Current Status of a SC-ECRIS of the Rare Isotope Science Project

Yonghwan Kim

ibs 기초과학연구원
Institute for Basic Science

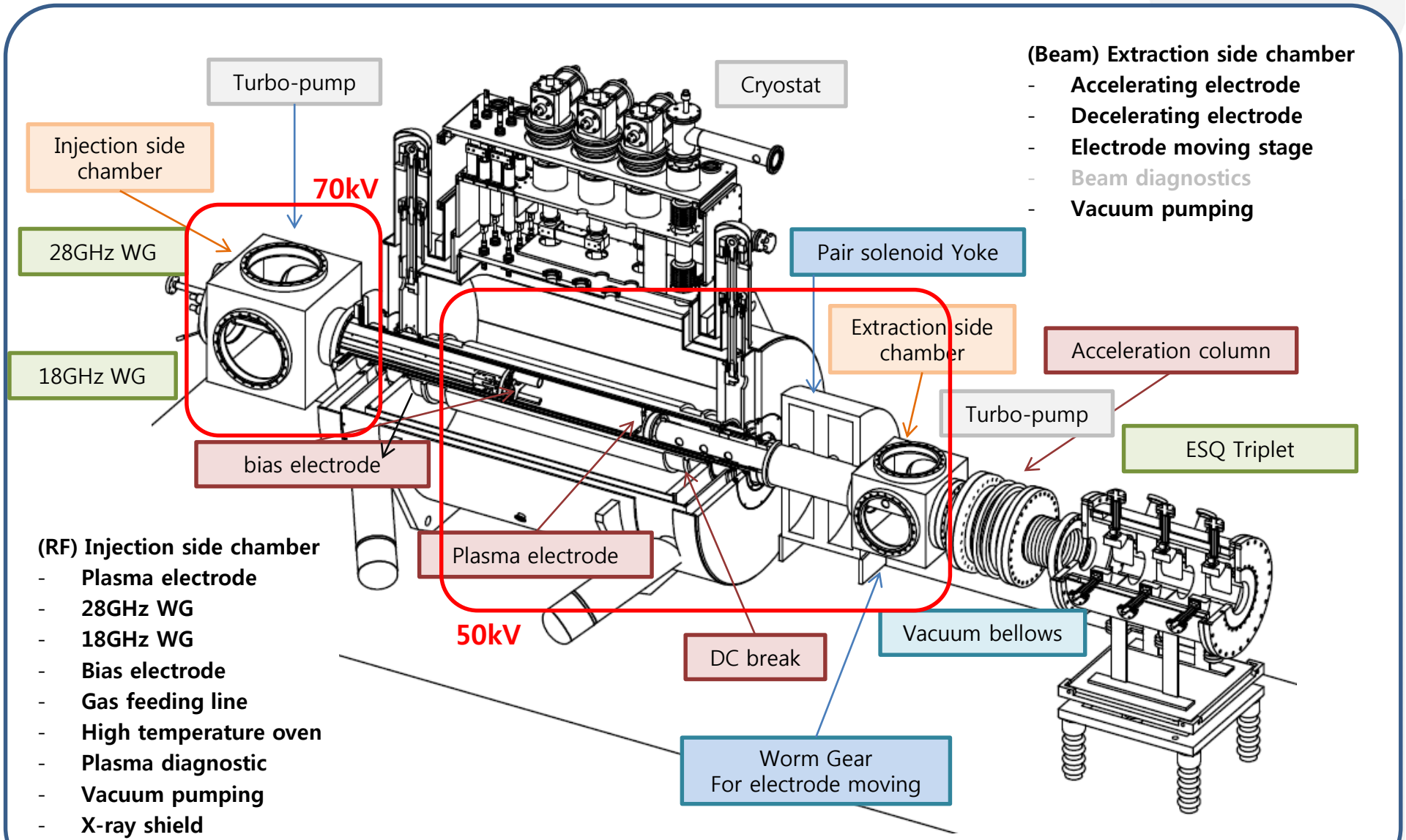
RISP

Design 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

Schematic View of ECRIS

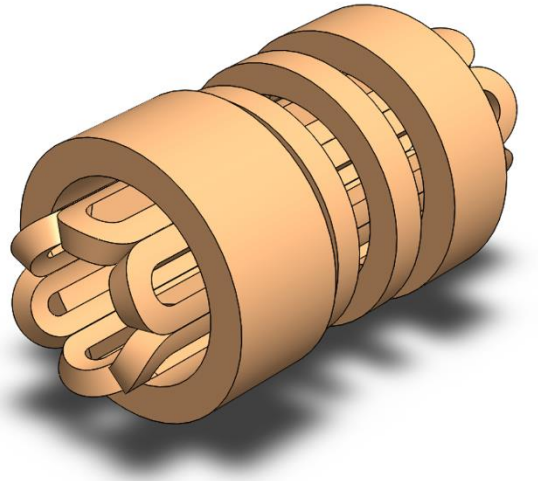


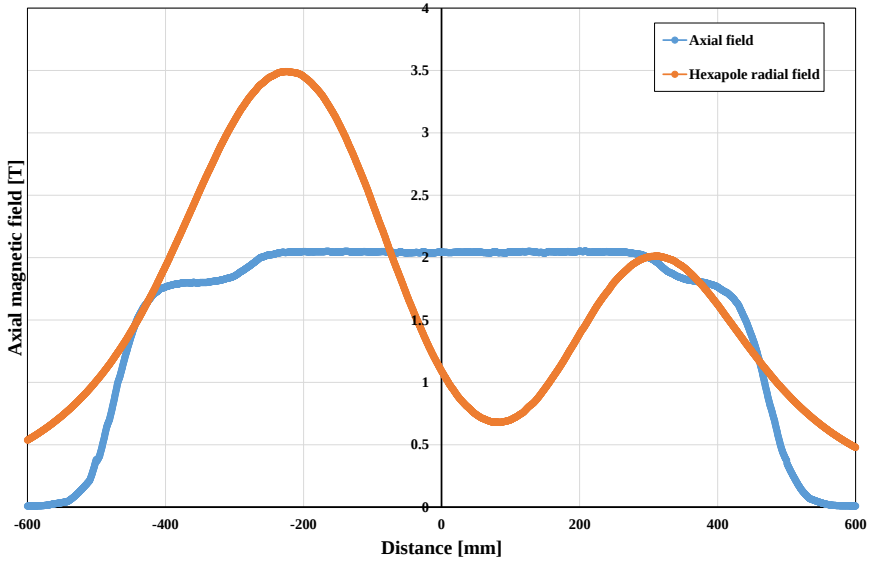
(Beam) Extraction side chamber
- **Accelerating electrode**
- **Decelerating electrode**
- **Electrode moving stage**
- **Beam diagnostics**
- **Vacuum pumping**

(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**

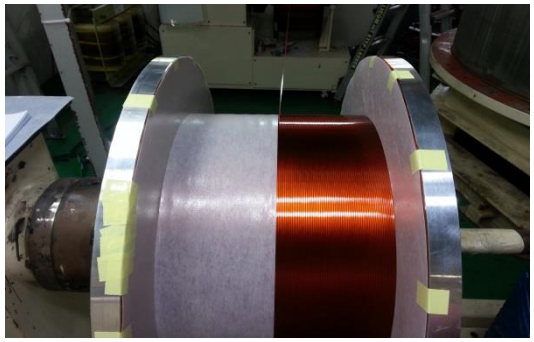
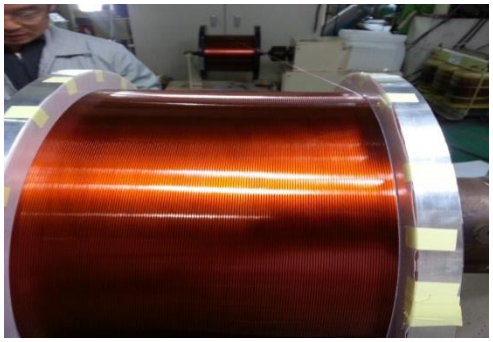
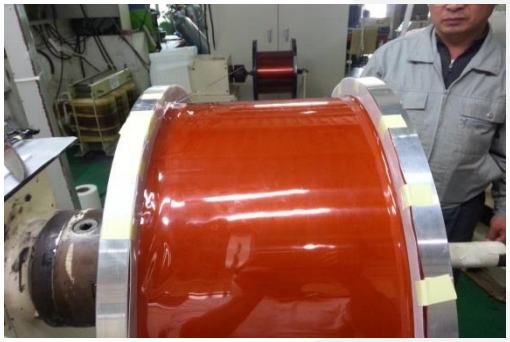
Design of superconducting magnet

	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

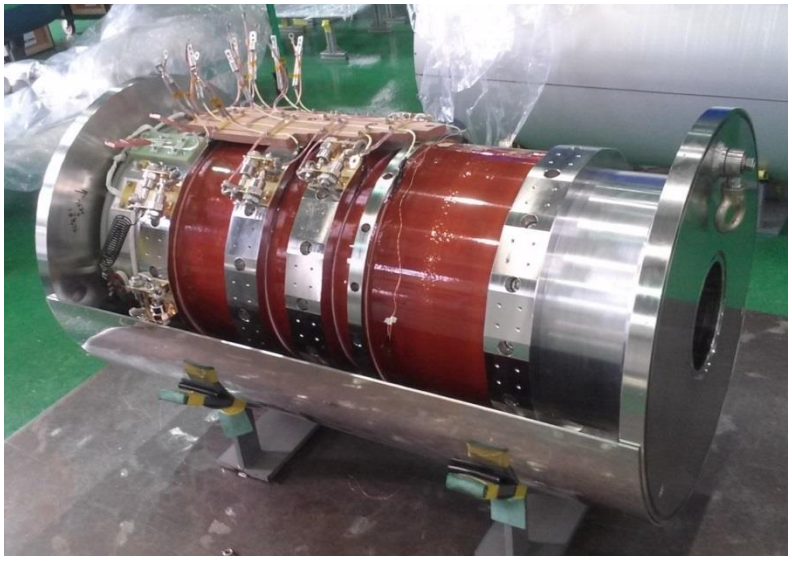


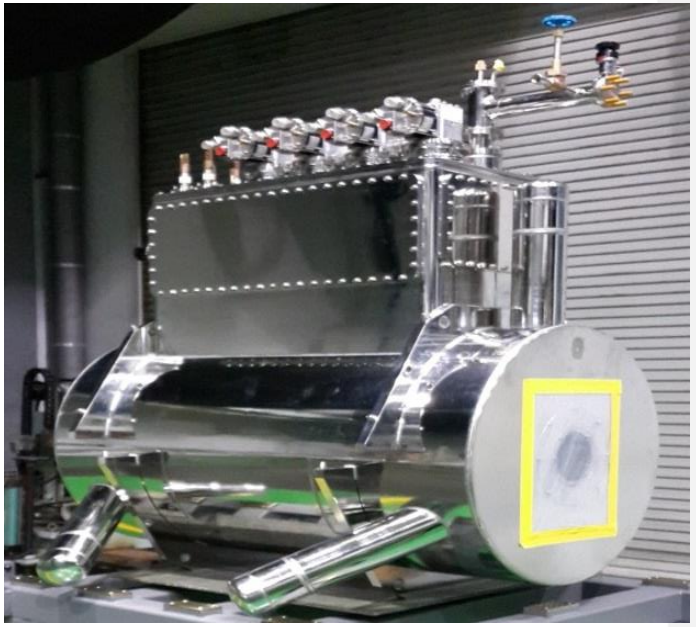


Fabrication of SC-coil with a Korean domestic company

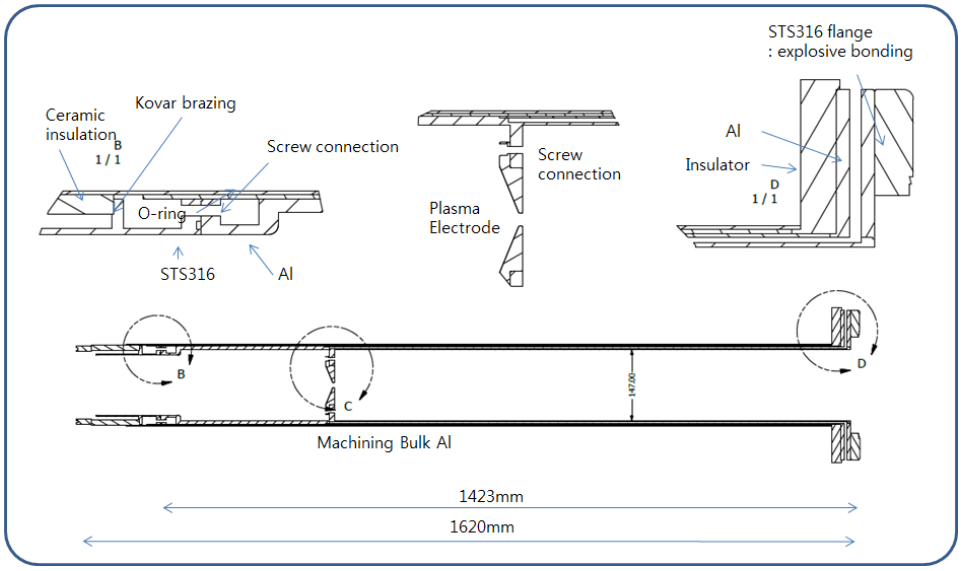
Cryostat assembly

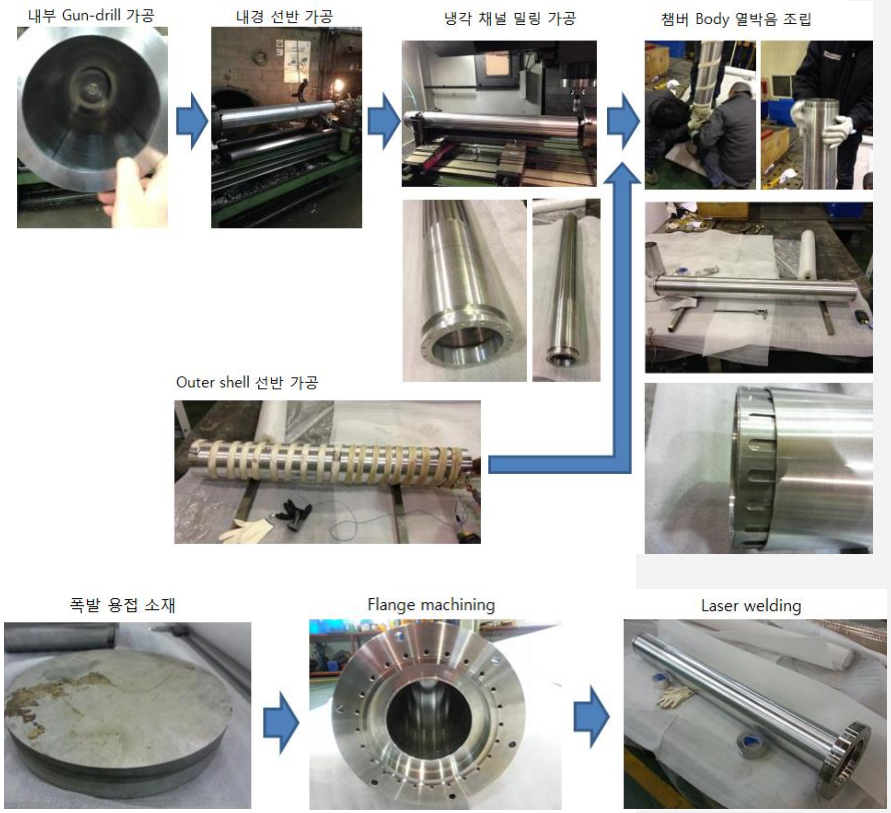




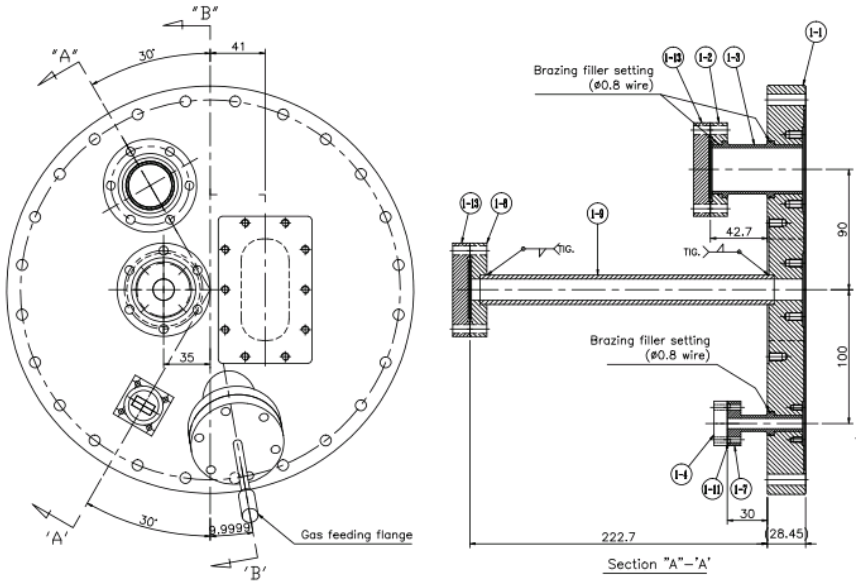
Plasma chamber design and fabrication

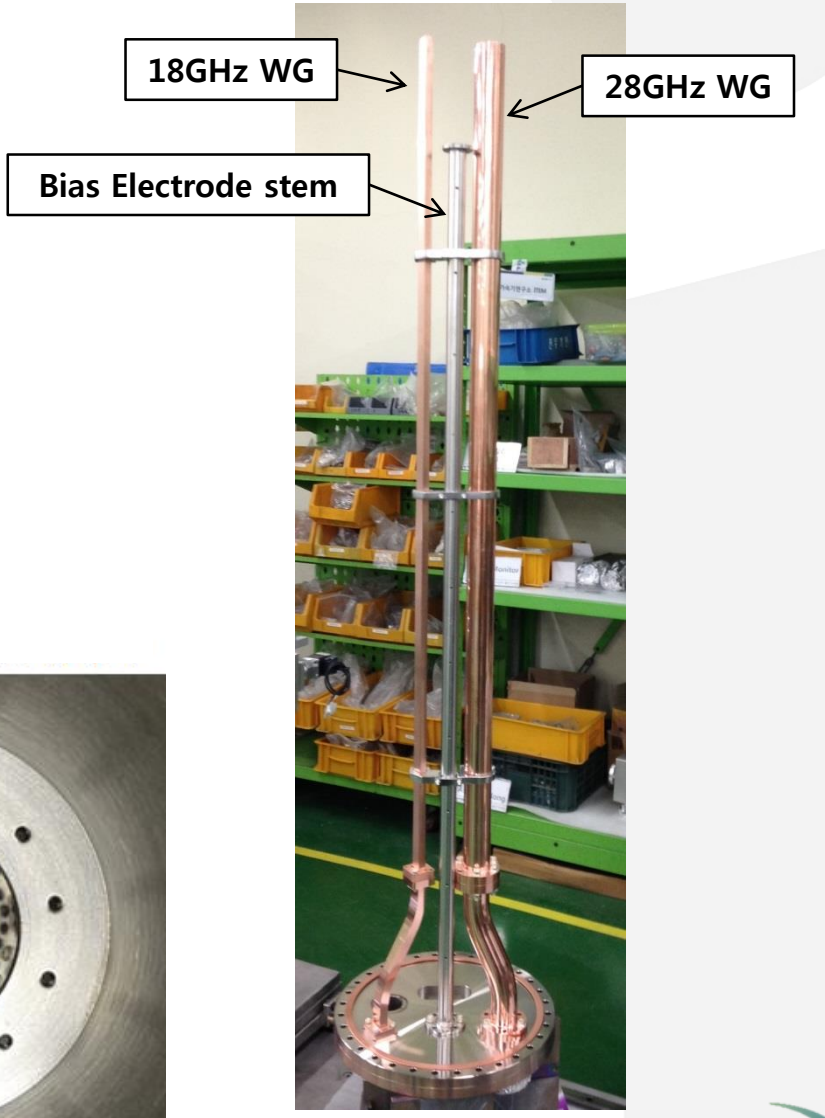
- Chamber material : Aluminum
- Vacuum seal : avoid o-ring seal but metal seal if it is possible



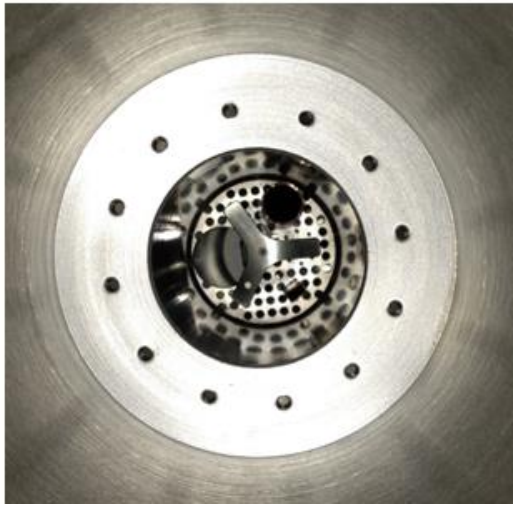


Microwave injection & plasma generation part





Plasma facing electrode

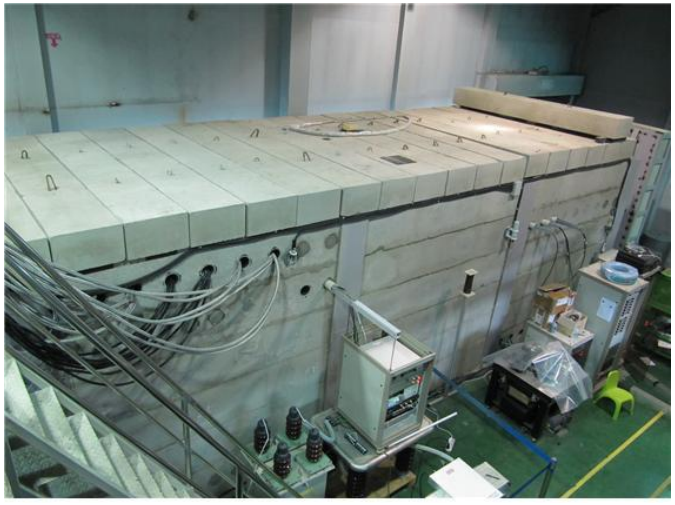


Installation History

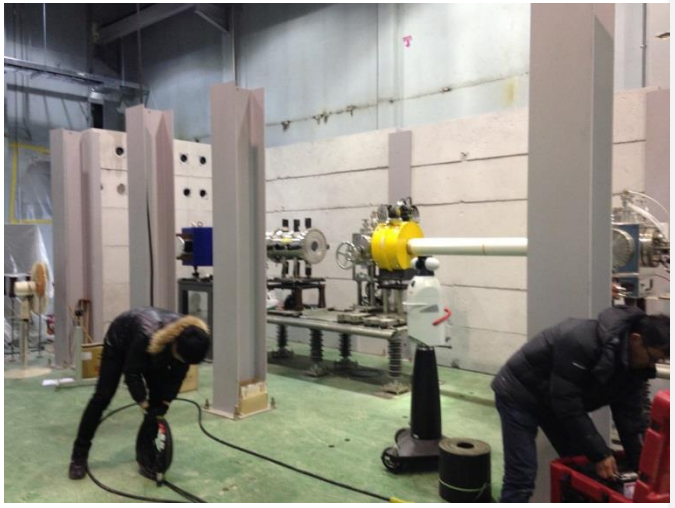
- 2014. 05. 26

- 2015. 01

- 2015. 03

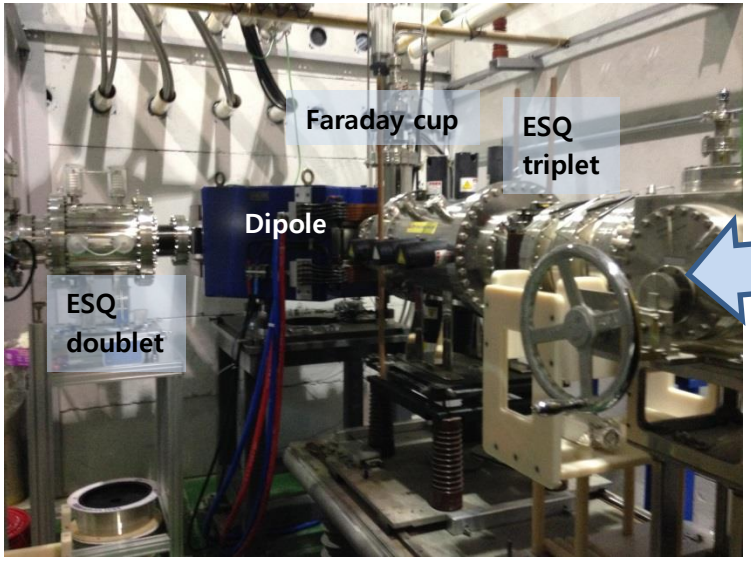


- 2016. 02

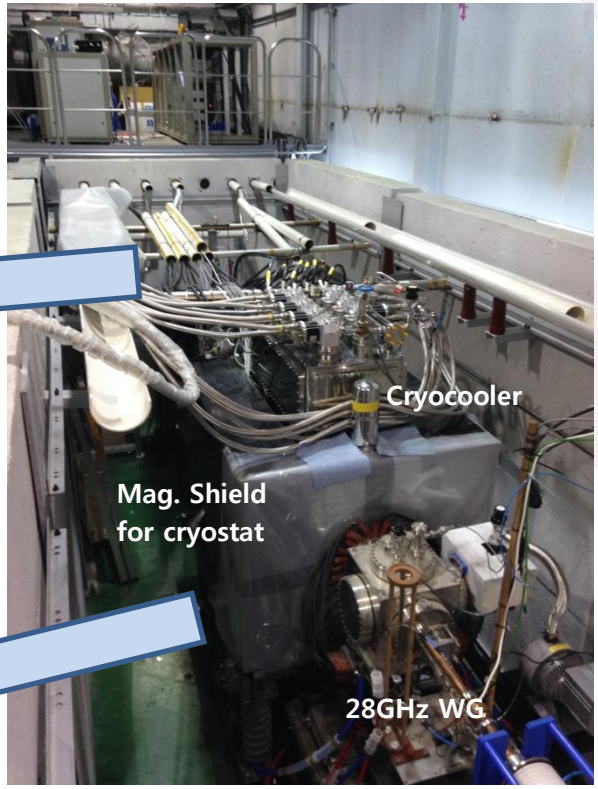


Installation History

- 2016.06

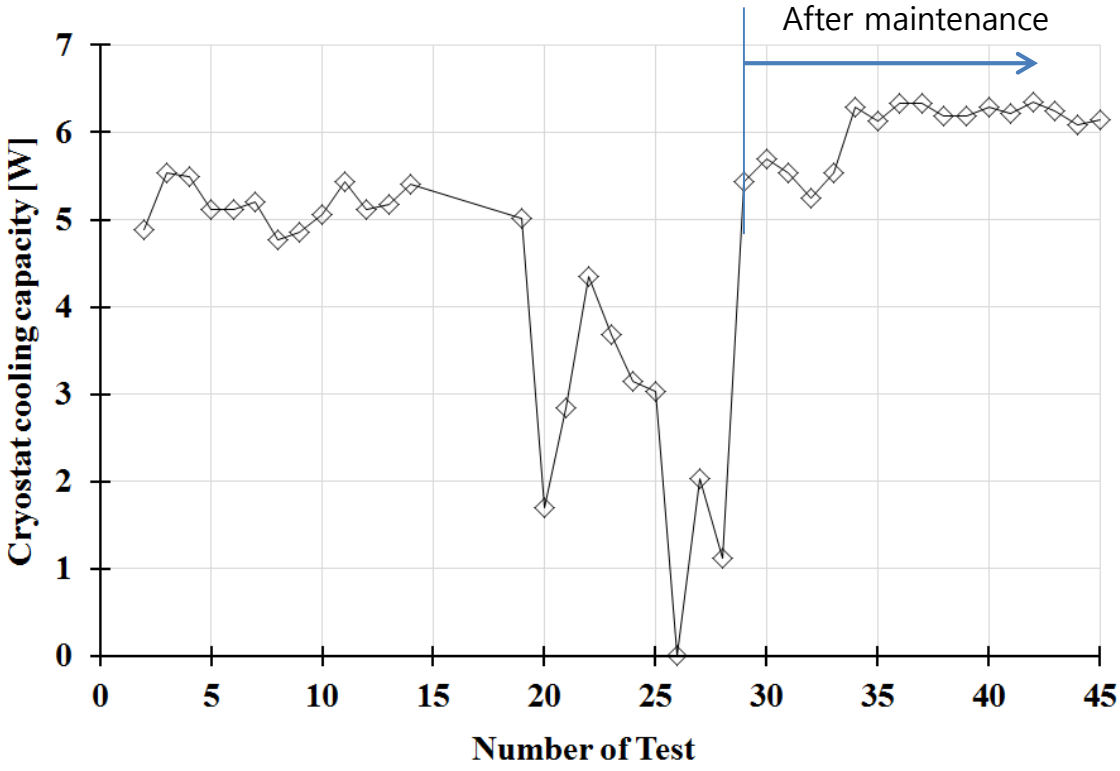


- 2016.08



Cryostat cooling capacity change

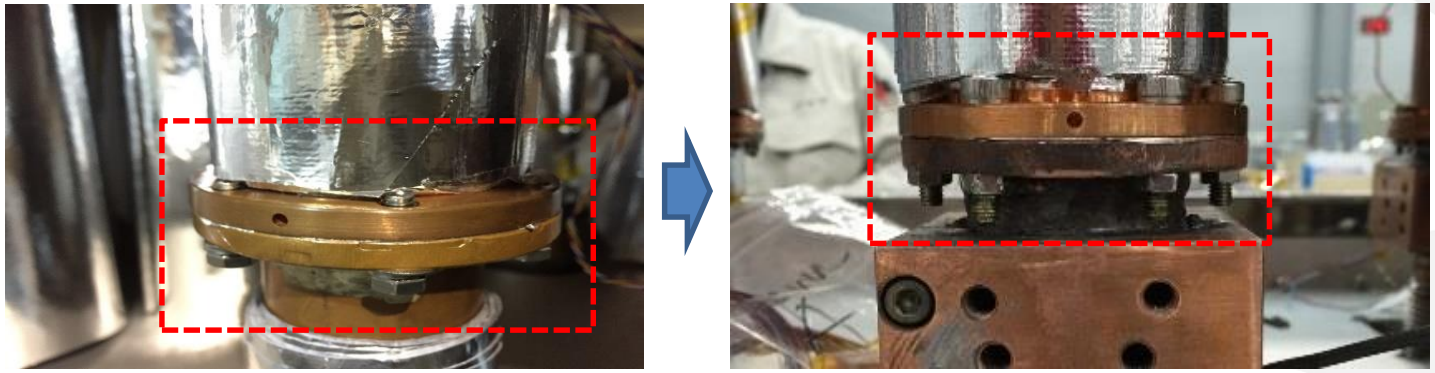
- Issue : Cooling capacity decreases during the experiments in 2015.



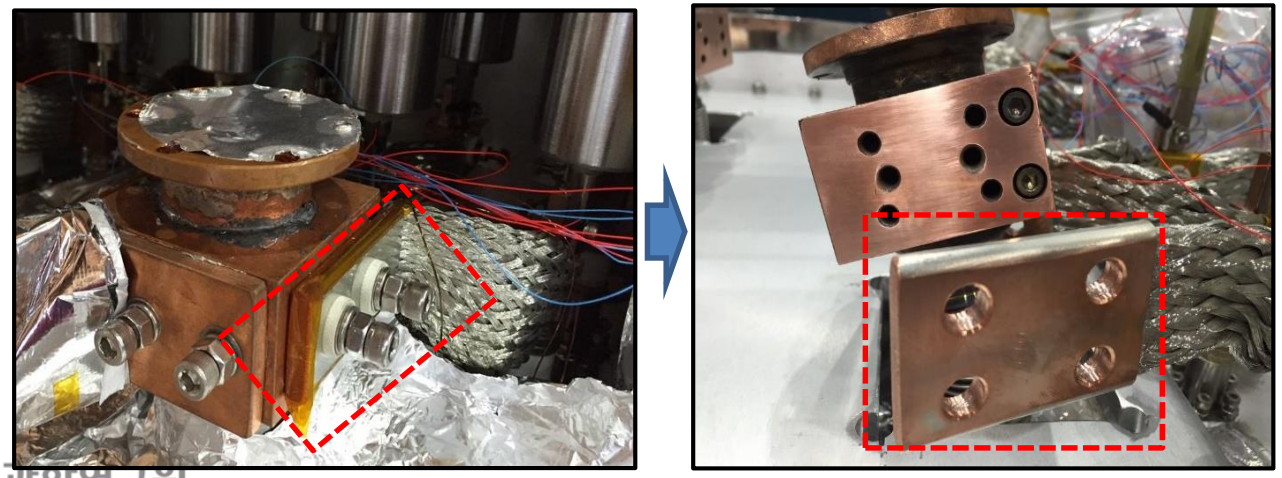
➔ Modification to enhance the cryo-system performance during the test facility building remodeling work

Modification of a cryo-system

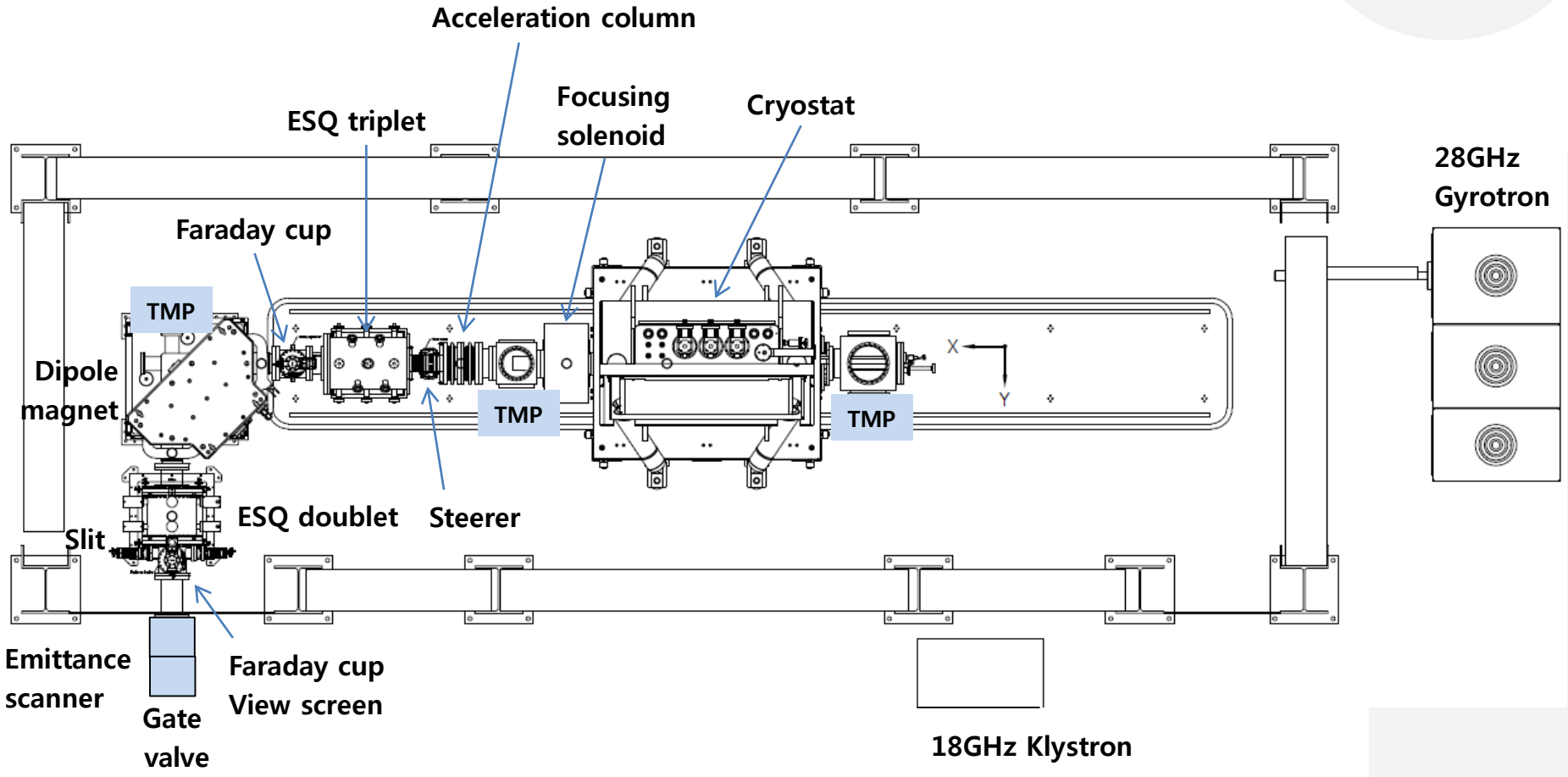
- Screw structure is modified



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

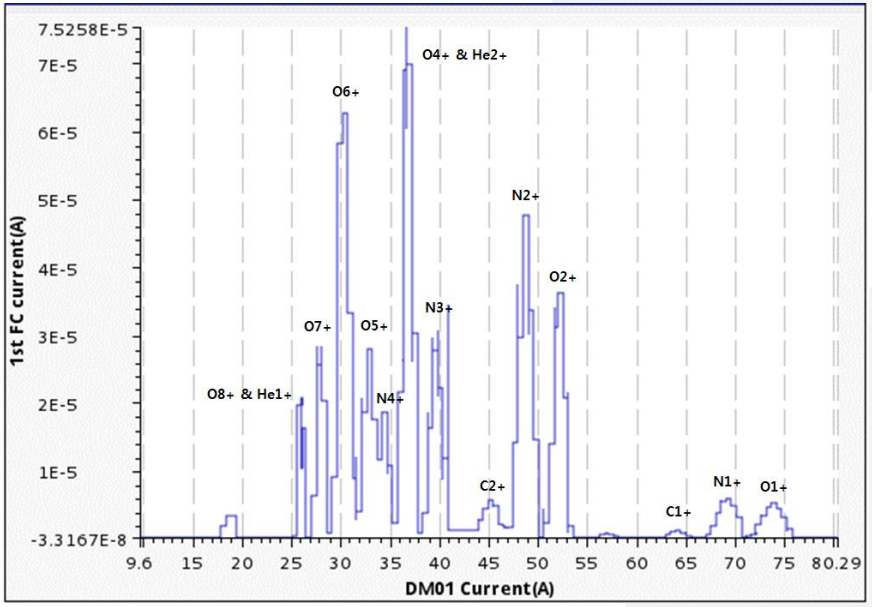


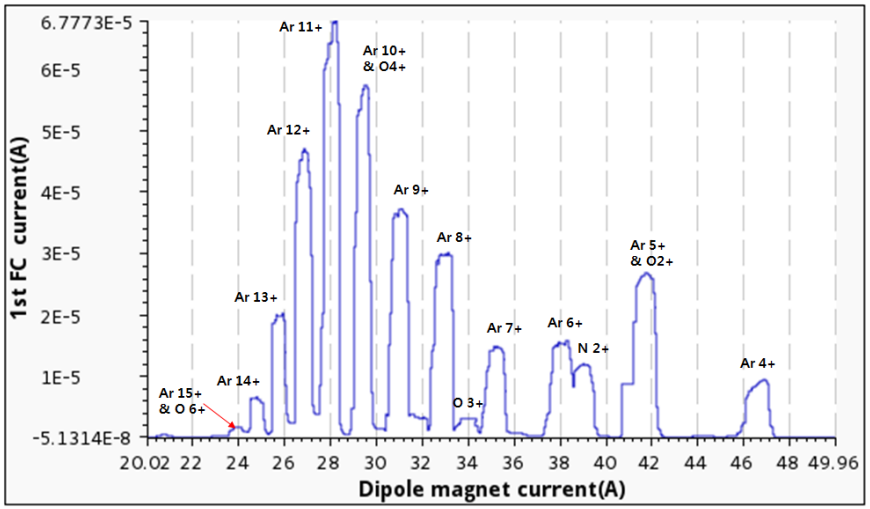
Test layout of the ECRIS after reinstallation in 2016



Low field level runs(18GHz RF power) at the early test period

Operation parameter	Operation range	Note
RF Power	18 GHz, 100~500 W	
Vacuum pressure in injection chamber	1.0e-8 ~ 1.0e-6 Torr	
Binj Bext Bmin Br	2.2 ~ 2.6 T 1.2 T 0.42 ~ 0.53 T 1.2 T	Suitable for 18GHz
Operation target	• Maximize O7+ beam current while sustaining a beam stability	



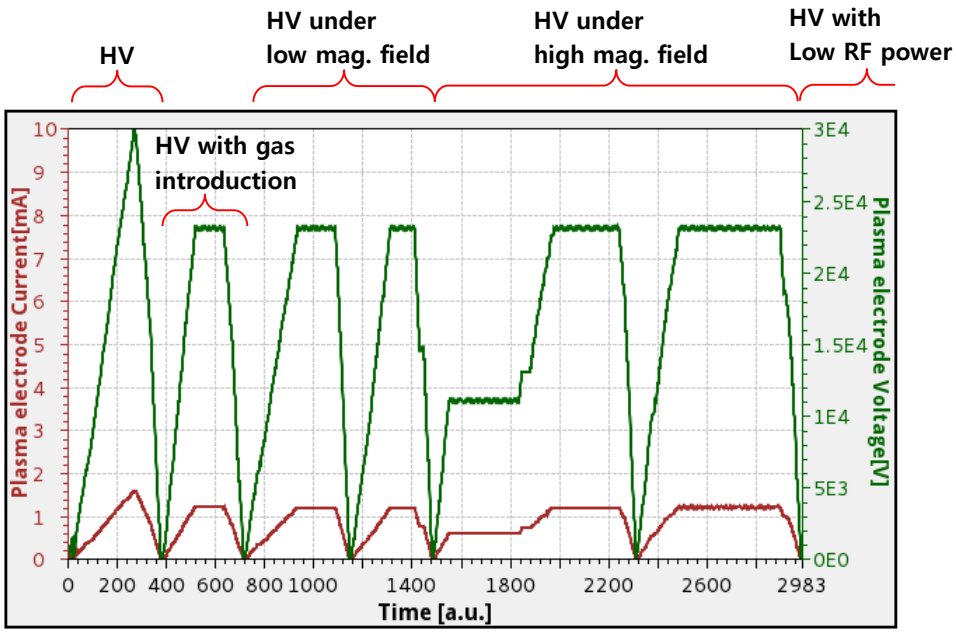


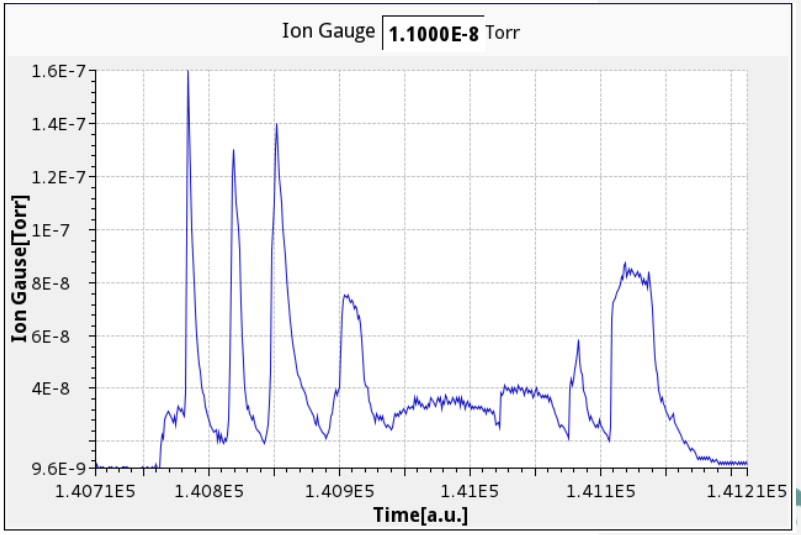
- As an early test stage,
  - O7+ of 30euA was extracted
  - Ar11+ of about 70euA was extracted.

Low field level runs(18GHz RF power) at the early test period

Issues of electronics damage by surge potential from a spark

- When a spark occurs, some electronic devices have some shock induced by the surge potential
  → We installed a protection circuit to protect the electronics and
  → We established the conditioning routine to suppress the spark occurrence
  → Especially we found that vacuum level showed a fluctuation,
  and we increased HV after the vacuum level was recovered

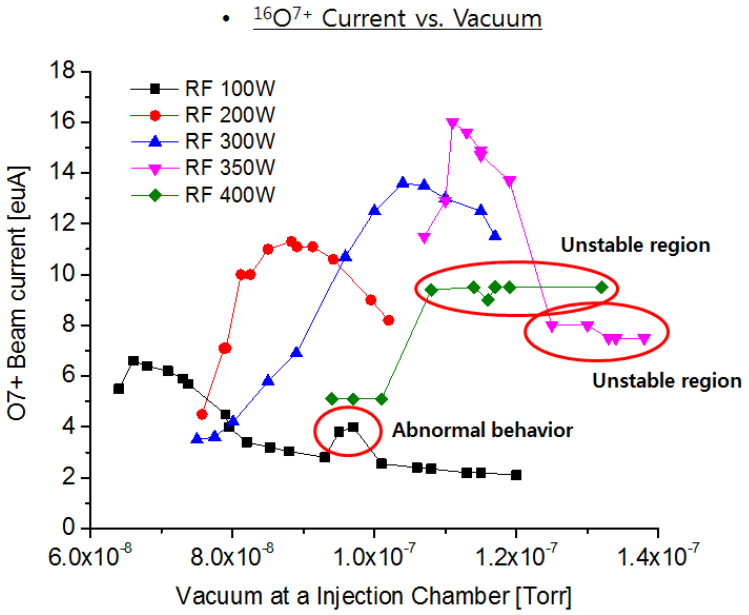


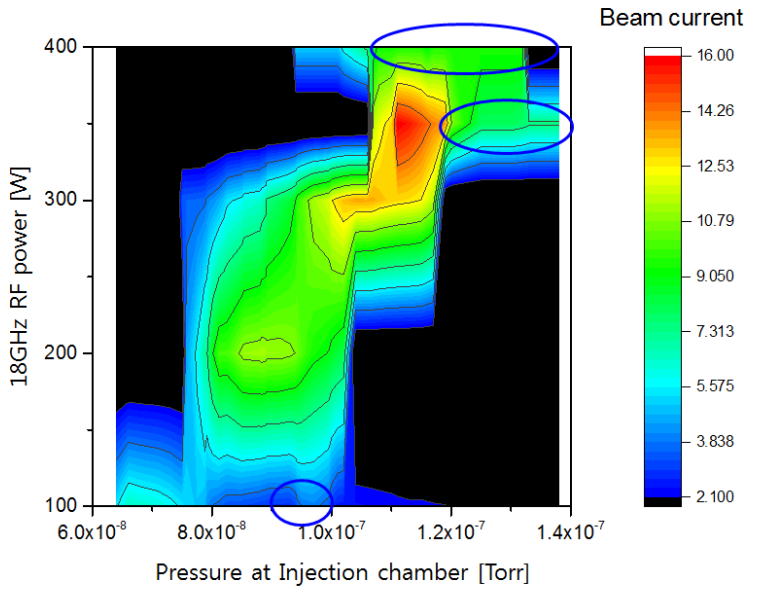


Low field level runs(18GHz RF power) at the early test period

Issues of the plasma stability

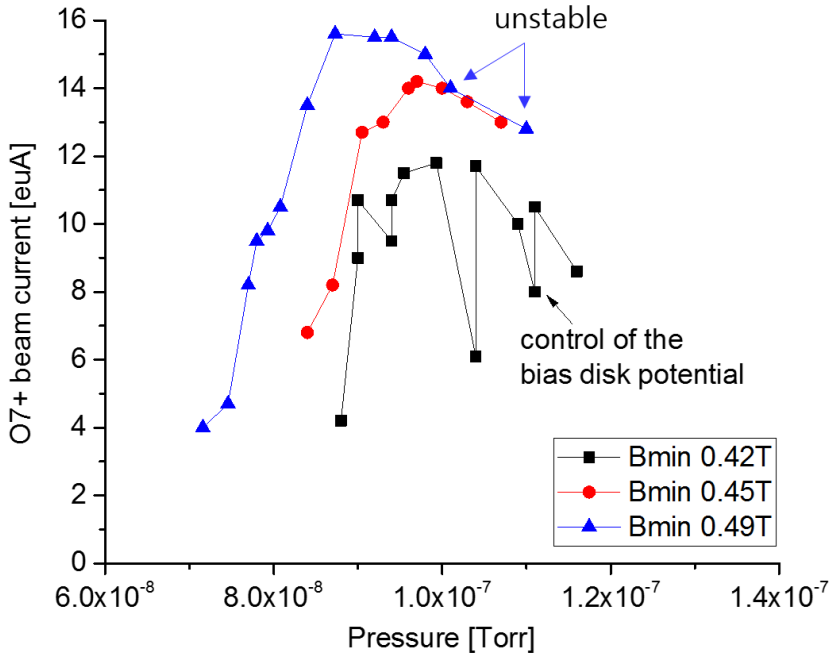
- When we applied just more than 400W of RF power for higher beam current test, plasma goes to unstable region



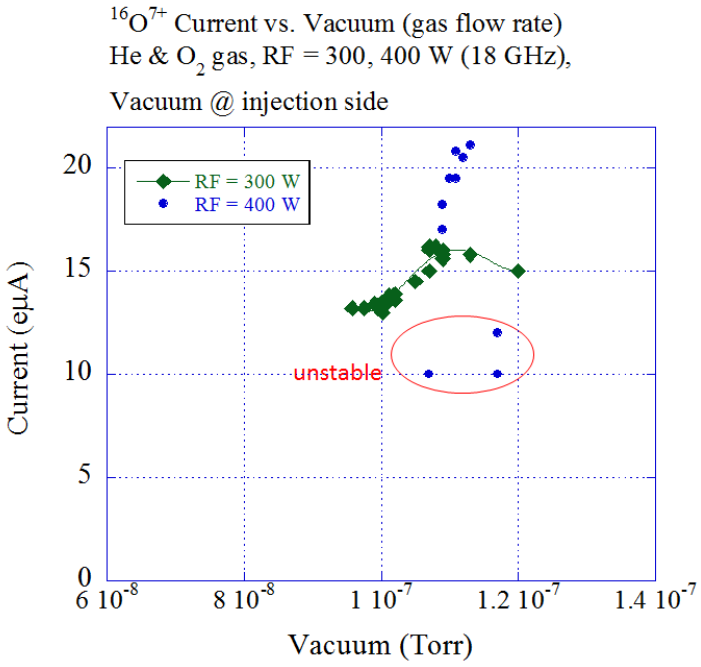


Low field level runs(18GHz RF power) at the early test period

Bmin control experiment



He gas mixing experiment

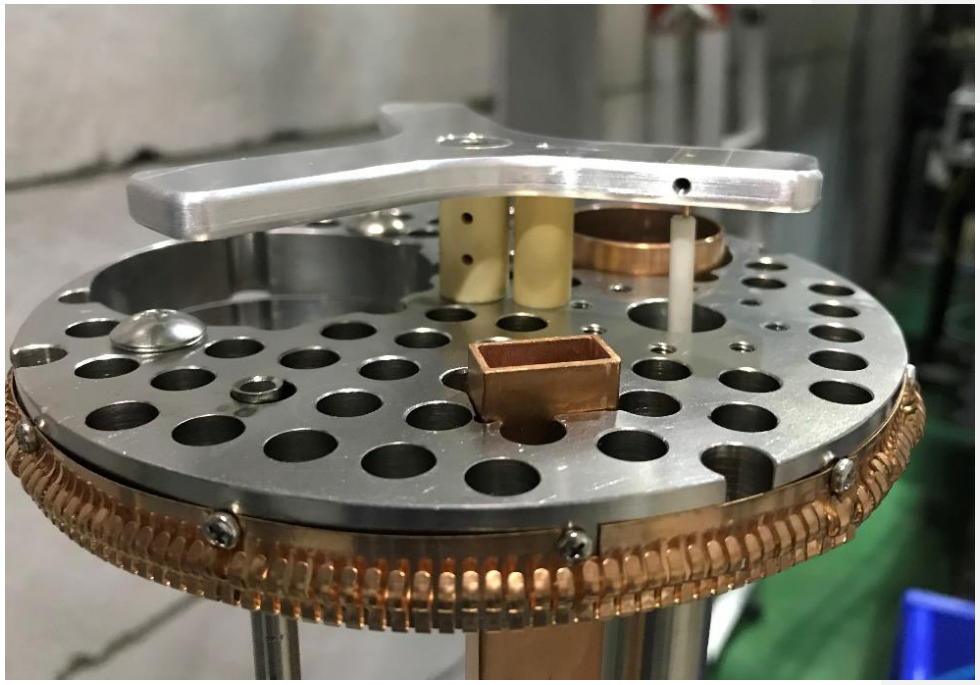


- We could not improve the plasma stability through Bmin control or gas mixing
- [Note] 400W is not a high power level because the plasma chamber volume is 10 Liter.

Internal inspection of the plasma chamber

- Mistake in the connection of hexapole polarity
- Spark occurs at the sharp edge inside of the chamber

Maintenance of the plasma chamber



- revise the connection of hexapole polarity
- Change the waveguide into a shorter one
- Remove the sharp edge inside of the chamber

- Now we are ready to start a beam extraction experiments again

Summary

1. We has built the 3rd generation SC-ECRIS since 2013
2. We began a system commissioning in 2015 and performance test since
3. We cleared some issues and now are ready to restart beam tests

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