

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

加速器学会 2022/10/21

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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 / Grinding



Annealing

Tuning / Straightening







Electro Polishing



High Pressure Rinsing

High Pressure Rinsing



Assembly





Vertical Test



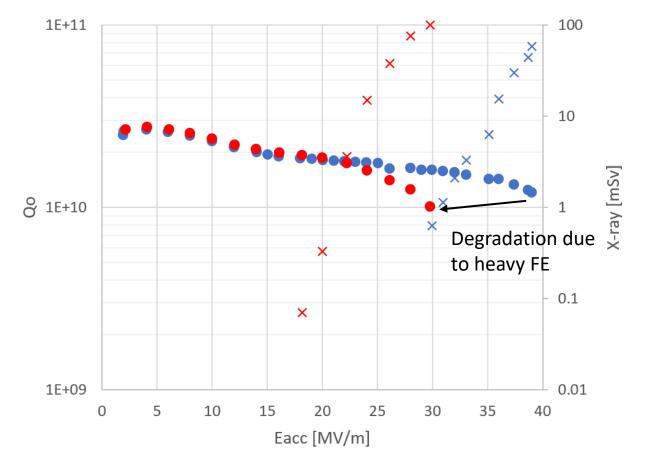


Efforts to improve the assembly work of SRF cavities in the clean room to suppress field emission

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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
 - \rightarrow We have to understand both



MT-4 VT4 Qo MT-4 VT6 Qo X MT-4 VT4 X-ray [mSv] X MT-4 VT6 X-ray [mSv]



Clean Room Survey Normal Light

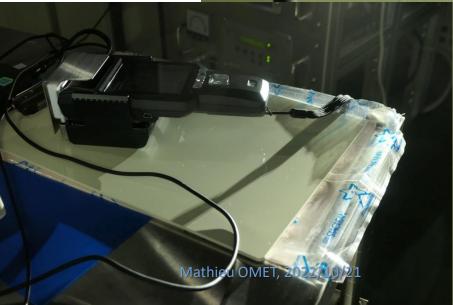
- Turned off all ambient lighting in STF class 1000 clean room (C1000CR) and class 10 clean room (C10CR)
- Used spotlight to illuminate surfaces in C1000CR

C10CR Airlock South Door



C10CR Airlock North Door

Dust and Fiber Particles on TableBesidePumping Station

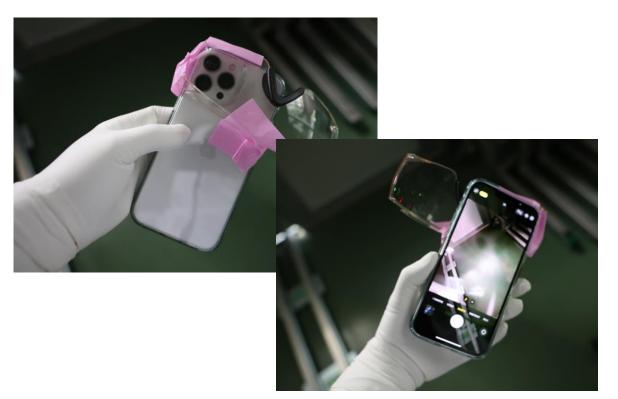




Clean Room Survey D light

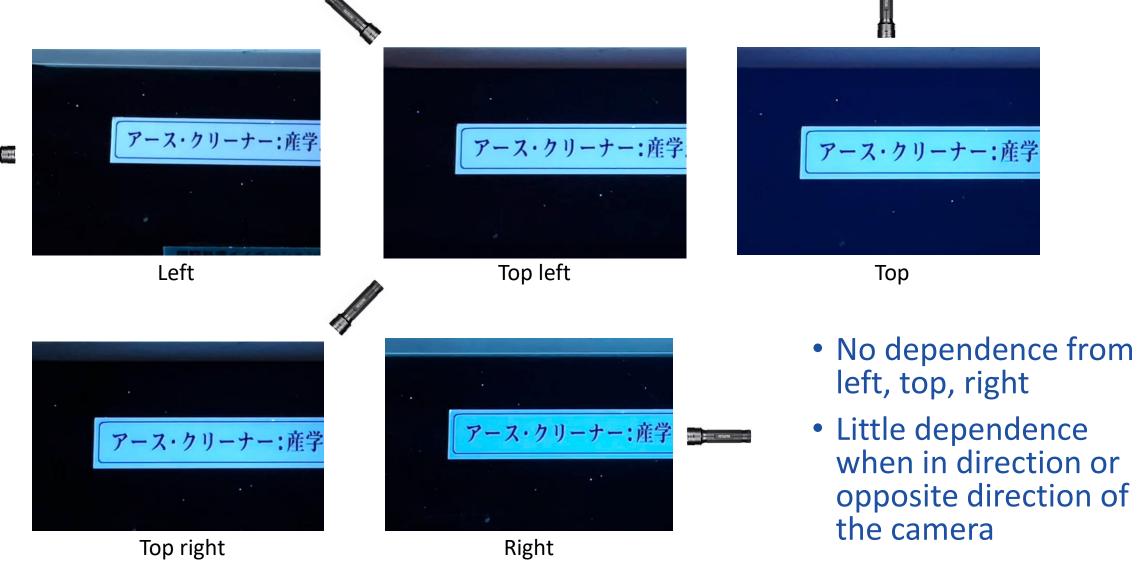
- Evaluate the capability of the D light to find dust in the clean room
- Evaluate the dust in the clean room using D light
- Light source used:





Check on Dependence of Angle





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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

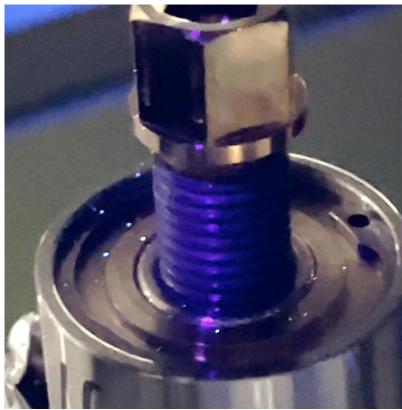
- Final situation
- A lot of dust was removed
- It is indeed dust we see



Checking other Surfaces with Cleaning (Air Blowing)



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

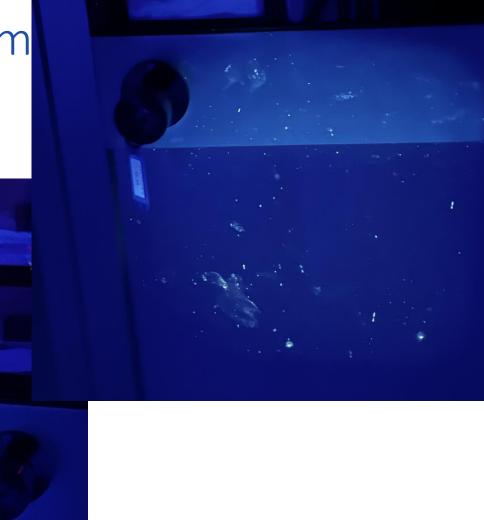


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Final situation after air blowing



STF Changing Room Door to Air Lock



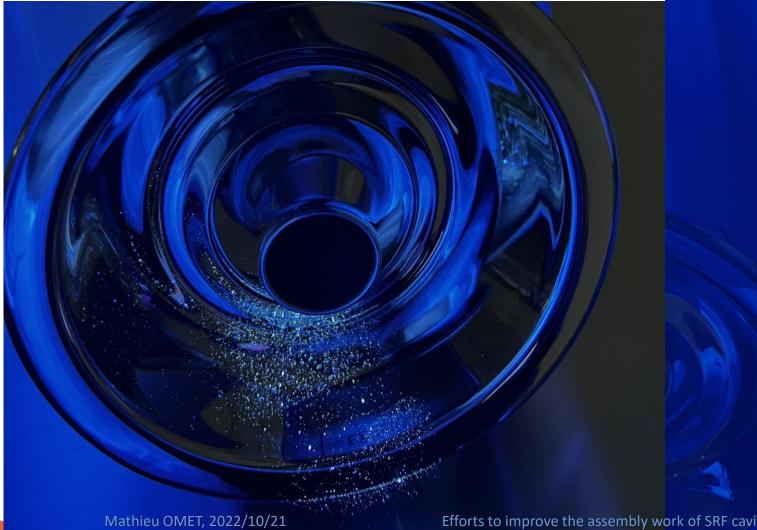






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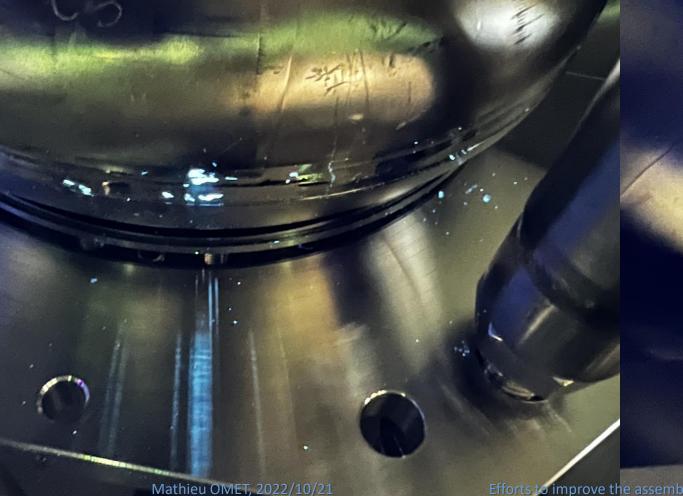
COI C1000CR -Air Lock

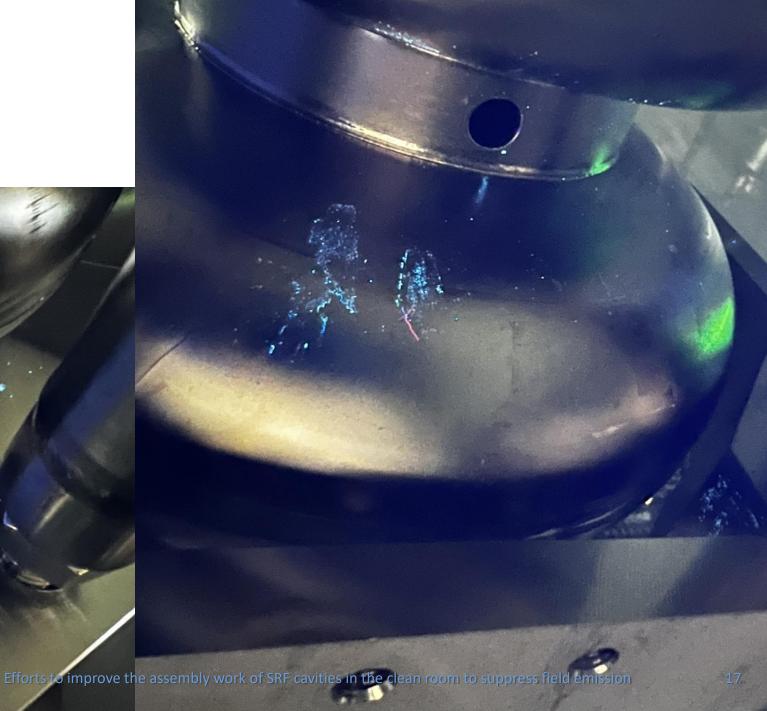


COI C1000CR – Pumping Station

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COI C1000CR – Cavity Stored in the CR

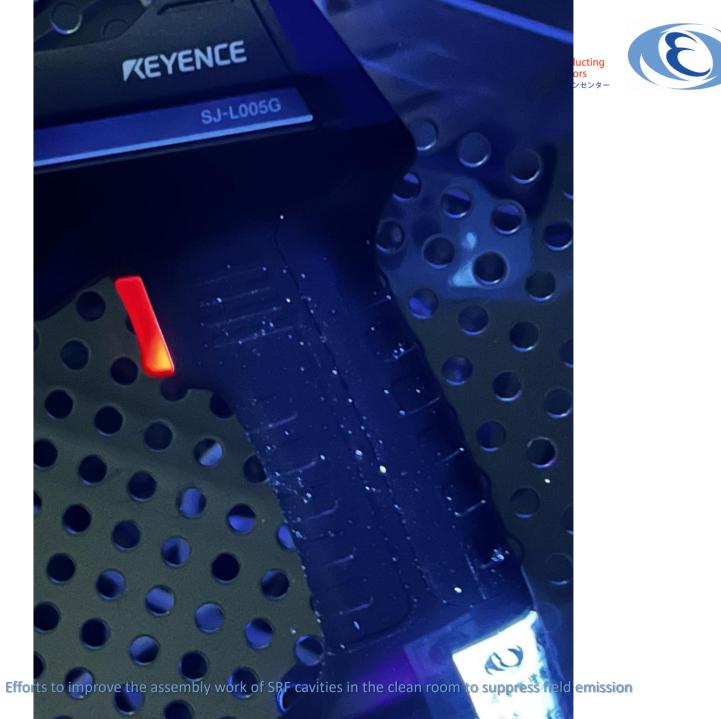




COI C1000CR – Items Stored in Shelf

COI C1000CR – Items Stored in Shelf

COI C10CR – Keyence Ion Gun



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STF C1000CR – Tray with Tools







COI C10CR – Tray with Tools

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STF C1000CR - Window of Air Lock between C1000CR and C10CR



Before cleaning



After cleaning



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Conclusion of Clean Room Survey



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- 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

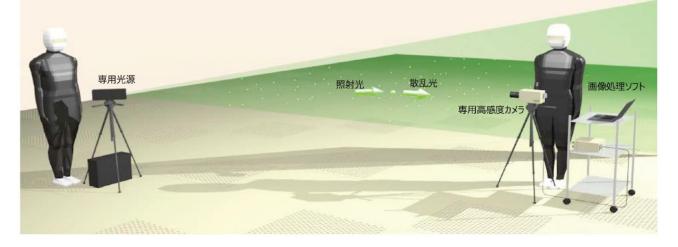
浮遊微粒子を可視化したい空間に専用光源で光を照射し、その照射光の中に浮遊する微粒子が発する微弱な散乱光を、微弱光に 特化した専用高感度カメラ(基本画像処理パッケージ附属 CCD カメラもしくは専用高感度カメラ「アイスコープ」)によってセンシングし、 リアルタイム画像処理により映像を表示する特殊な撮影技術です。

■ 微粒子可視化技術とは





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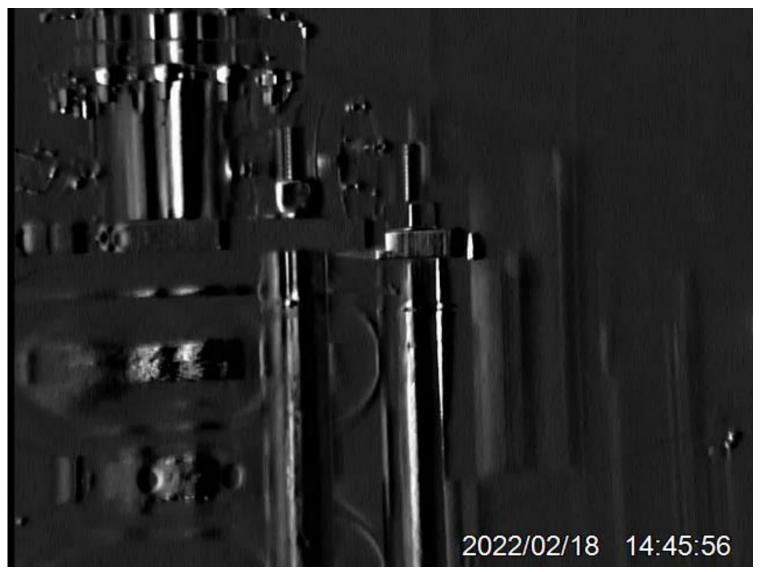
Masking of the Clean Room Windows



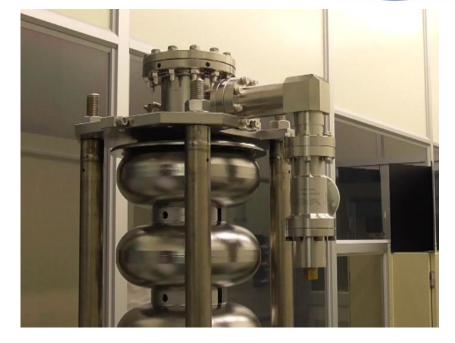


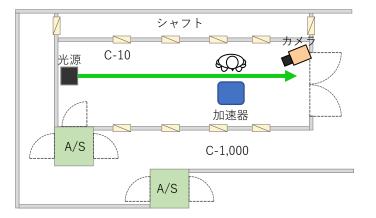
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Clean Blowing





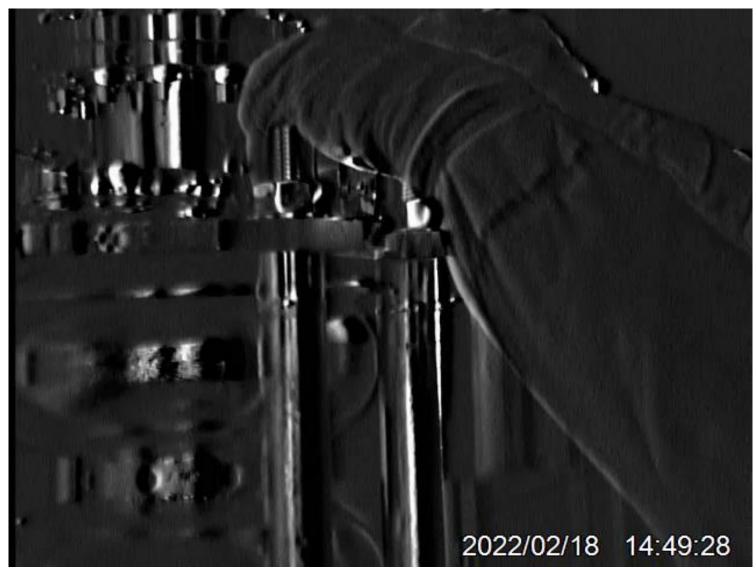


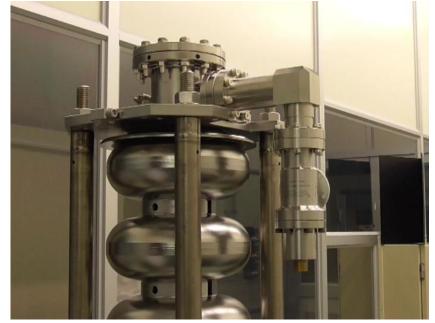


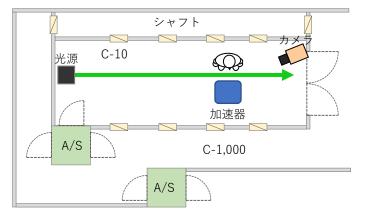
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Release of Bolts of Blind Flange









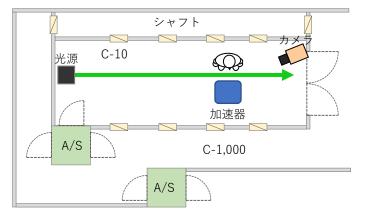
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Tightening Bolts of Attachment









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Work Plan for Assembly



tall screws. NA

n pick-up port v in blow hands v an blow blind fla l pick-up flange v let NAT persor

mel help to instal I will tighten with

et NAT perso

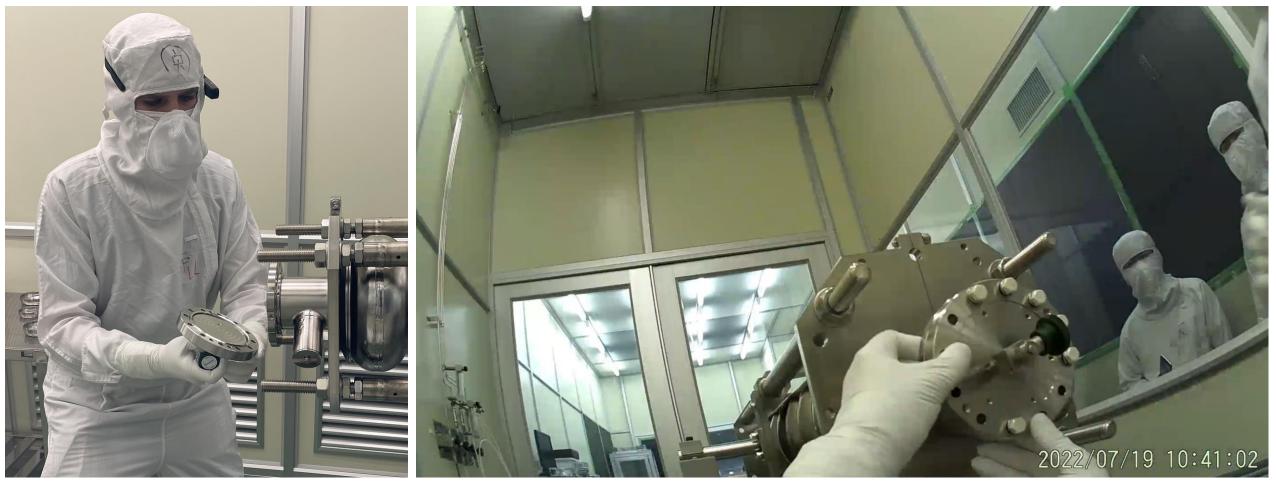
- Detailed assembly procedure is described
- Written for every single assembly
- Discussed with supporting technical staff before the assembly
- Document is accessible during the assembly via tablet in the C1000CR

	2021/10/01		2021/10/01	
	1	EP setup (Friday, 2021/10/01)		Change to new gloves. Clean blow hands with particle counter. C
F-4 Preparation Plan for VT9		5 µm cold EP (Monday, 2021/10/04)		at top HOM port with particle counter. Clean blow gasket and blin counter until just before installation. At the same time let NAT pe
paration by NAT (by latest Tuesday, 2021/10/04)		Post-cleaning (Monday, 2021/10/04)		of blind flange. When flange is open, I put blind flange with gas
 Prepare and clean blow blind flanges and O-rings 		 Ultra-sonic cleaning for 15 mins 		sure screw hole alignment is ok. Let NAT personnel help to
 Ix Al gasket and VT blind flange for top beam-pipe port 		 Brushing ports with degreaser Set cavity to HPR stand 		personnel will step back to the far end of the CR. I will tighten wit
paration by NAT (by latest Tuesday, 2021/10/05)				top HOM port with particle counter. Clean blow bottom HO
 Prepare and clean blow all VT flanges and gaskets in C10CR 		HPR (Monday, 2021/10/04)		counter. Clean blow wrench with particle counter. Step back from cavity and let air settle for 30 minutes. (outside b
 Further preparation and clean blow in C10CR Assemble valve and leave it separate: 		Outside HPR (15 min) Open HPR (3 cycles)		 Put on new gloves. Clean blow hands with particle counter. Clean
		Open HPR (3 cycles) Assembly of top flange with Aluminum gasket	with 10 Nm within HPR stand	bottom HOM port with particle counter. Clean blow gasket a
		 Close coupler port, top HOM port, bottom H 		particle counter until just before installation. At the same tim
		and blind flanges (tighten blind flanges only h	ry turning the short end of the wrench)	loosen screws of blind flange. When flange is open, I put blind flan port. Make sure screw hole alignment is ok. Let NAT personnel
		 Let cavity sit in HPR stand over night 		NAT personnel will step back to the far end of the CR. I will tights
		HPR (Tuesday, 2021/10/05)		blow bottom HOM port with particle counter. Clean blow botto
		Outside HPR (15 min)		particle counter. Clean blow wrench with particle counter. Cl
		Closed HPR (3 cycles)		particle counter.
Assemble L-shape vacuum pipe to bellow and leave it		Wet assembly (Tuesday, 2021/10/05)		 Change to new gloves. Clean blow hands with particle counter. C at bottom pick-up port with particle counter. Clean blow gasket an
 Semiconal reaction in the system water in 	approx.	Close bottom beam pipe flange with O-ring at		particle counter until just before installation. At the same tim
(Clean blow O-ring and blind flange wi Tighten with not too hard force (turni 		loosen screws of blind flange. When flange is open, I put pick-up
		 Use L-shape profile to install cavity directly or 		the port. Make sure screw hole alignment is ok. Let NAT per
¥ .		 Dry blow cavity in C1000CR 		screws. NAT personnel will step back to the far end of the CF wrench. Clean blow bottom pick-up port with particle counter
		Move cavity to C10CR	107 (107) 1000 (107)	beam-pipe port with particle counter.
-70		 Clean blow with particle counter and ion gan Change to new gloves, Clean blow hands with 		 Put on new gloves. Clean blow hands with particle counter. Clea
y		 Change to new goives, Clean blow hands with at coupler port with particle counter. Clean blo 		bottom beam-pipe port with particle counter. Clean blow gas
		until just before installation. At the same time	let NAT personnel loosen screws of blind	particle counter until just before installation. At the same tim
-cleaning (Friday, 2021/10/01)		flange. When flange is open, I put valve with t	flange on the port. Make sure screw hole	loosen screws of blind flange. When flange is open, I put coupl port. Make sure screw hole alignment is ok. Let NAT personnel
 Ultra-sonic cleaning for 15 mins 		alignment is ok. Let NAT personnel help to	install screws, NAT personnel will step	Tighten them until the ring is flat. Only then get the torque wren
 Brushing ports with degreaser 		back to the far end of the CR. I will tighten w stays away until the very last moment. Clean		Together we will tighten with torque wrenches to the final torque
		Clean blow top HOM port with particle count	ND.	bottom beam-pipe port with particle counter.
				 Put on clean gloves. Clean blow hand with particle counter. Tight
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		077074202		2021/10/01
		2021/10/01		2021/10/01
		v top flange with particle counter. Clean blow cavity	No. of Lot of Lo	
	valve with particle counter. Clean	blow hands with particle counter. ands with particle counter. Clean blow again bellow		
	 Fut on new groves, Crean blow in with L-shape vacuum pipe. Attach 		the start and	at the second
	Clean blow cavity with particle cos			and the second
	 More cavity to C1000CR. 			
	Connection to pumping station (Tue	sday, 2021/10/05)	Move cavity to VT area (Monday, 20) Disconnect bellow from pumping a	
		avity to pumping station, ask them to wash hands.	 Disconnect below from pumping a Move cavity to VT area 	(2C)ON
	 Connect pumping station 		Mount cavity to VT suspension	
	 Open cavity value slowly Pumping over night 		 Bake VT stand vacuum piping 	
			Further VT preparation (Tuesday, 20	21/30/12)
	Leak check (Wednesday, 2021/10/0	.6)	4 K test (Wednesday, 2021/10/13)	an an an
	 Leak check of cavity 		 Insertion into cryp pit #1 	
	Baking start (Wednesday, 2021/10/	06)	 Fast cool-down to 4 K (with pumpi 	ng)
	 Prepare cavity for baking Perform 75/120 °C baking 		 4 K test 	
	-		2 K test (Thursday, 2021/10/14)	
	Baking end (Friday, 2021/10/08)		Fast cool to 2 K (with pumping)	
	Change from TMP & rough pump		Warm-up (Friday, 2021/10/15)	
	 Disconnect vacuum pipe h Wait 10 Minutes 	eater		
	 Turn off all remaining heat 	ders		
	 Wait until all temperatures 	s dropped below 110 deg C		
	 Close value to TMP 			
	 Open valve to ion pump 			
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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



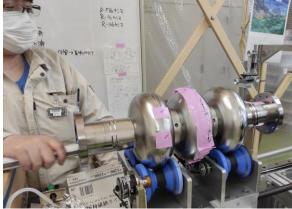
Emission

• Iris grinding of cavities





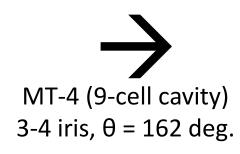
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Example of iris grinding on 3-cell cavity Picture courtesy of H. Araki



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









Further Measures to Suppress Field Emission



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





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Further Measures to Suppress Field Emission



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



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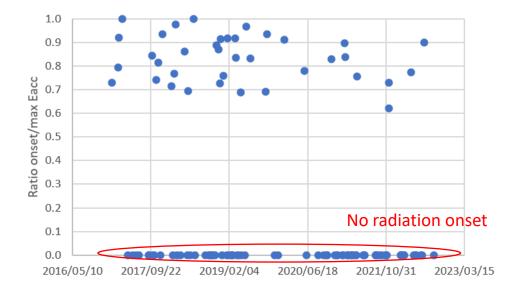






History of Field Emission in single-cell Cavities

All Eacc_max and Eacc_onset (final π -mode at 2 K) no FE 45.0 40.0 35.0 Eacc [MV/m] 30.0 25.0 20.0 15.0 10.0 5.0 0.0 2016/05/10 2017/09/22 2019/02/04 2020/06/18 2021/10/31 2023/03/15 - Eacc max [MV/m] ▲ Eacc onset [MV/m]

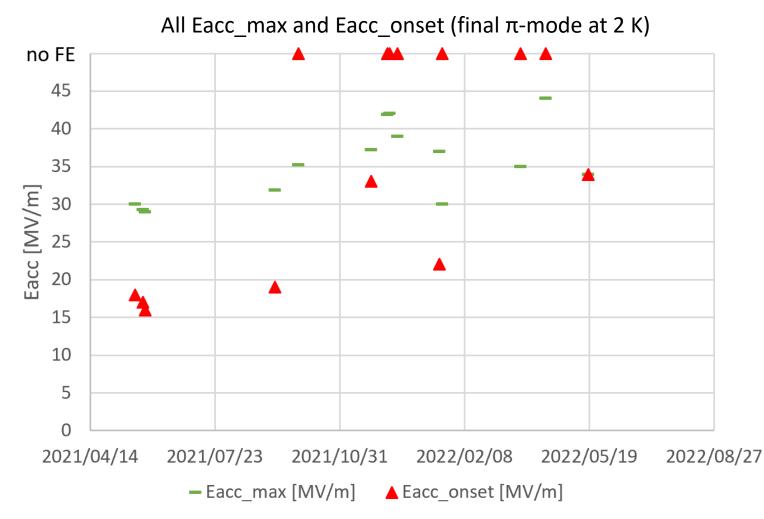


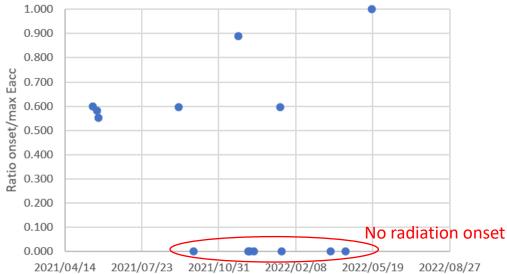
Number of VTs	112
VTs with radiation	37 (33.0%)
VTs w/o radiation	75 (67.0%)
Mean Eacc_onset	27.3 MV/m
Mean ratio (onset/max)	0.832

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History of Field Emission in 3-cell Cavities

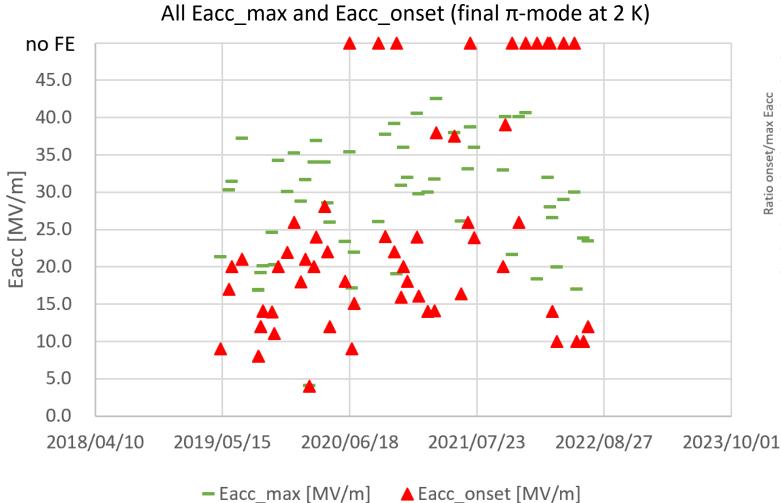


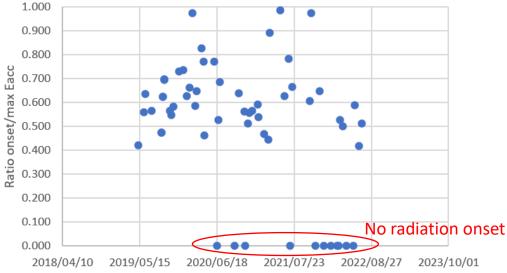


Number of VTs	14
VTs with radiation	7 (50.0%)
VTs w/o radiation	7 (50.0%)
Mean Eacc_onset	22.7 MV/m
Mean ratio (onset/max)	0.688



History of Field Emission in 9-cell Cavities



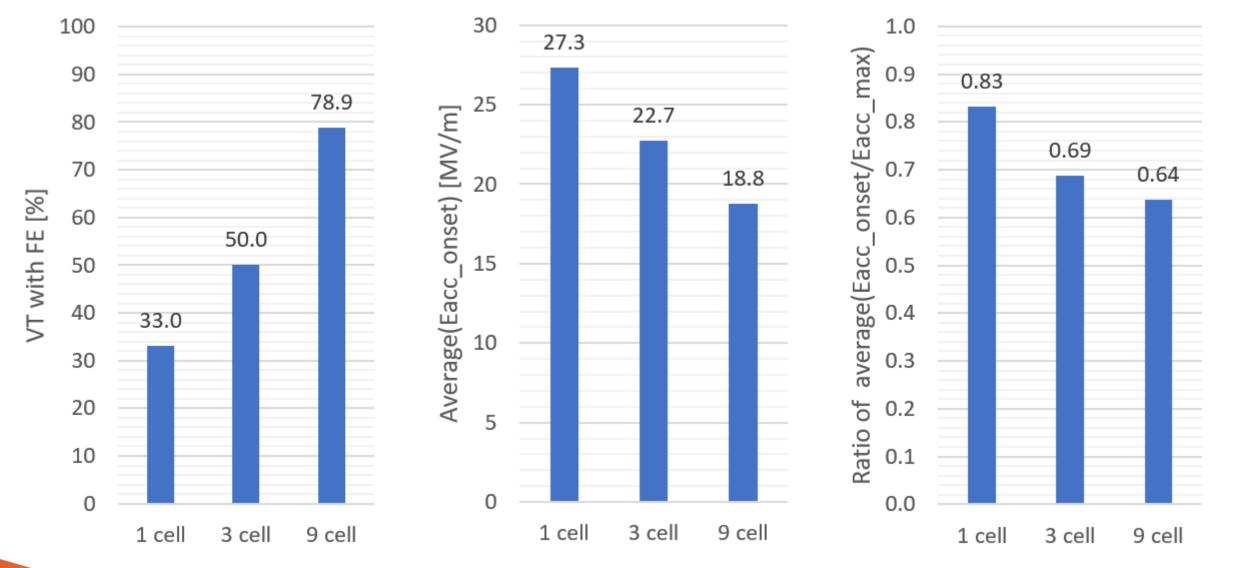


Number of VTs	52
VTs with radiation	41 (78.9%)
VTs w/o radiation	11 (21.2%)
Mean Eacc_onset	28.8 MV/m
Mean ratio (onset/max)	0.637

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FE Comparison





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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
 - 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?