Current Status of a SC-ECRIS of the RAON Accelerator

Yonghwan Kim

ibs 기초과학연구원
Institute for Basic Science

RISP

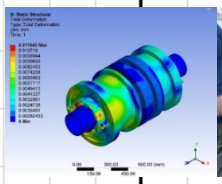
Specifications of a SC-ECRIS for RAON accelerator

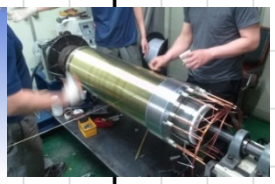
Magnet and magnetic field	SC Wire	NbTi
	Number of Solenoid Coils	4
	Hexapole Winding Type	Saddle
	B_{inj} (T)	>3.5
	B_r (T)	2
	B_{ext} (T)	2
	B_{min} (T)	0.4 ~ 0.8
RF system	RF Frequency (GHz)	28+10
	RF power (kW)	10+2
Plasma chamber and beam extraction system	Chamber material	Al
	Plasma volume	About 8.5 Liter ID = 147 mm L = 500 mm
	Triode electrode system Acceleration column	~ 25 kV ~ 50 kV

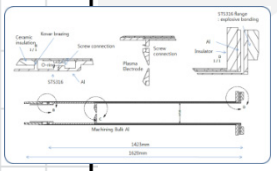
Goal : 400eμA of Uranium 33+/34+, 10keV/u

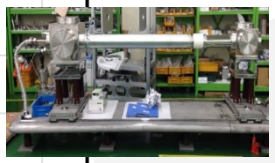
28GHz SC-ECRIS Development History and Plan

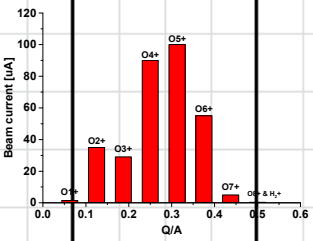
Plan	2013	2014	2015	2016	2017	2018
Design and Fabrication						
SC Magnet & Cryosystem design						
Magnet fabrication						
Cryosystem fabrication						
plasma system design						
plasma system fabrication						
Install and test						
SC Magnet individual test						
SC Magnet whole system test						
plasma system HV and vacuum test						
initial beam commissioning						
test facility building remodeling work						
Disassemble and Maintenance						
reassemble						
beam commissioning						
metal beam extraction						
Transfer to main site						
beam commissioning at main site						

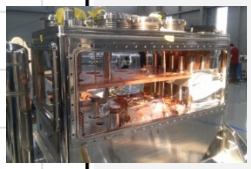




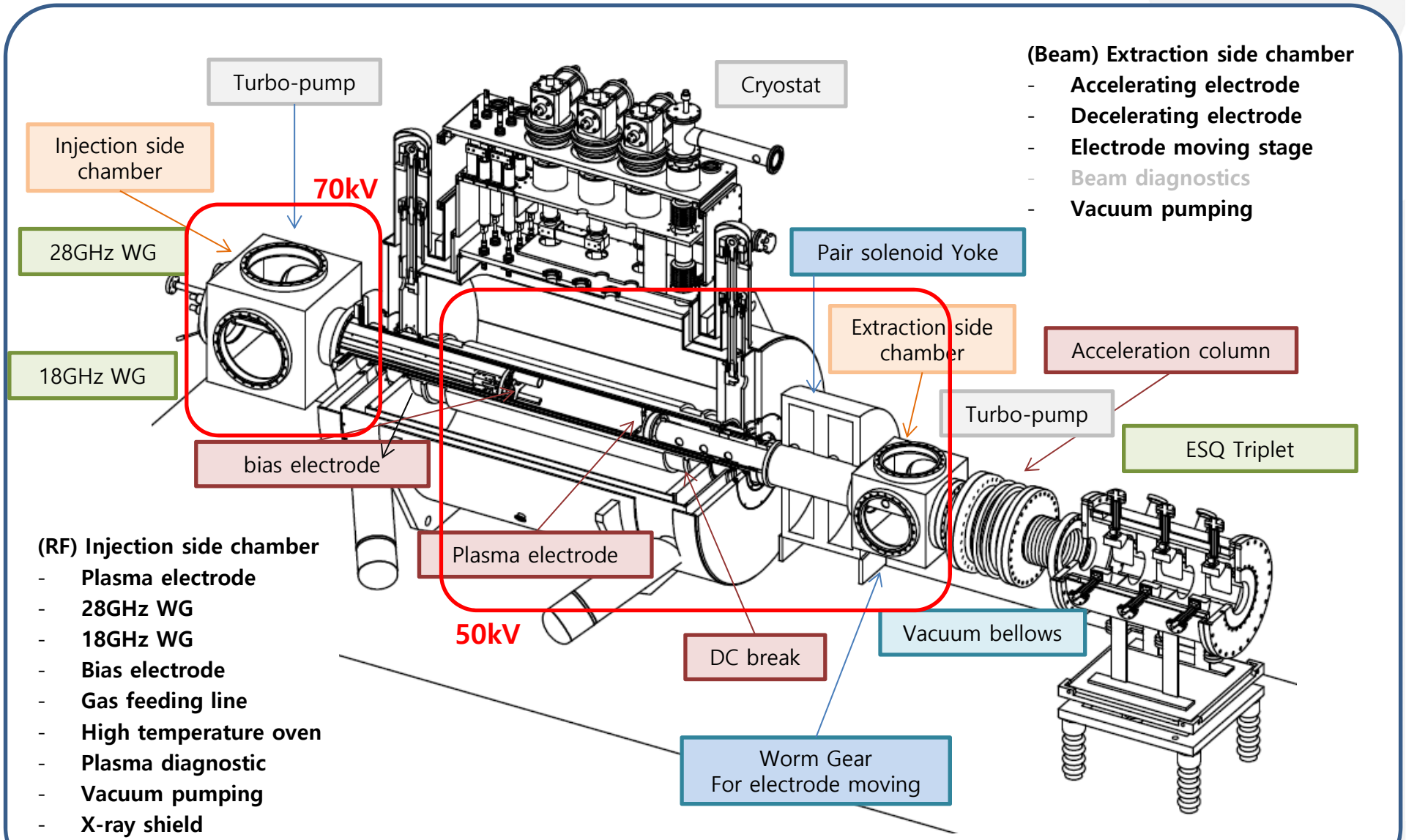








Schematic View of ECRIS

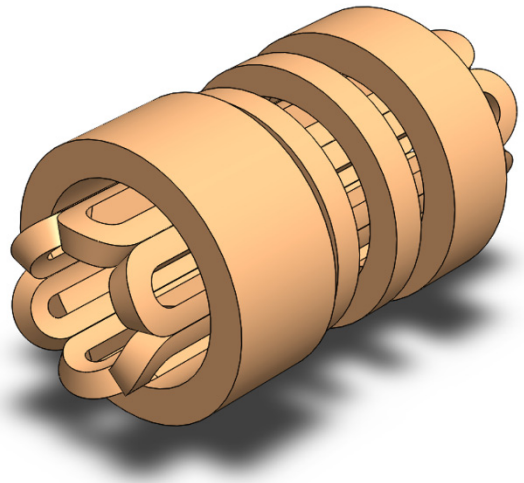


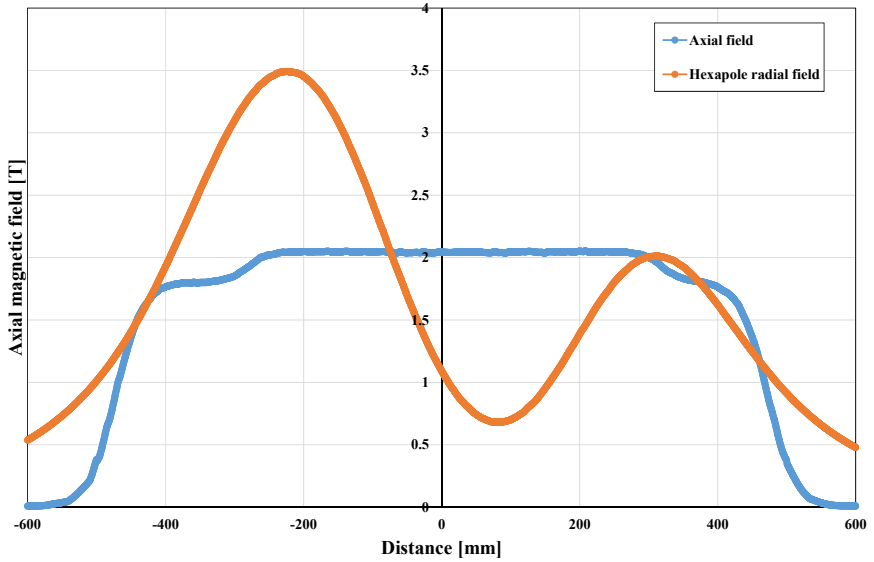
(Beam) Extraction side chamber
- **Accelerating electrode**
- **Decelerating electrode**
- **Electrode moving stage**
- **Beam diagnostics**
- **Vacuum pumping**

(RF) Injection side chamber
- **Plasma electrode**
- **28GHz WG**
- **18GHz WG**
- **Bias electrode**
- **Gas feeding line**
- **High temperature oven**
- **Plasma diagnostic**
- **Vacuum pumping**
- **X-ray shield**
- **Insulation**

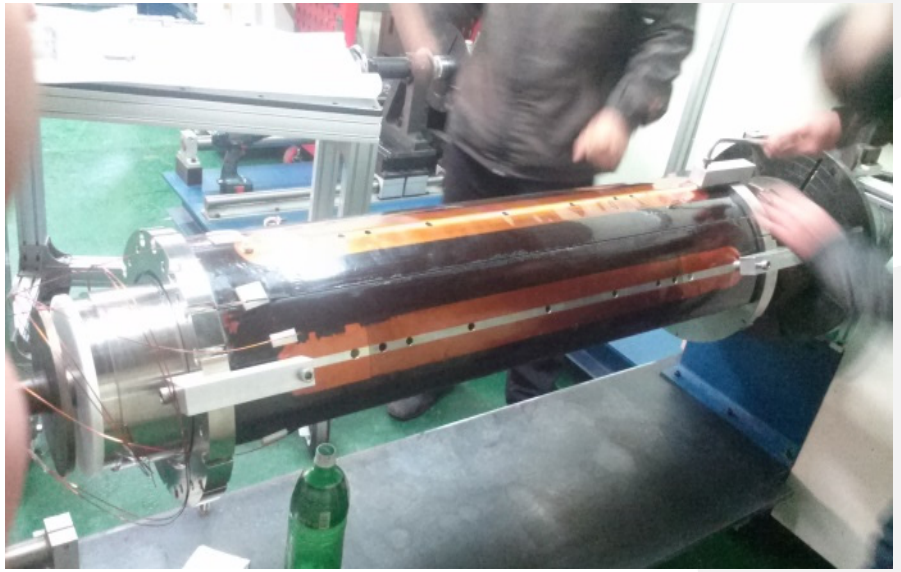
Design of superconducting magnet

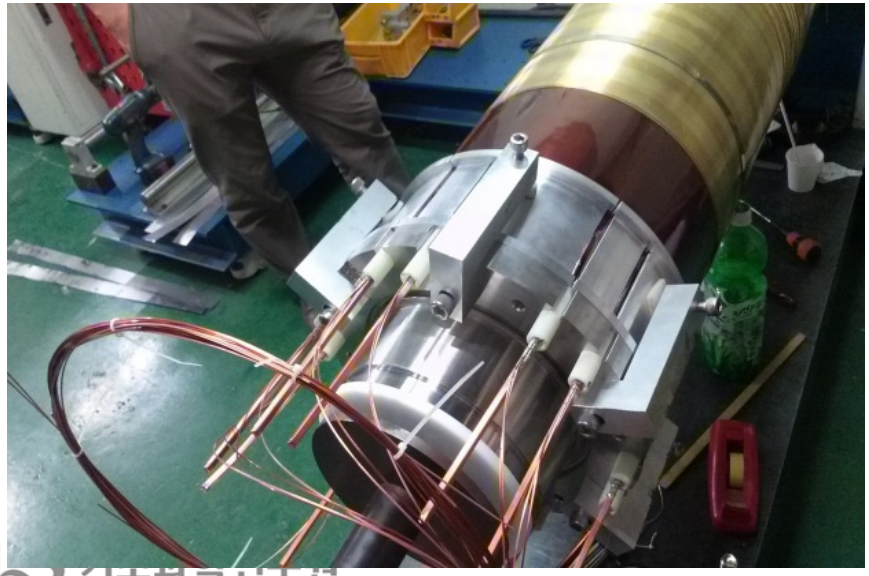
	sol1	sol2	sol3	sol4	Hexapole
Axial position of center [mm]	-250	-76	65	250	
Inner radius [mm)]	188	188	188	188	108
(radial) Thickness [mm]	67	45	58	67	50
Width [mm]	230	55	65	145	
Conductor [mm]	1.6 x 0.91	1.6 x 0.91	1.6 x 0.91	1.6 x 0.91	1.43 x 0.98
Cu/NbTi ratio	3.65	3.65	3.65	3.65	3
Turns/coil	9724	1435	2320	5670	1367
Design Current (A)	151.8	-125.1	-132	143.2	254
Wire length (km)	13.55	1.9	3.16	7.89	2.56 km/unit

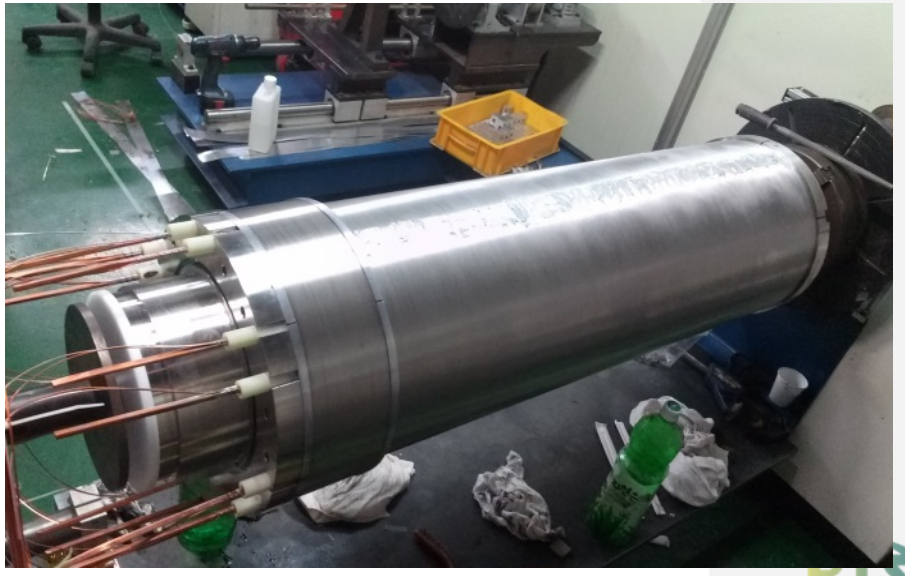




Fabrication of SC-coil with a Korean domestic company







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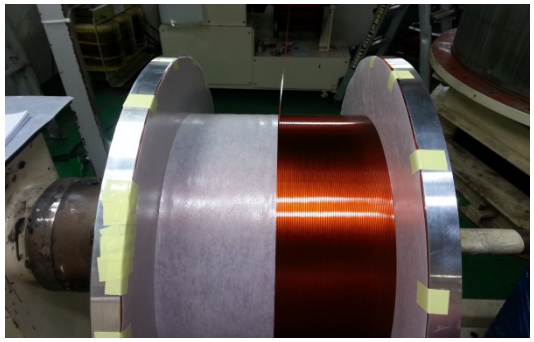
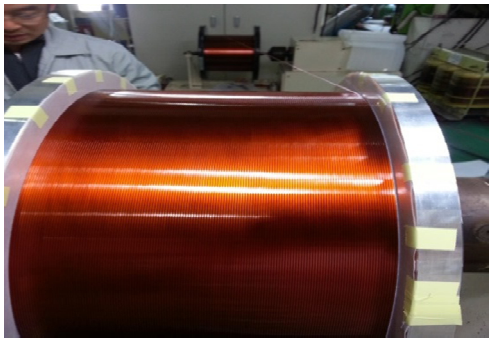
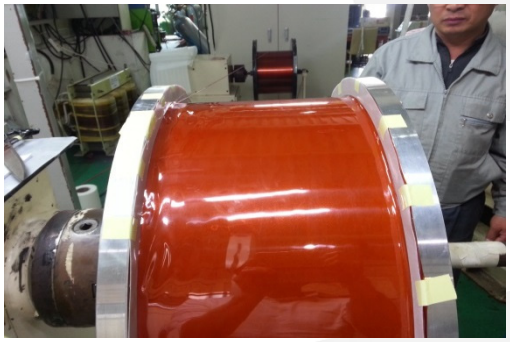
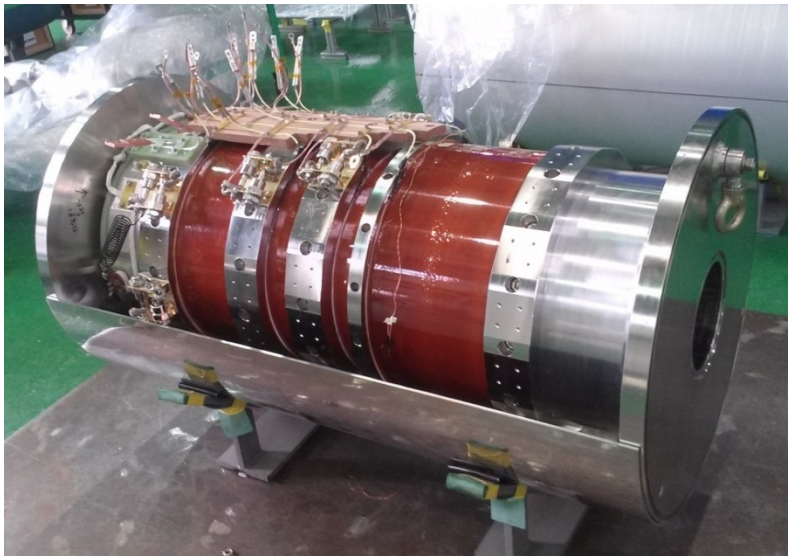
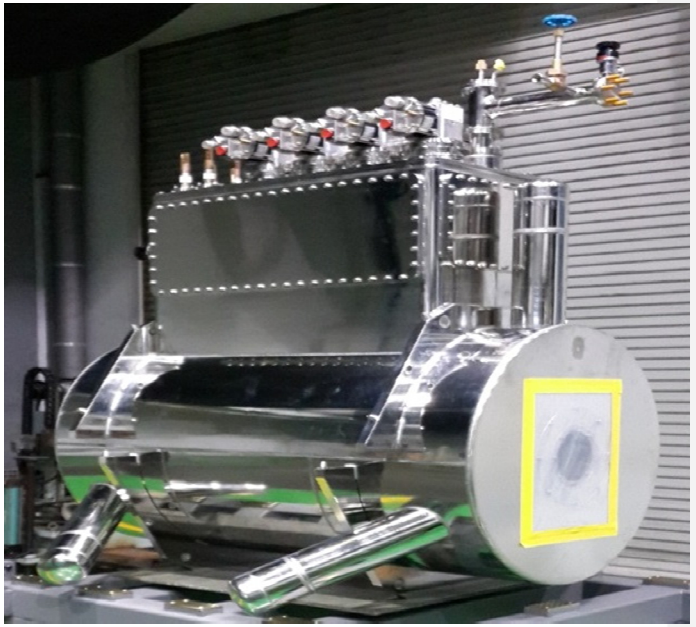




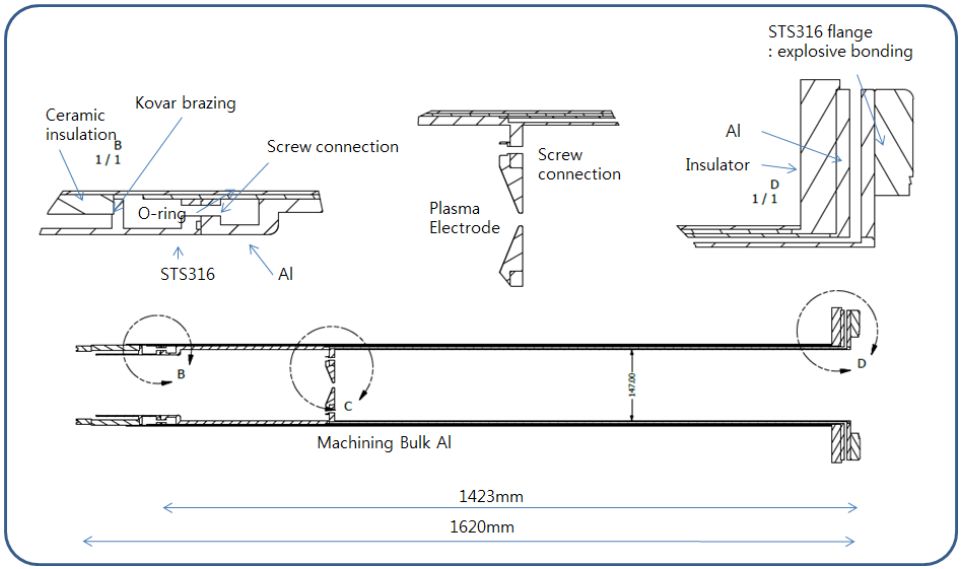
Cryostat assembly

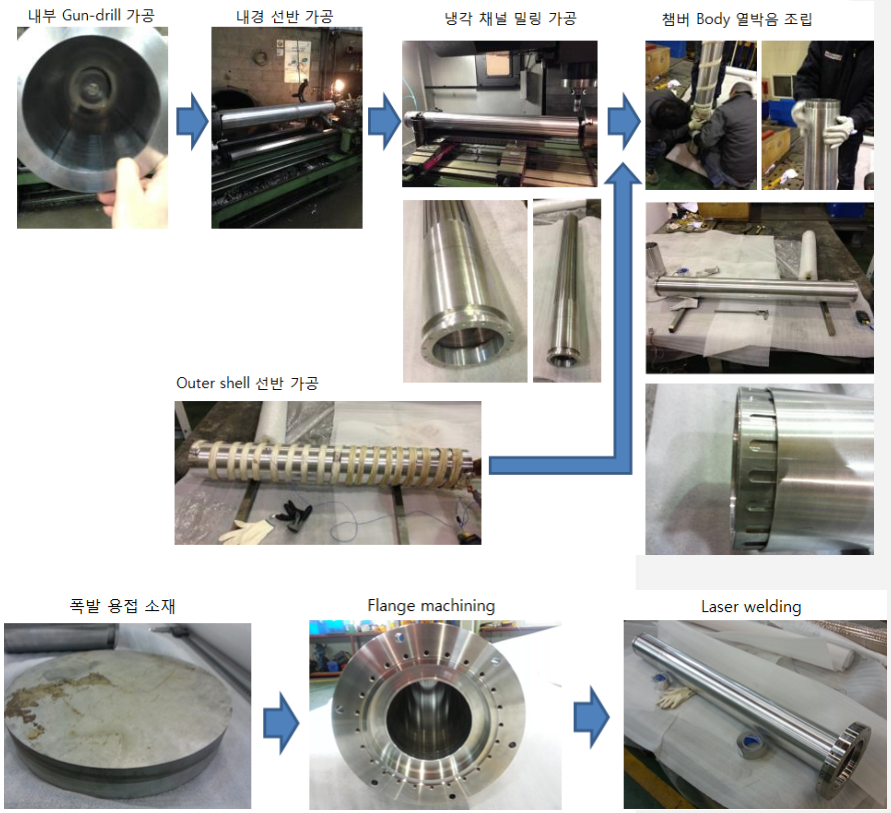




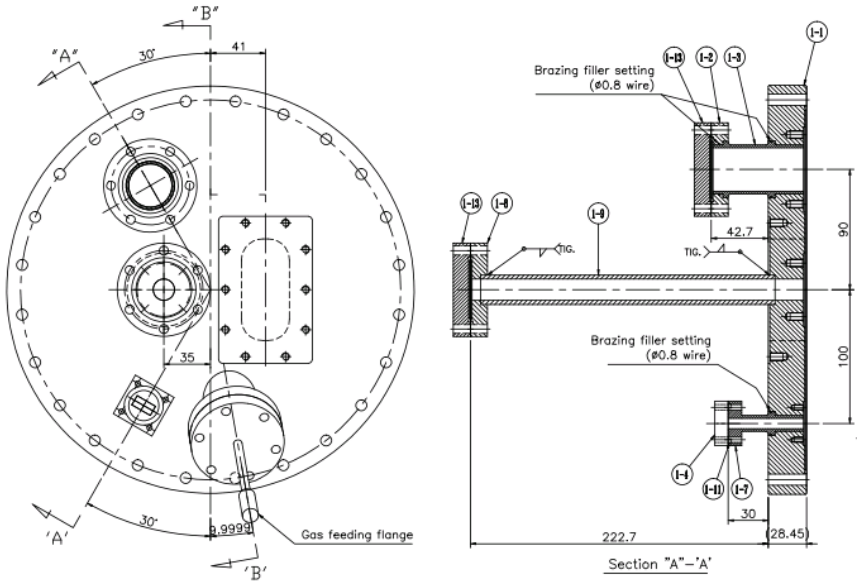
Plasma chamber design and fabrication

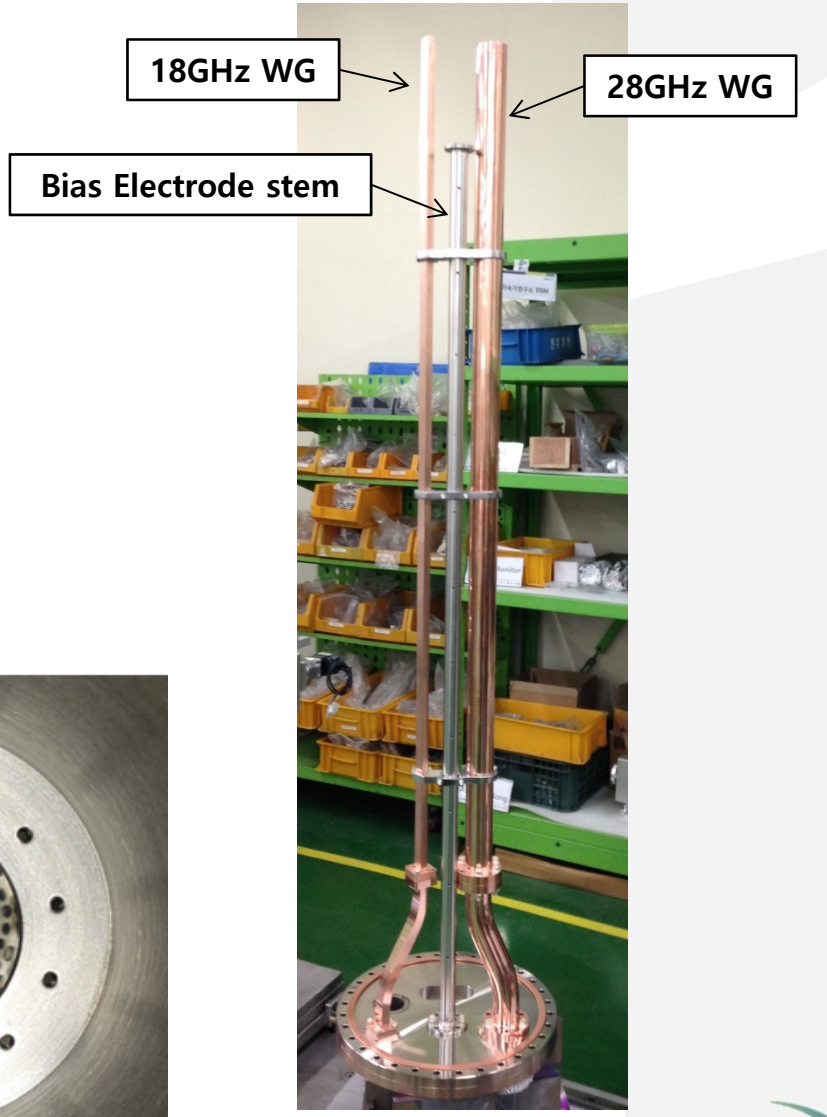
- Chamber material : Aluminum
- Vacuum seal : do not use o-ring seal but metal seal if it is possible



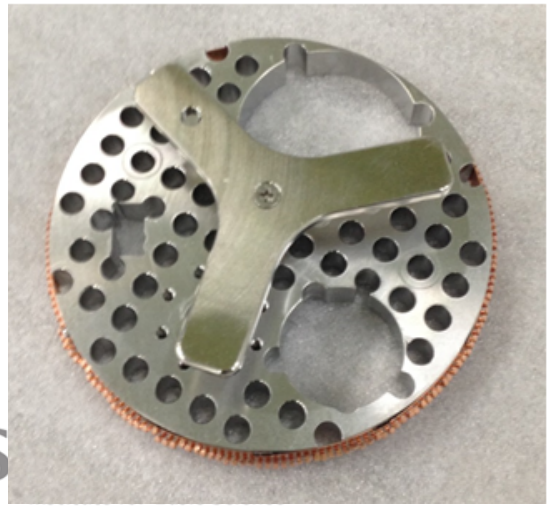


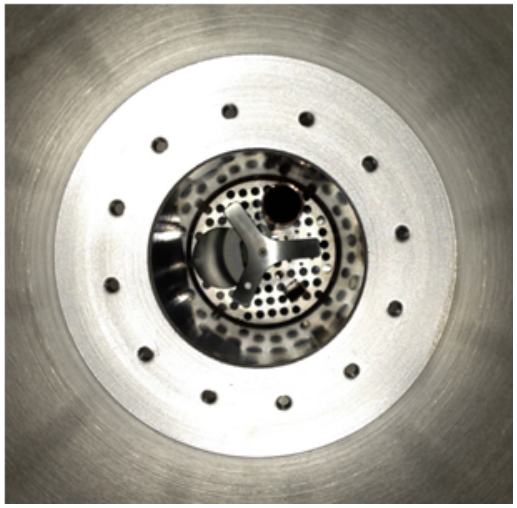
Microwave injection & plasma generation part





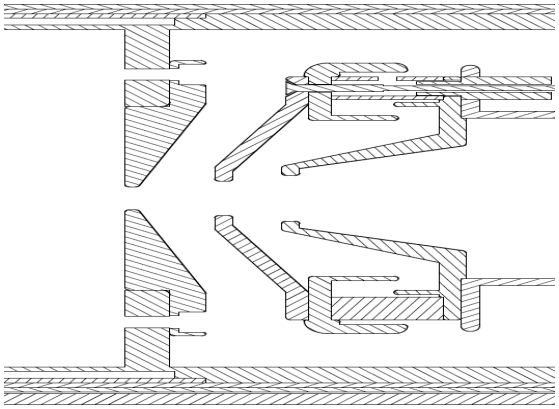
Plasma facing electrode

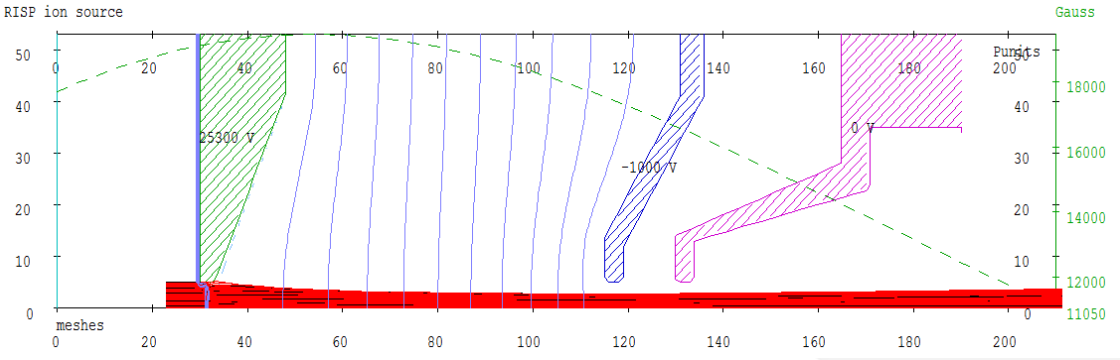




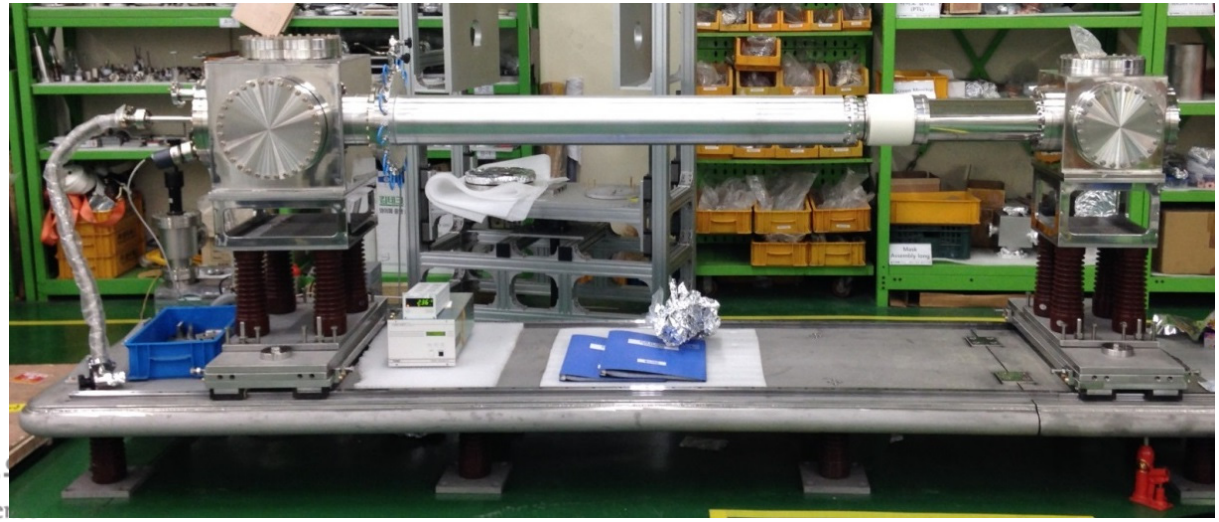
Beam extraction part

Triode system





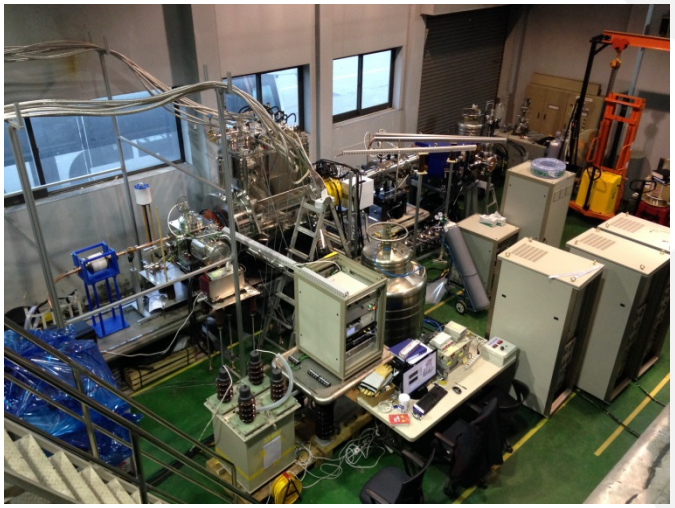
Plasma chamber



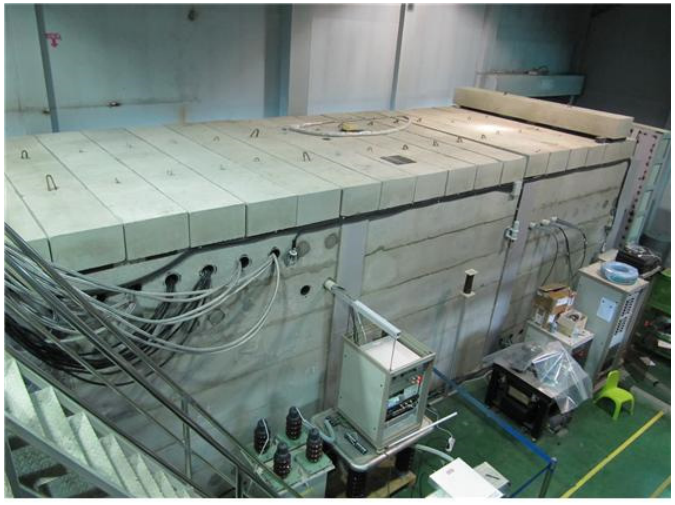
Installation History

- 2014. 05. 26

- 2015. 01



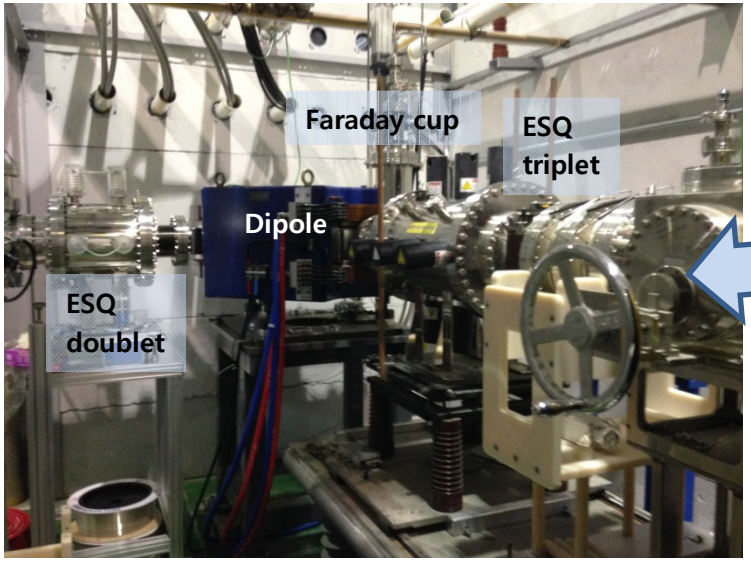
- 2015. 03

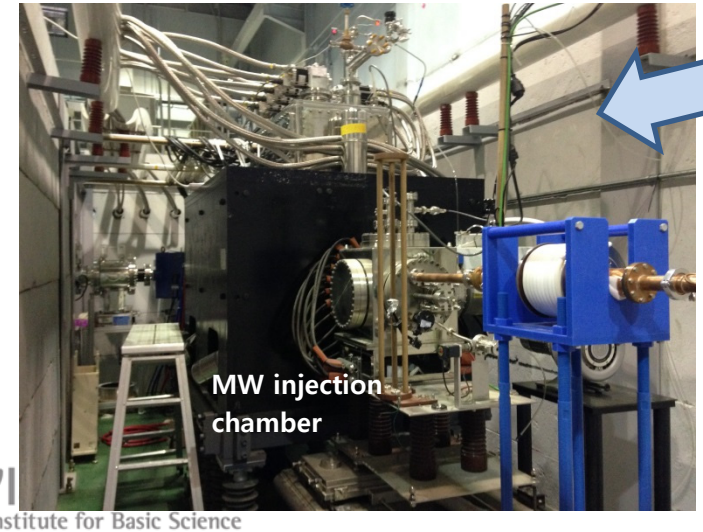


- 2016. 02

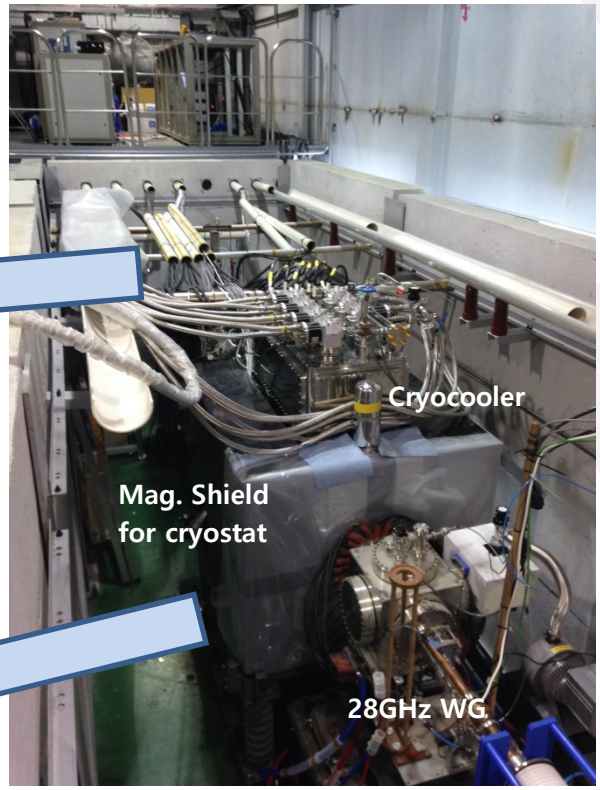
Installation History

- 2016.06

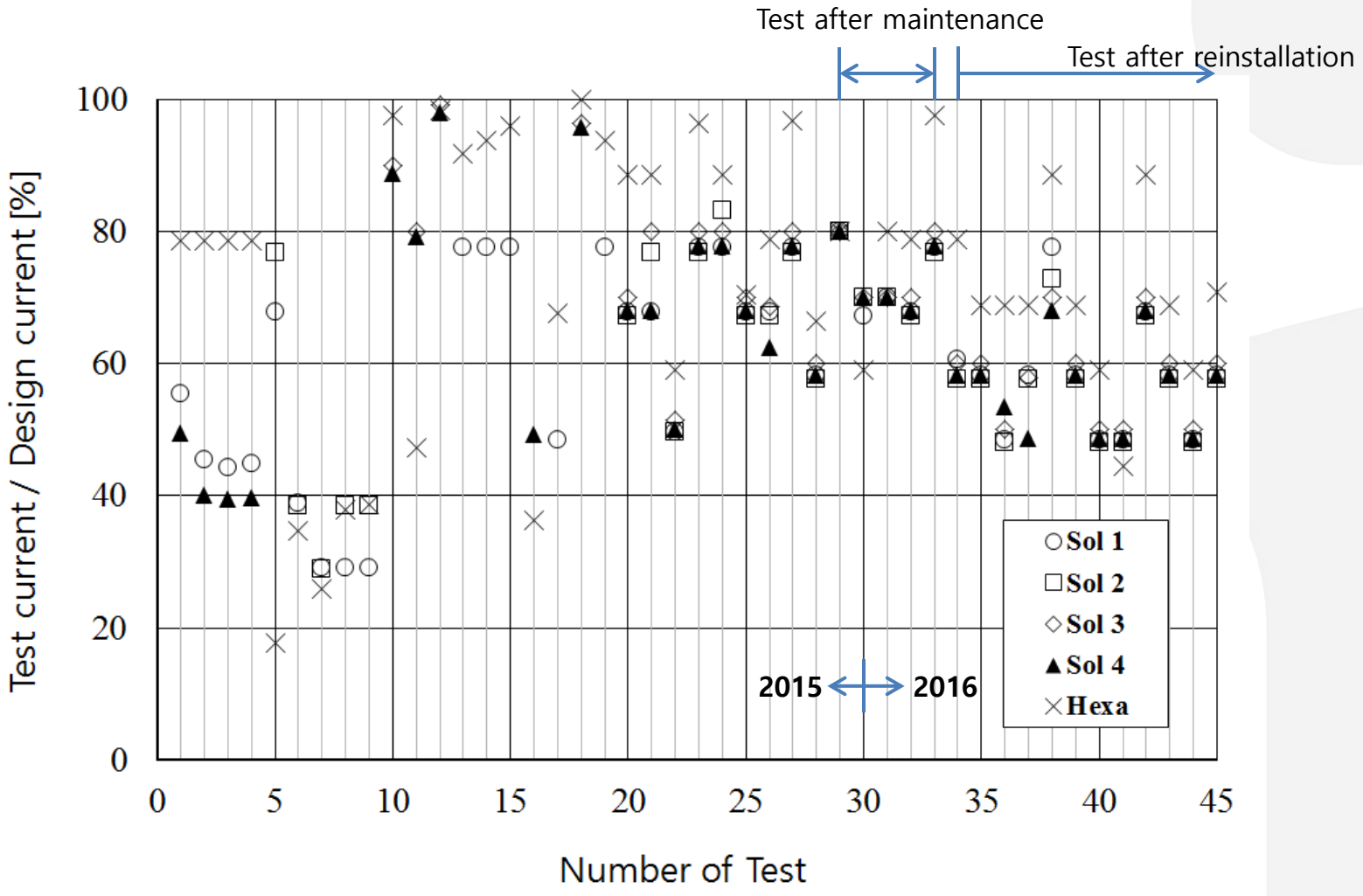




- 2016.08

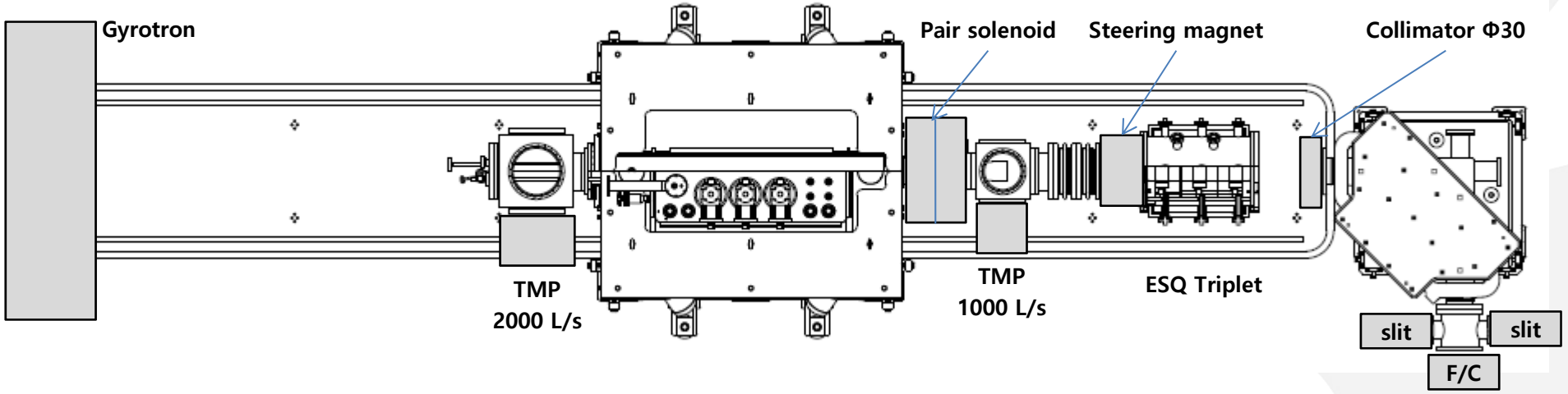


Record of SC magnet test



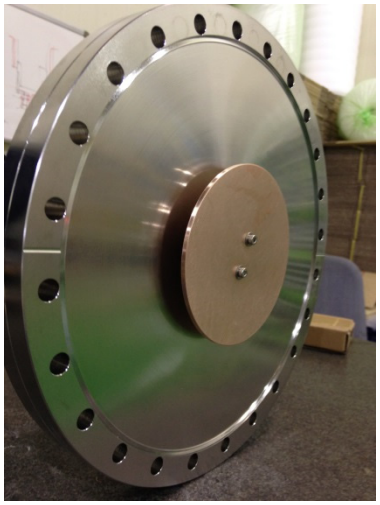
- Test various ramp up sequences and ramp rates
- Sustain magnetic field for several hours

Commissioning test in 2015

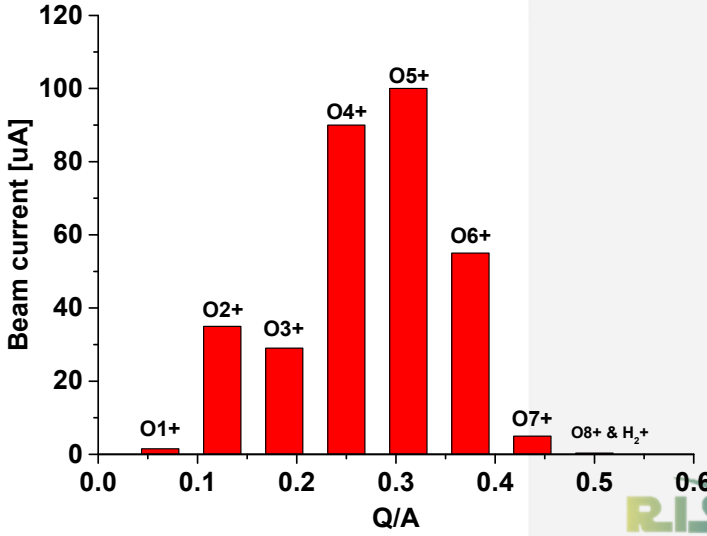


Beam current measurement

Φ10

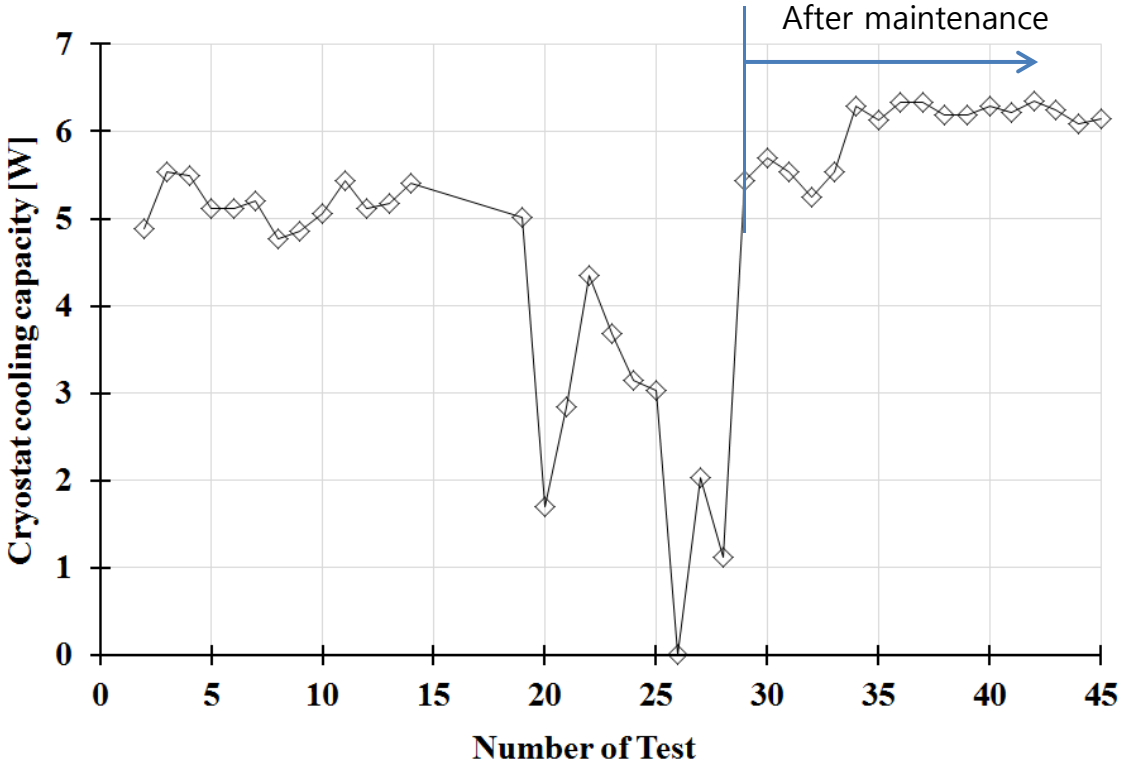


Φ90



Cryostat cooling capacity change

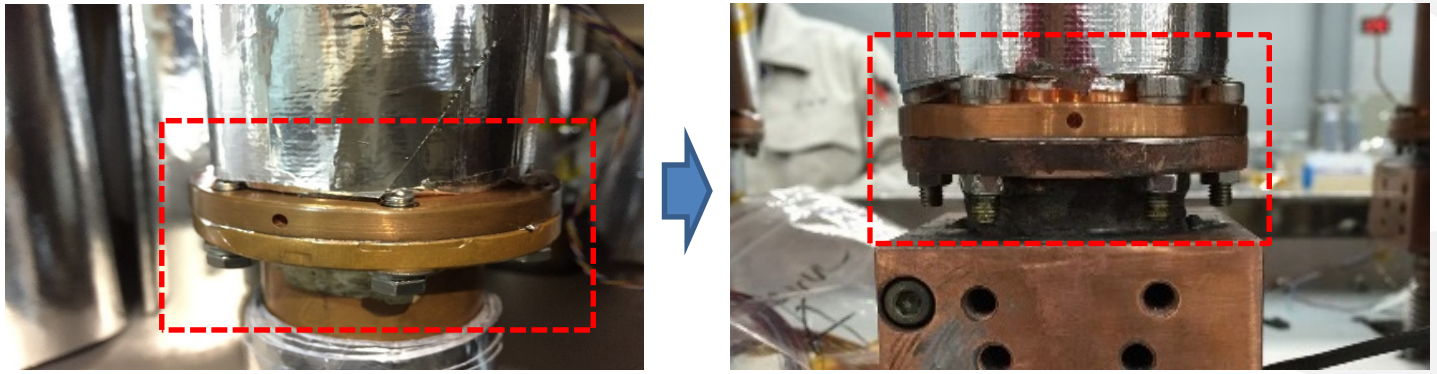
- Issue : Cooling capacity decreases during the experiments in 2015.



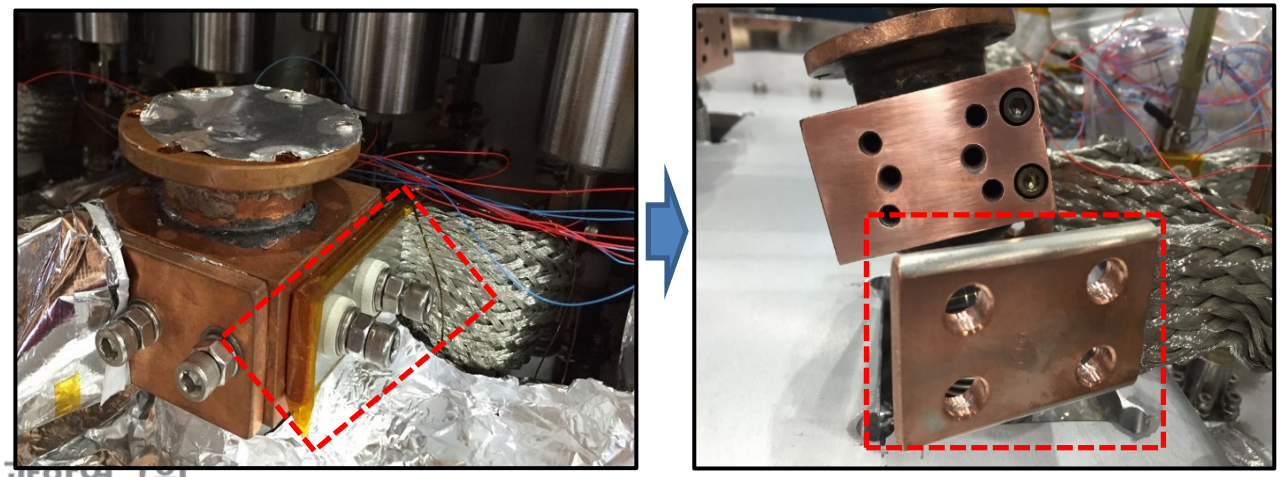
➔ Modification to enhance the cryo-system performance during the test facility building remodeling work

Modification of a cryo-system

- Screw structure is modified



- Change the heat transfer cable between cryo-cooler and SC coil current lead into thicker and wider one

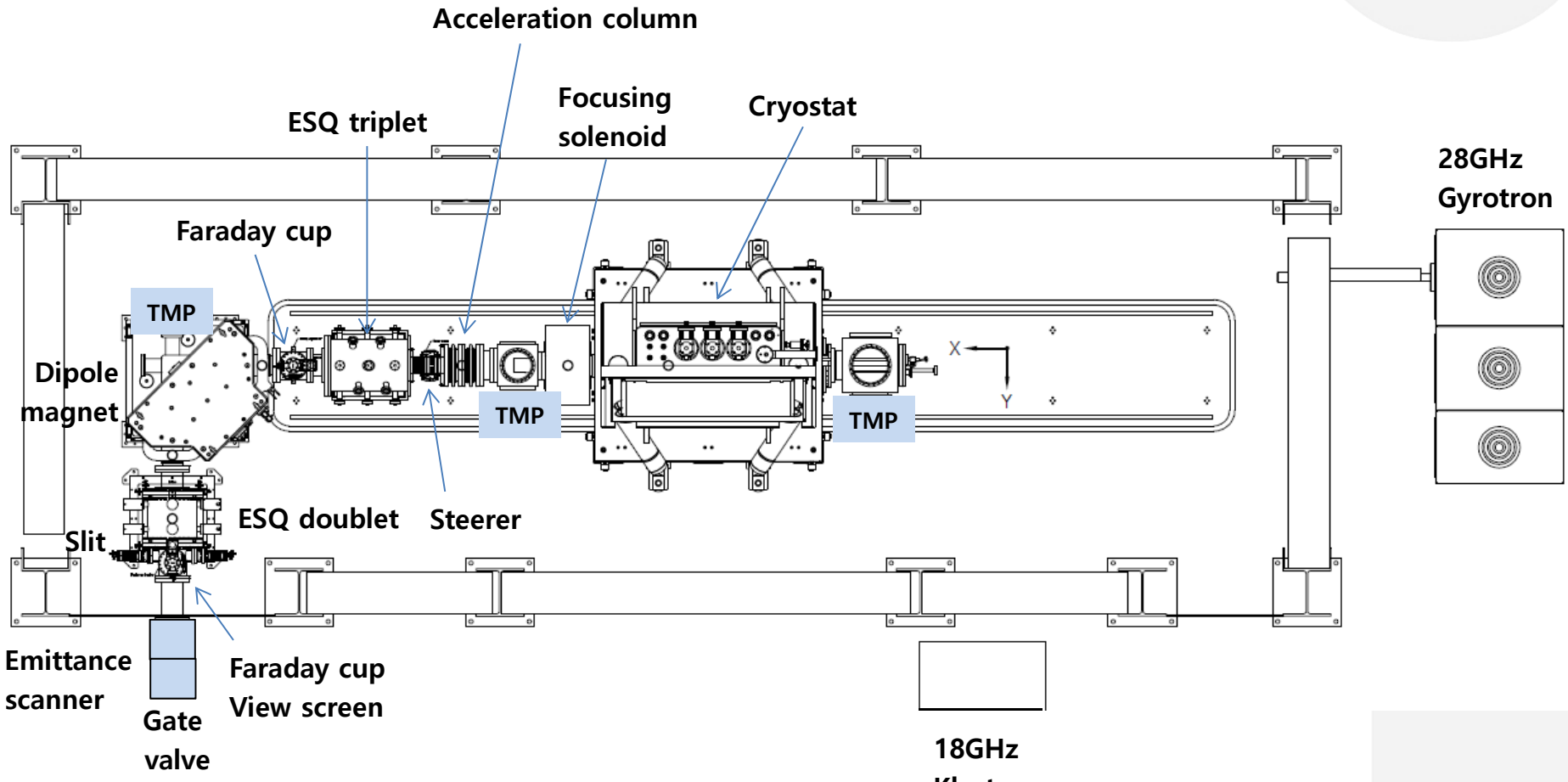


Modification of a cryo-system

- Enlarge a surface area of a LHe condensing part

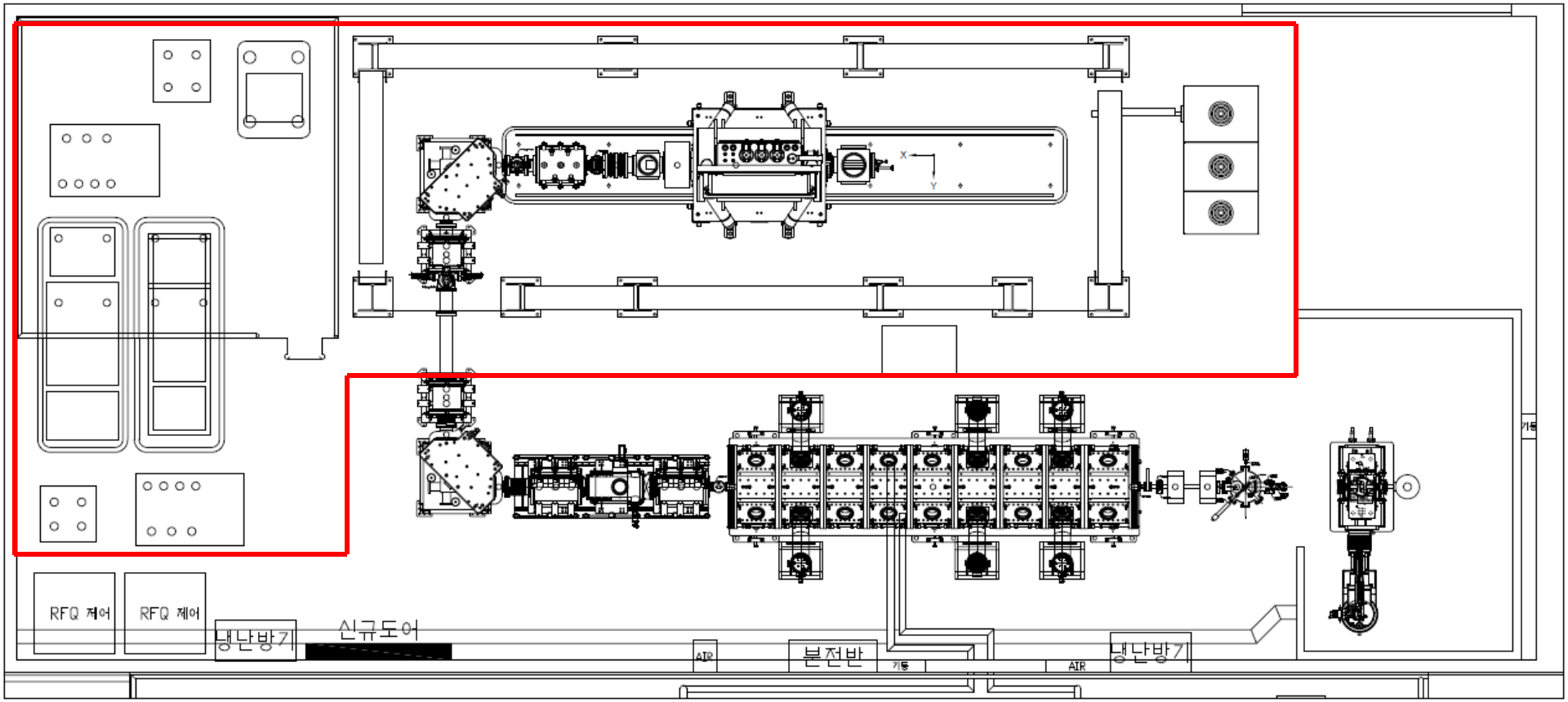
- After modification, cryostat cooling capacity was recovered over 6 W

Test layout of the ECRIS after reinstallation in 2016



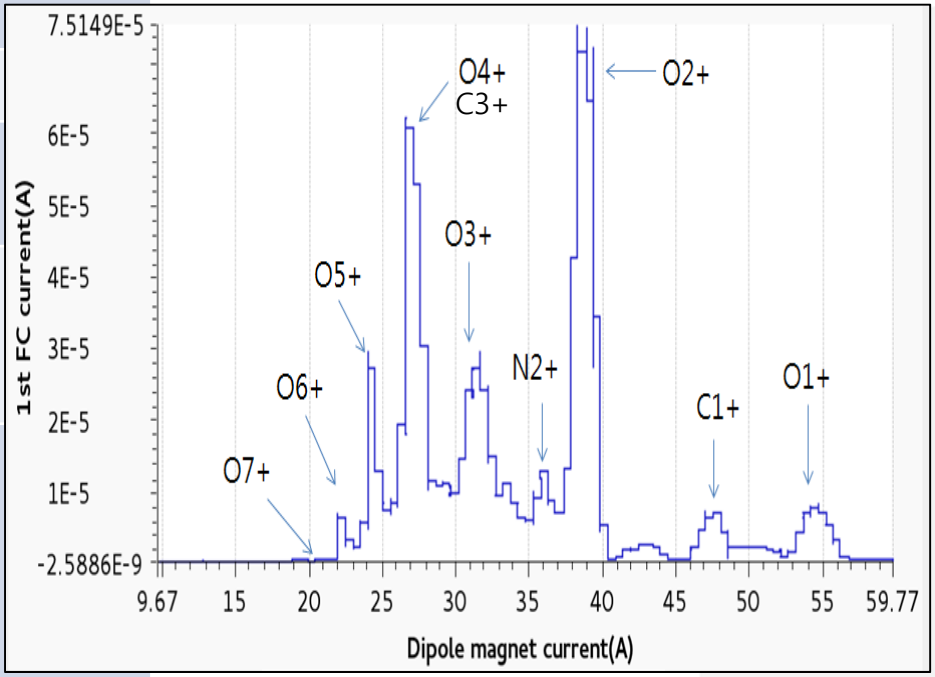
Test layout of the ion source as a part of SCL Demo

ECRIS test layout



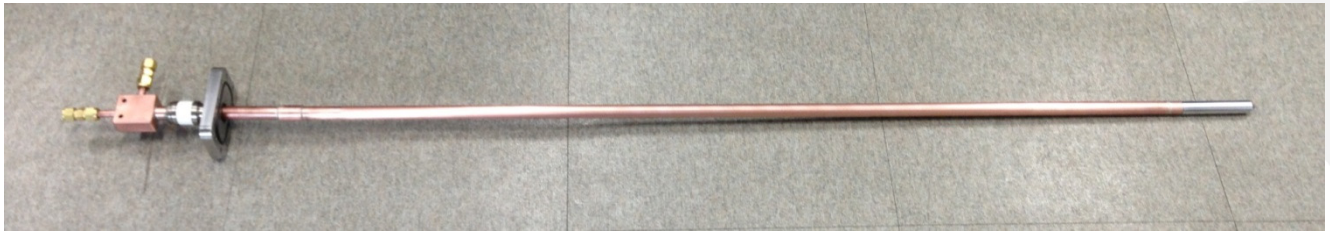
beam commissioning in 2016

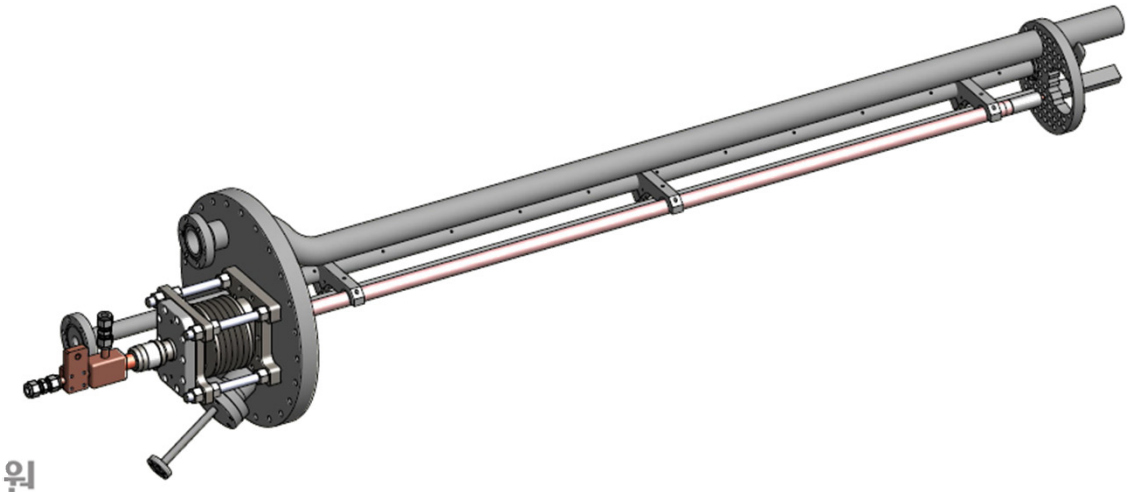
Parameters	value	Note
Mag. Field	60% for Solenoid, 70% for Hexapole	
Base pressure	3.0 x 10e-8 Torr	
Operating pressure	1.0 x 10e-7 Torr	
Operating gas	Oxygen	
RF power	28 GHz 200 W → 250 W → 300 W → 400 W	
Applied potential	Plasma electrode : 12.5 kV Acceleration electrode : -1 kV → -2 kV Deceleration electrode : grounded	
Focusing solenoid	170 A	For O5+
ESQ triplet	#1 : 1.0 kV #2 : 1.8 kV #3 : 0.9 kV	
ESQ doublet	#1 : 0.9 kV #2 : 0.3 kV	
Steerer	X : 0 A Y : 0 A	



Preparation for metal beam test

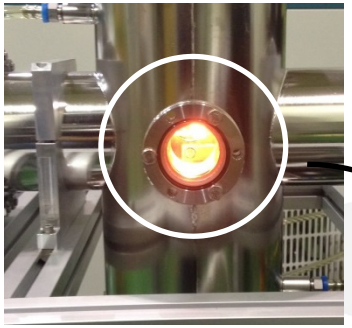
- Target beam : Bi which has many test data from other research group
- Sputtering rod with water cooling system
  : melting point of Bi is 271.5°C

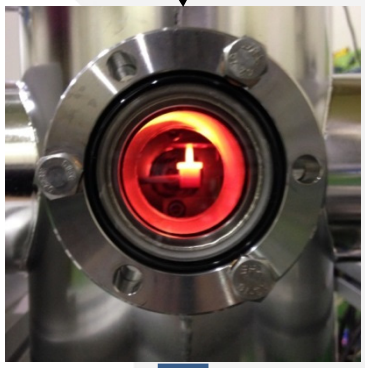


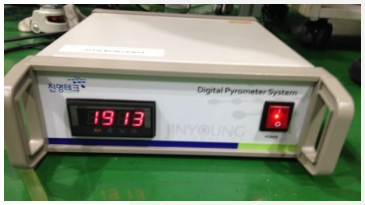


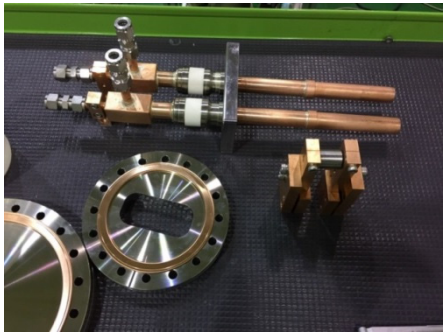
Preparation for metal beam test

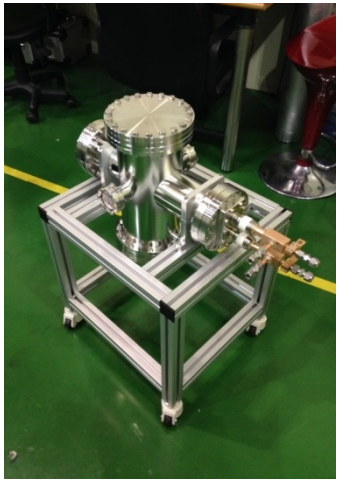
- Test oven : a benchmark of other research groups. Made of Tungsten











- 1900°C was achieved with 1.1kW

Summary

1. We has built a 3rd generation SC-ECRIS since 2013
2. We began a machine commissioning in 2015
3. Our machine will supply a test beam for SCL demonstration of RISP through a beam commissioning
4. Current status of our machine are as follows
   1) Cryo-cooling capacity of 6.3W is being sustained
   2) SC magnets are being operated stably at the 70% level of the design value
   3) Still doing Electrode conditioning :
      : to get the stable operating condition with the potential difference between plasma electrode and acceleration electrode is 25kV
   4) Beam commissioning is being done to supply a O7+ beam of 10uA to RFQ
      : this year's goal
   5) Metal beam test is being prepared parallely

- I would like to thank to Dr. Nakagawa, Dr. Sun, and Dr. Thuillier who give me many valuable advices always.