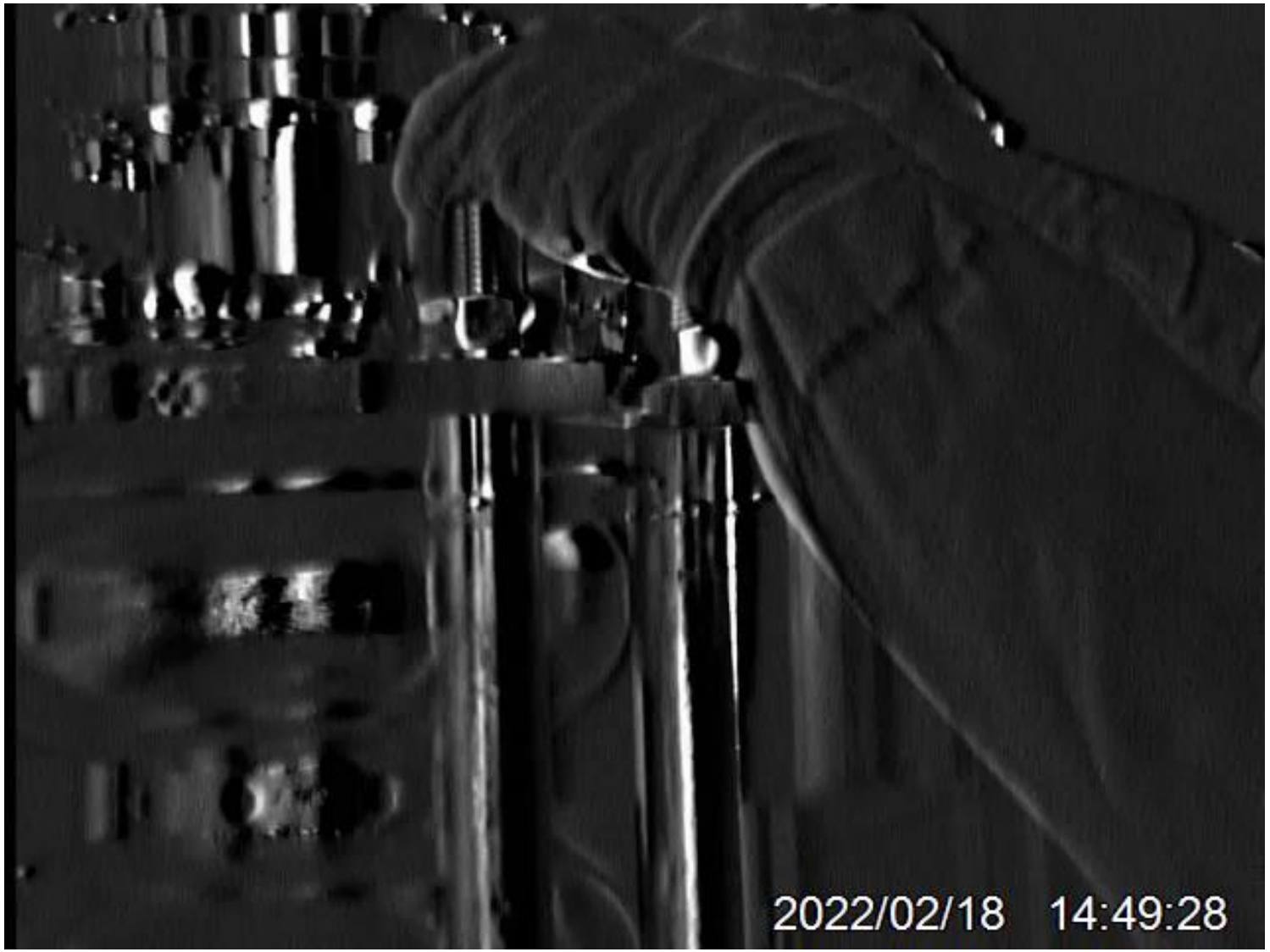
Clean Blowing

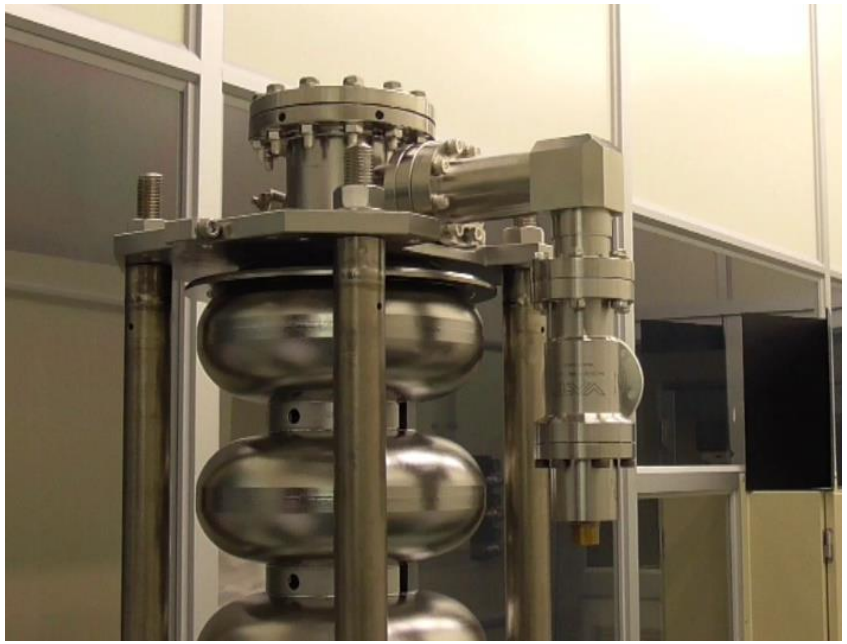


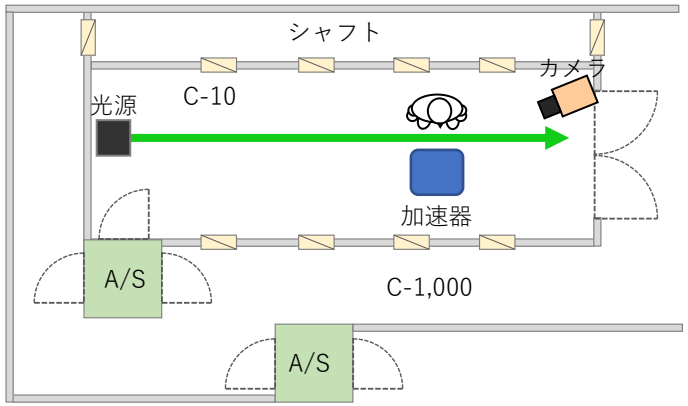




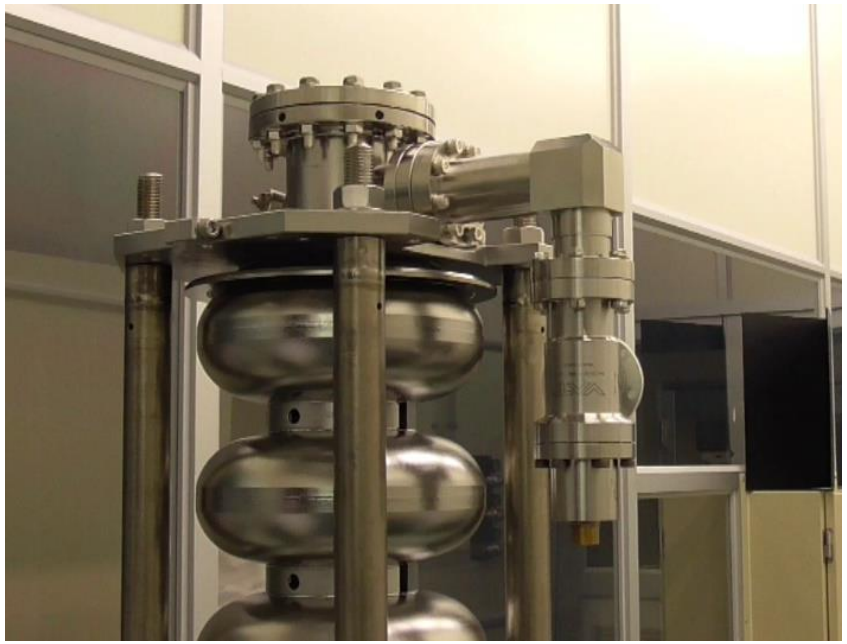
Release of Bolts of Blind Flange

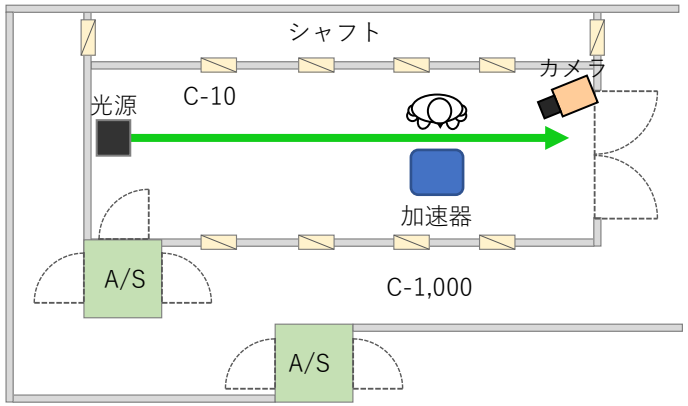






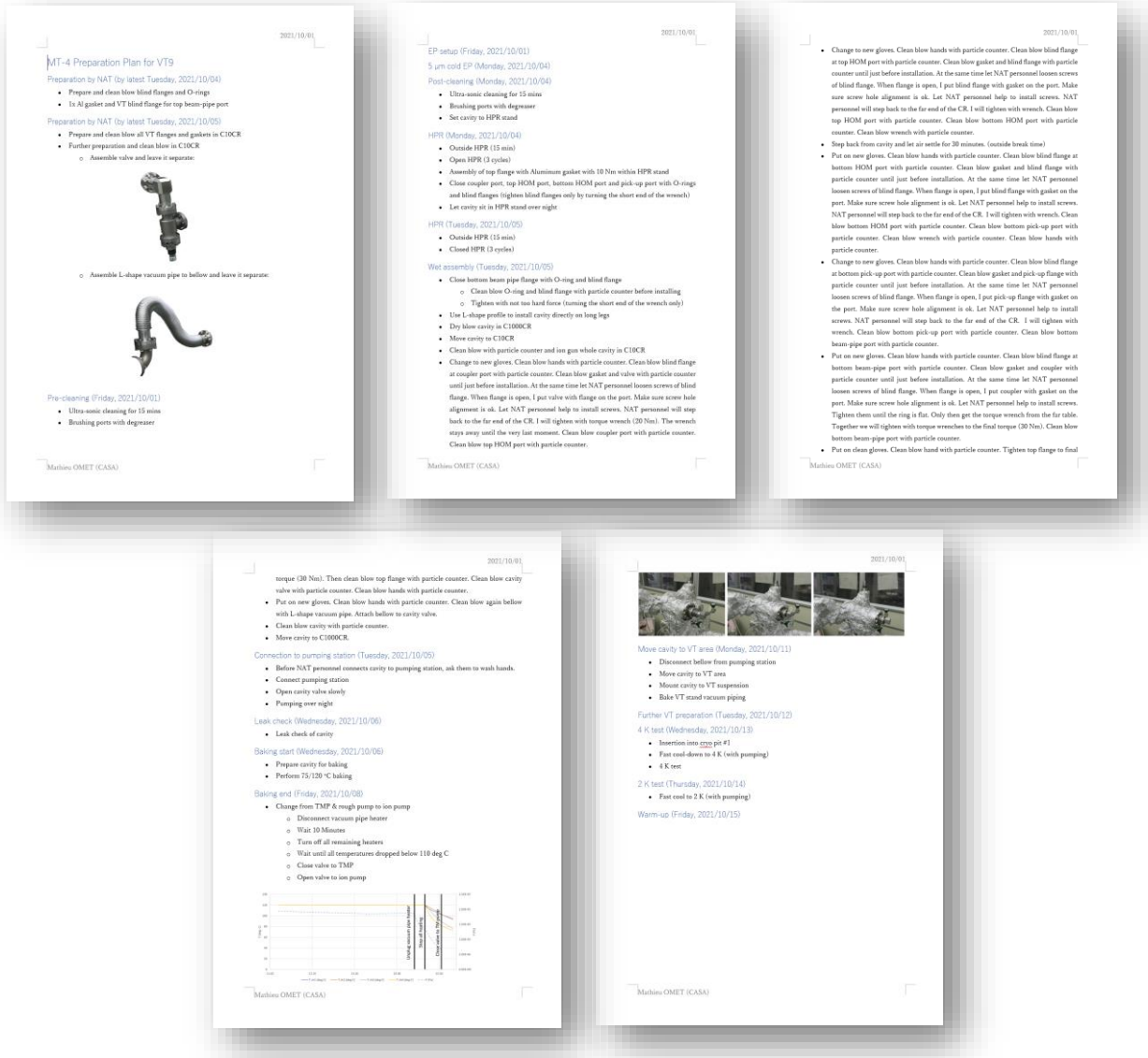
Tightening Bolts of Attachment



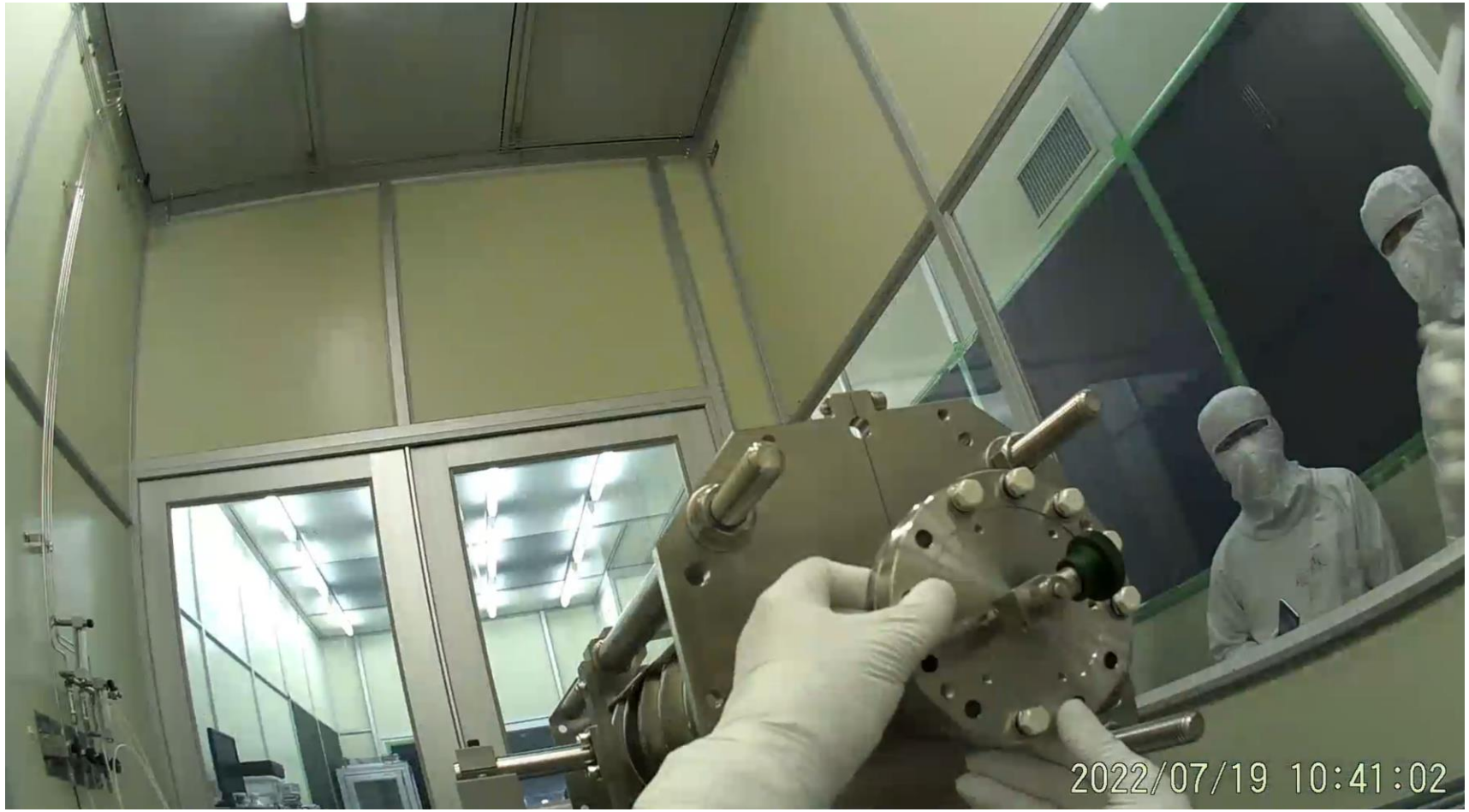


Work Plan for Assembly

- 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



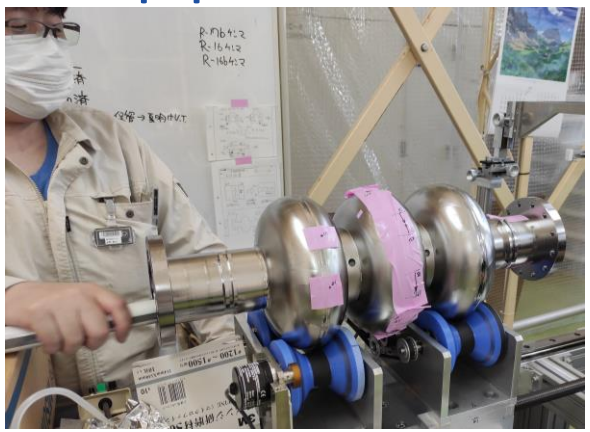
Picture courtesy of T. Dohmae

Analysis of Assembly Work

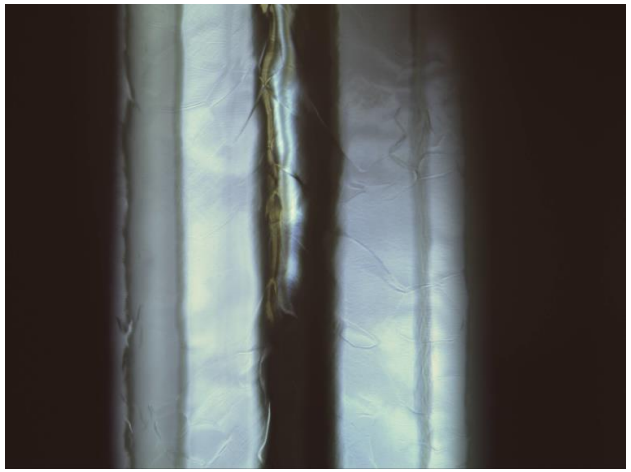
- After the assembly divergence from the work plan are noted down
- Recorded pictures and videos are shared with all group members via internal services (picture gallery, cloud storage, electronical logbook)
- A work report is compiled (typically a Power Point presentation) and discussed with all group 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, θ = 0 deg.

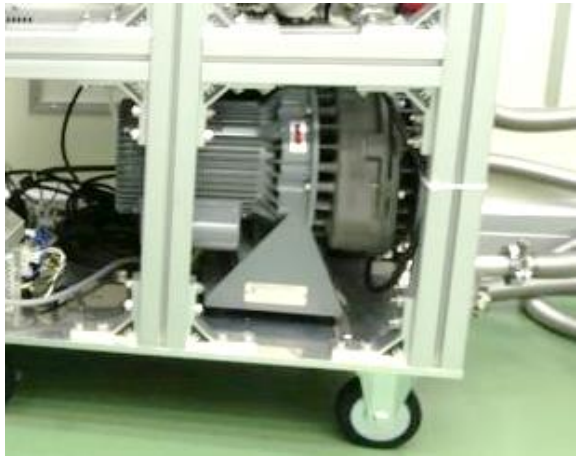
MT-4 (9-cell cavity)
3-4 iris, θ = 162 deg.

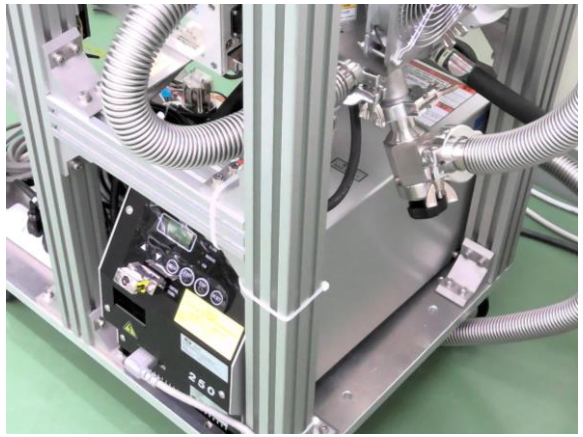
Further Measures to Suppress Field Emission

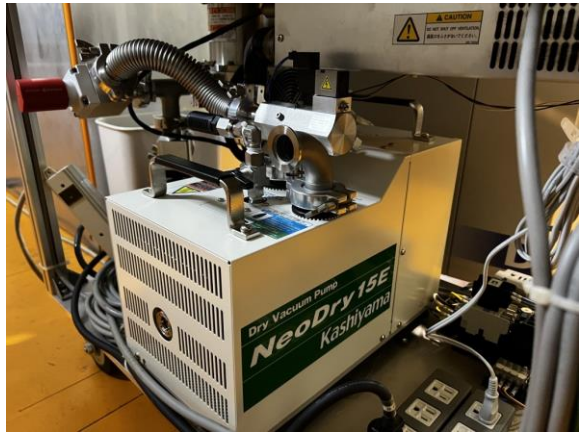
- Exchange ion gun from TOP GUN to KEYENCE SJ-L005G with filter

Further Measures to Suppress Field Emission

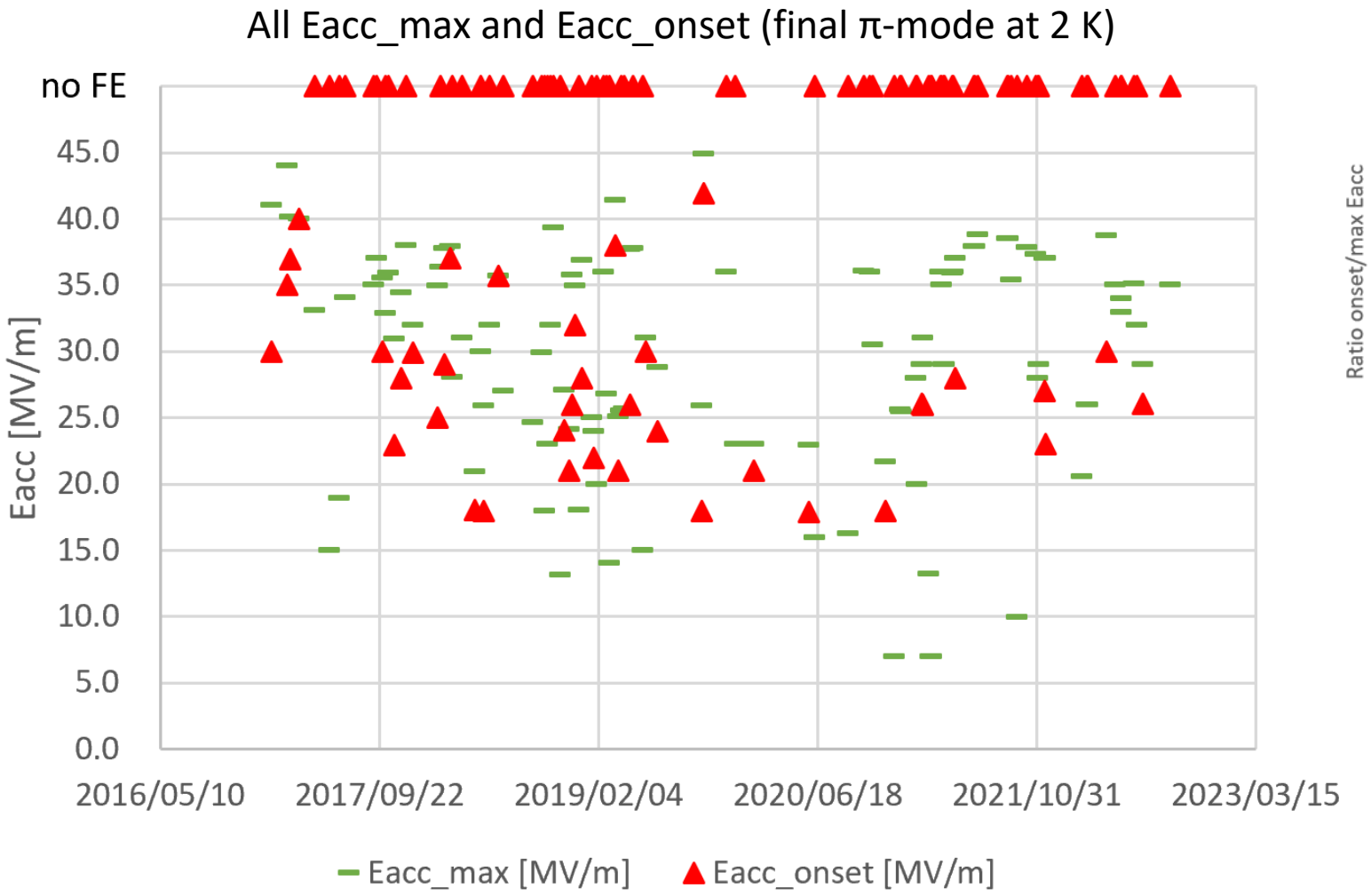
- Exchange the scroll pump with dry pump in clean room and at VT stand

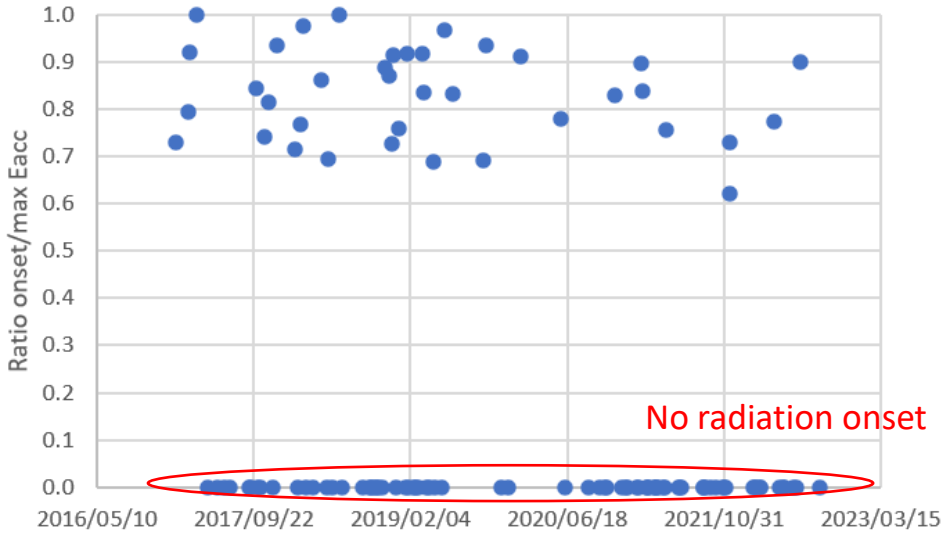






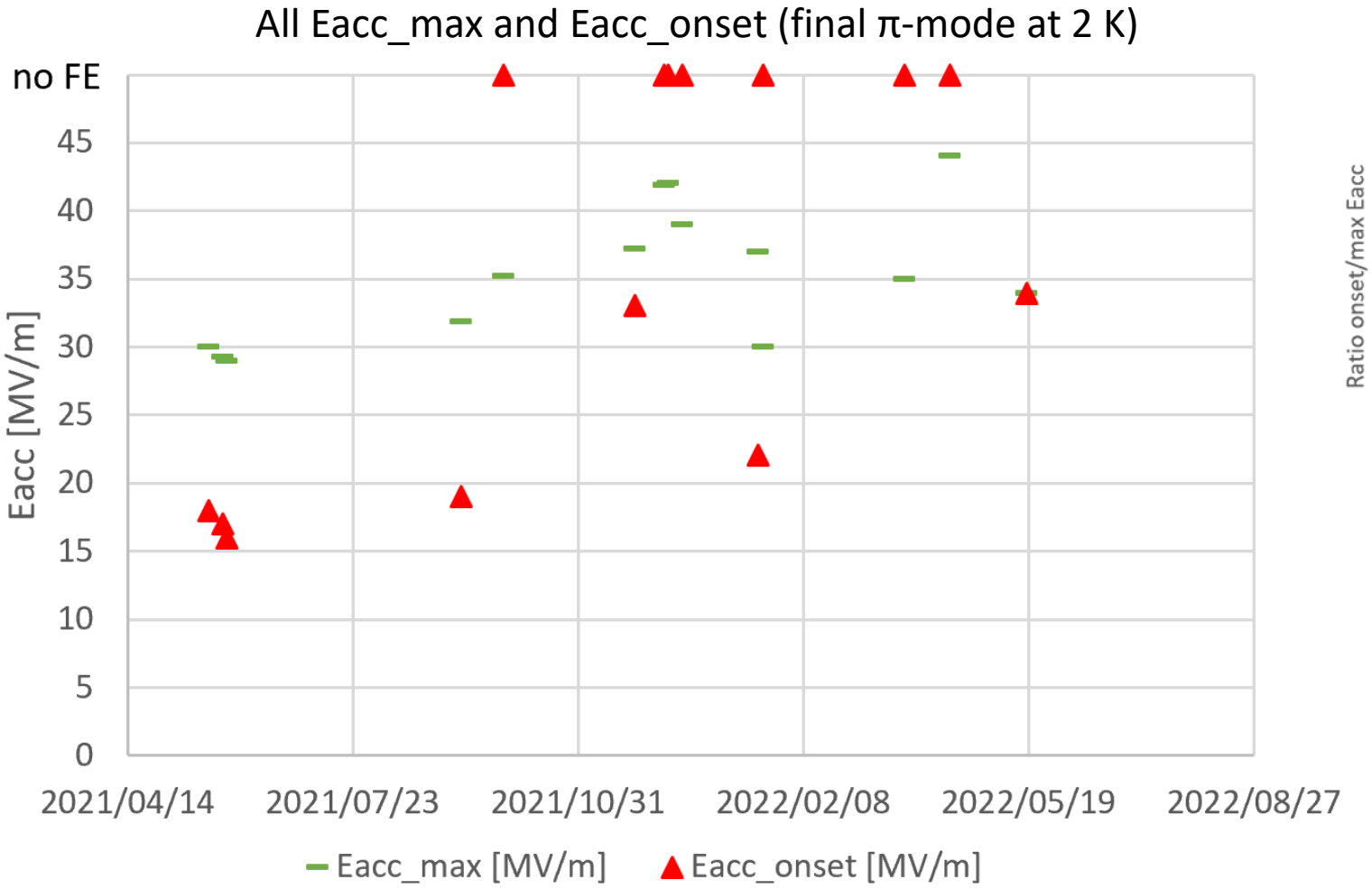
History of Field Emission in single-cell Cavities

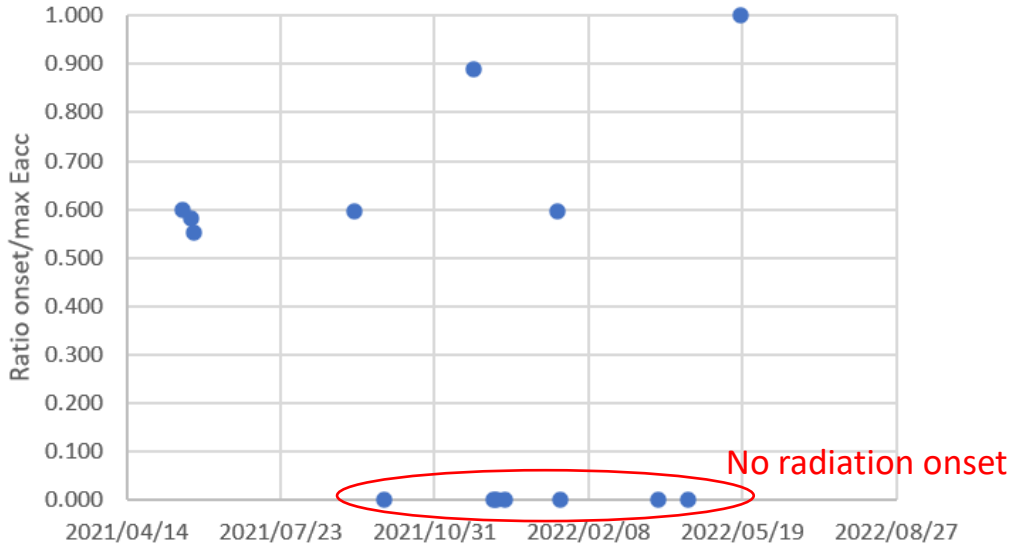




Number of VTs	112
VTs with radiation	37 (33.0%)
VTs w/o radiation	75 (67.0%)
Mean Eacc_onset	27.3 MV/m
Mean ratio (onset/max)	0.832

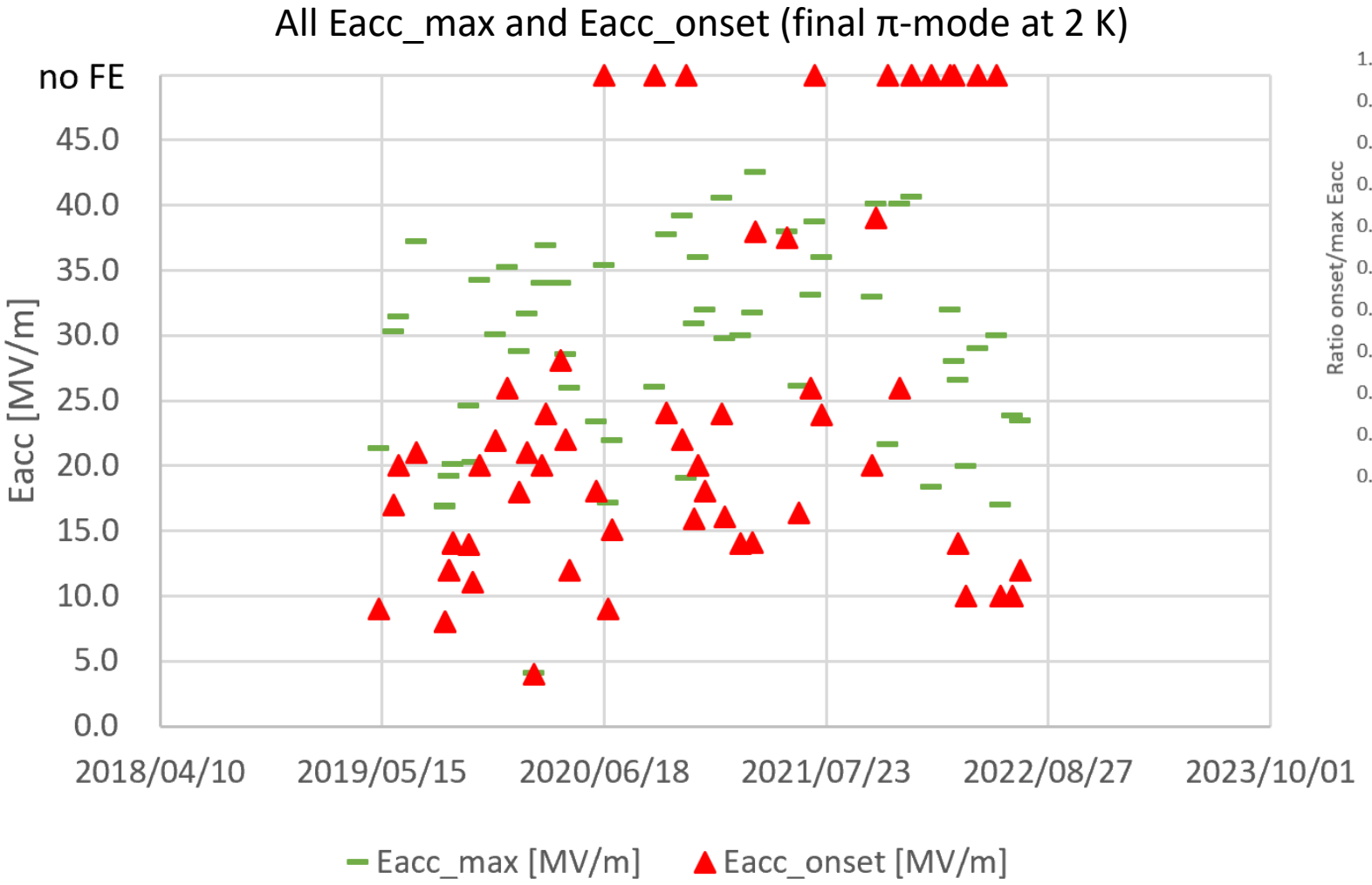
History of Field Emission in 3-cell Cavities

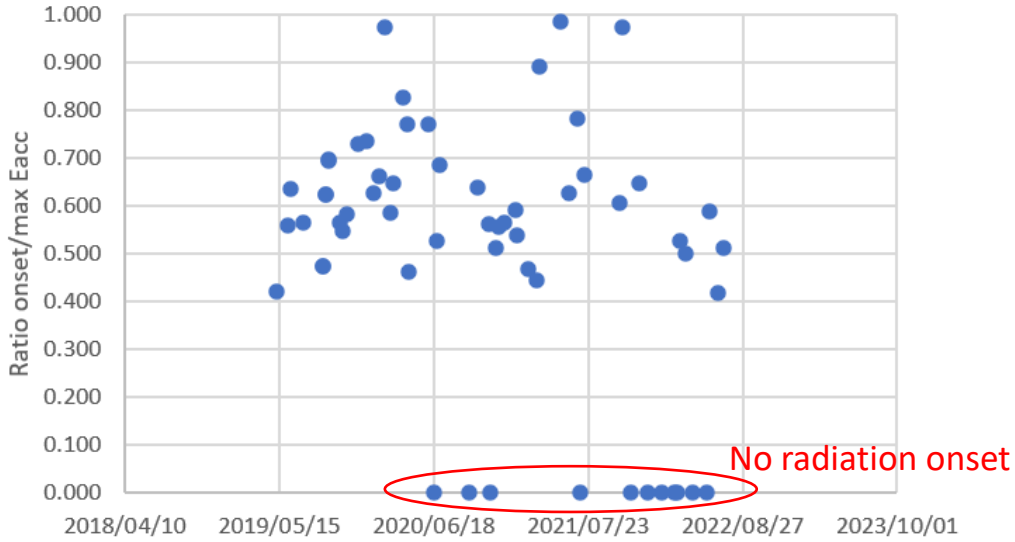




Number of VTs	14
VTs with radiation	7 (50.0%)
VTs w/o radiation	7 (50.0%)
Mean Eacc_onset	22.7 MV/m
Mean ratio (onset/max)	0.688

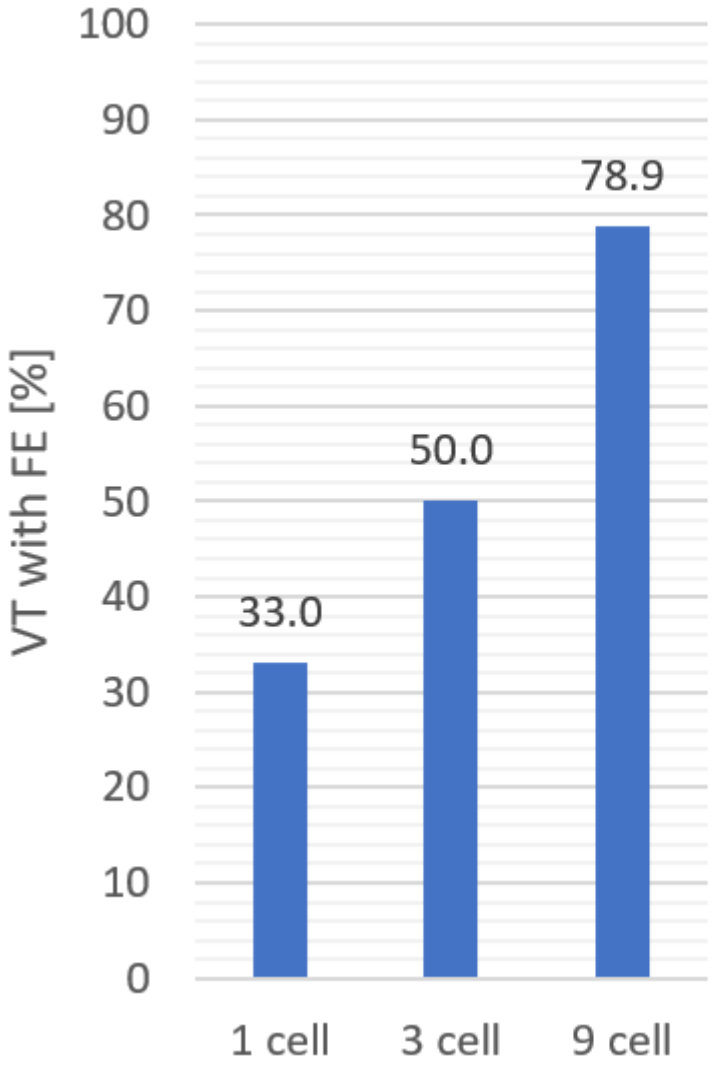
History of Field Emission in 9-cell Cavities

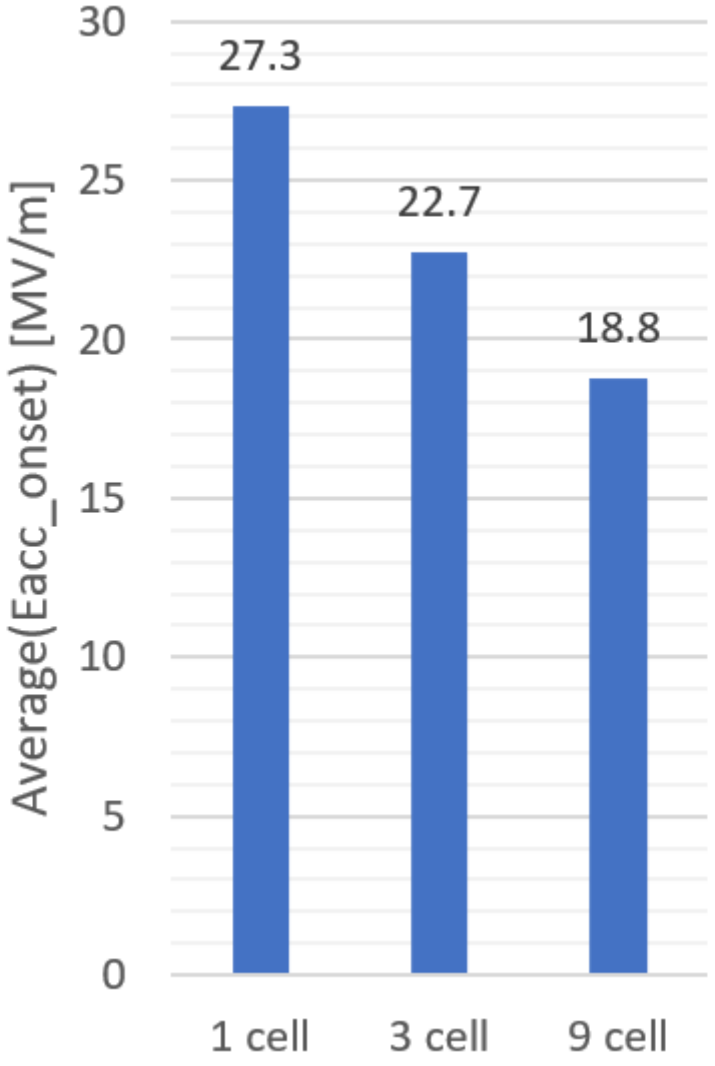


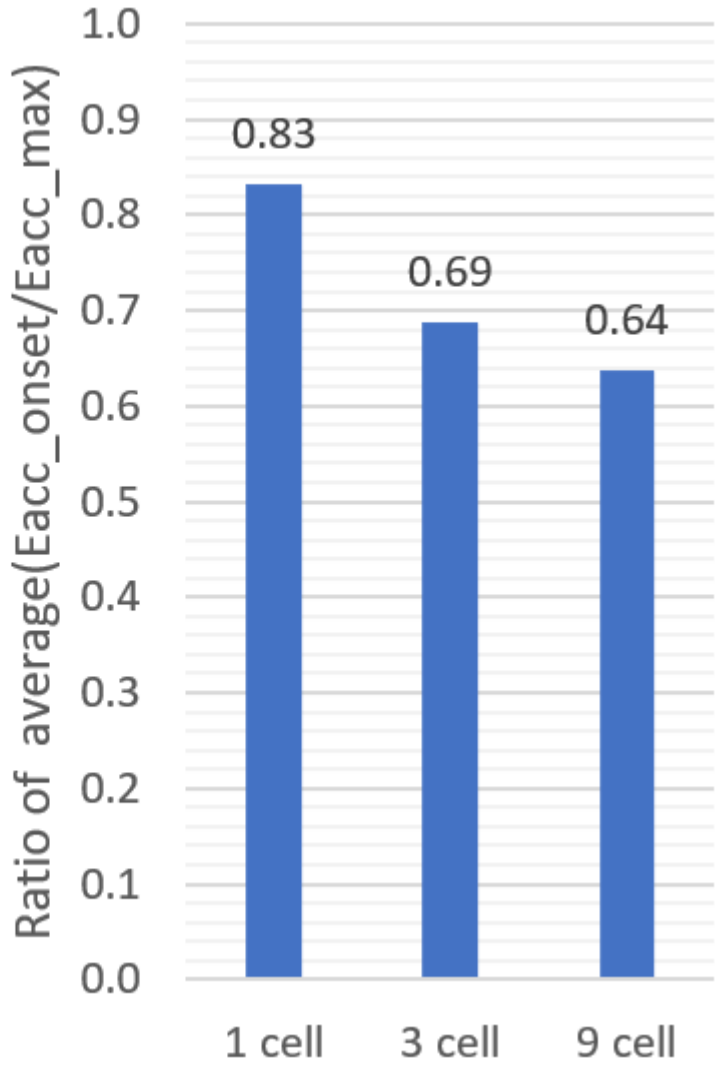


Number of VTs	52
VTs with radiation	41 (78.9%)
VTs w/o radiation	11 (21.2%)
Mean Eacc_onset	28.8 MV/m
Mean ratio (onset/max)	0.637

FE Comparison







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
  - Clear improvements over the last 3 years for 3- and 9-cell cavities
- With on all points above, we are improving the quality of our assembly processes

- Thank you very much for your attention! Questions?