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Development of 14.5 GHz ECR Ion Source at KAERI

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KAERI 한국원자력연구원 Korea Atomic Energy Research Institute

CONTENTS

Our motivation of this development

A heavy ion accelerator for cancer treatment is planned in Korea.

The accelerator could be

- Cyclotron or
- Synchrotron.

The construction schedule;

- from 2010 to 2015,
- at this moment it is in conceptual design phase,
- the accelerator type will be fixed at the end of this year.

There needs ECR ion sources for multi-charged carbon beam.

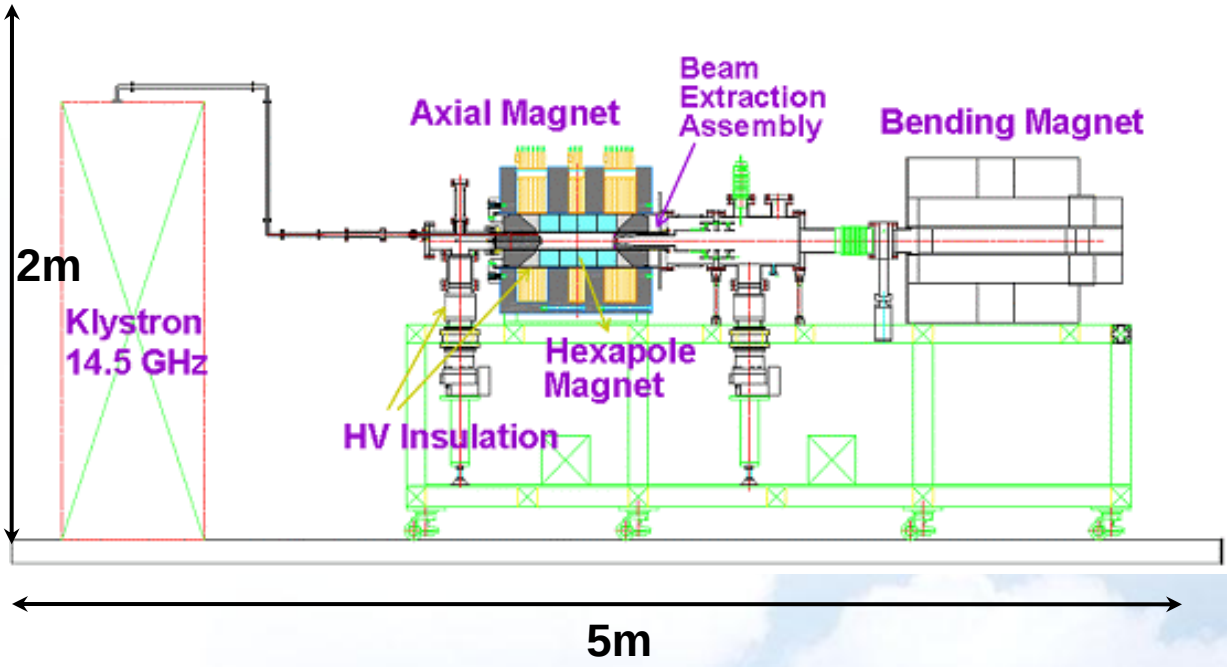
This work was started 3 years before as one of the base study of the project.

CONTENTS

- Objective of the Development
- ECRIS Design and Fabrication
- Field Measurement Results
- Results on ECR Plasma Experiments
  - *Camera images*
  - *Optical sensor and PM tube*
  - *Bremsstrahlung X-ray*
- Summary and Future Works

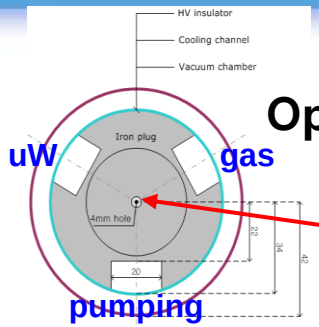
Designed Specifications of KAERI ECRIS

Device Parameters	EM-type
Frequency	14.5 GHz
Power	2.0 kW
B_{ECR}	0.52 T
B_{inj}	1.7 T
B_{ext}	1.1 T
B_{rmax}	1 T
R_{inj}	3.3
L_{ECR}	90 mm
V_{plasma}	85 cm^3
$ID_{chamber}$	68 mm
$L_{chamber}$	320 mm
D_{ext}	8 mm
V_{ext}	20 kV
I_{C6+}	20 eμA



Drawing of the designed KERI ECR ion source

Magnet System Design



Opening of the Input plug

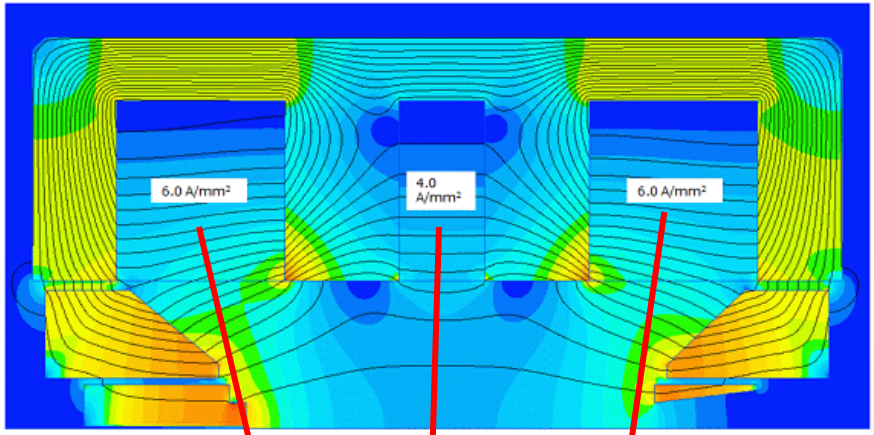
uW

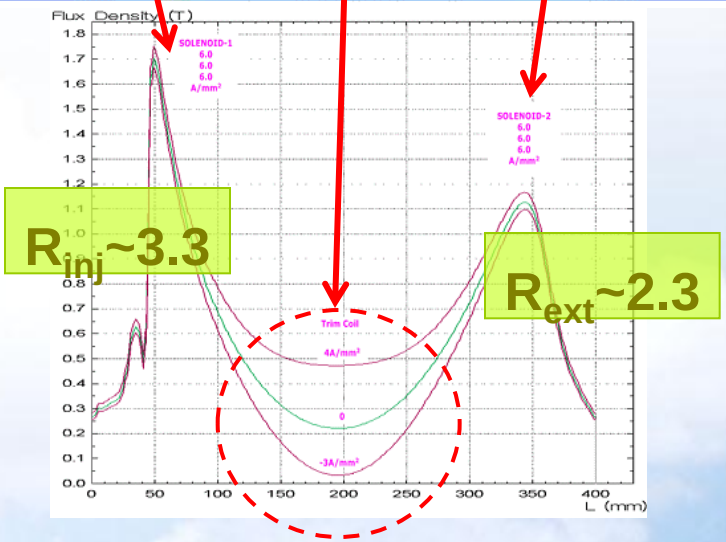
gas

Bias disc

pumping

Structure of the magnet system





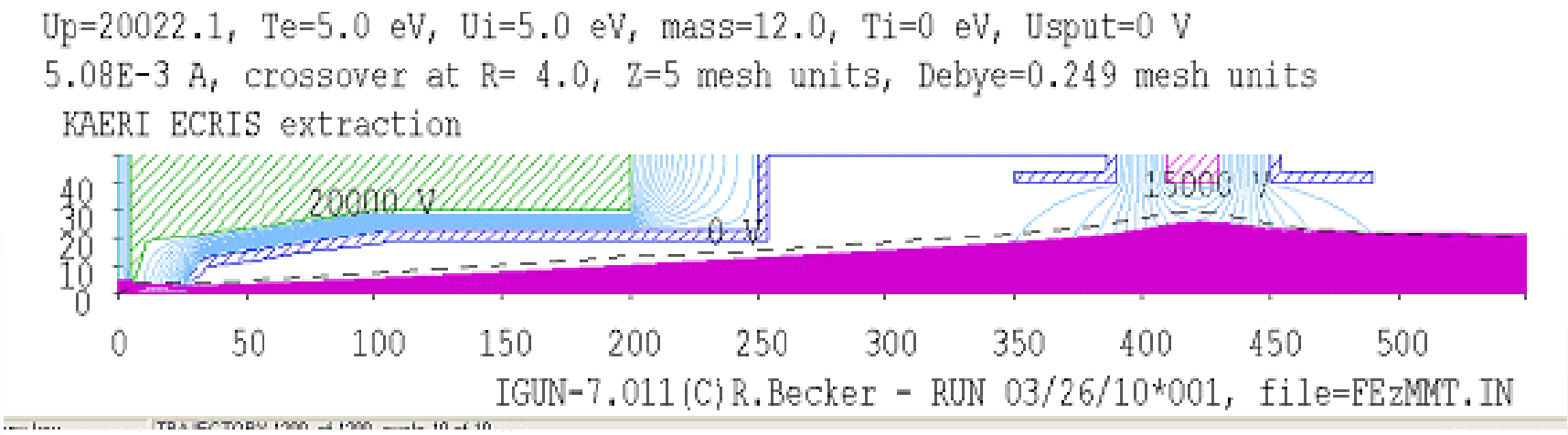
R_{inj}~3.3

R_{ext}~2.3

Axial field distribution

- Could be controlled by trim coil current

Beam Extraction Optics (IGUN Simulation)



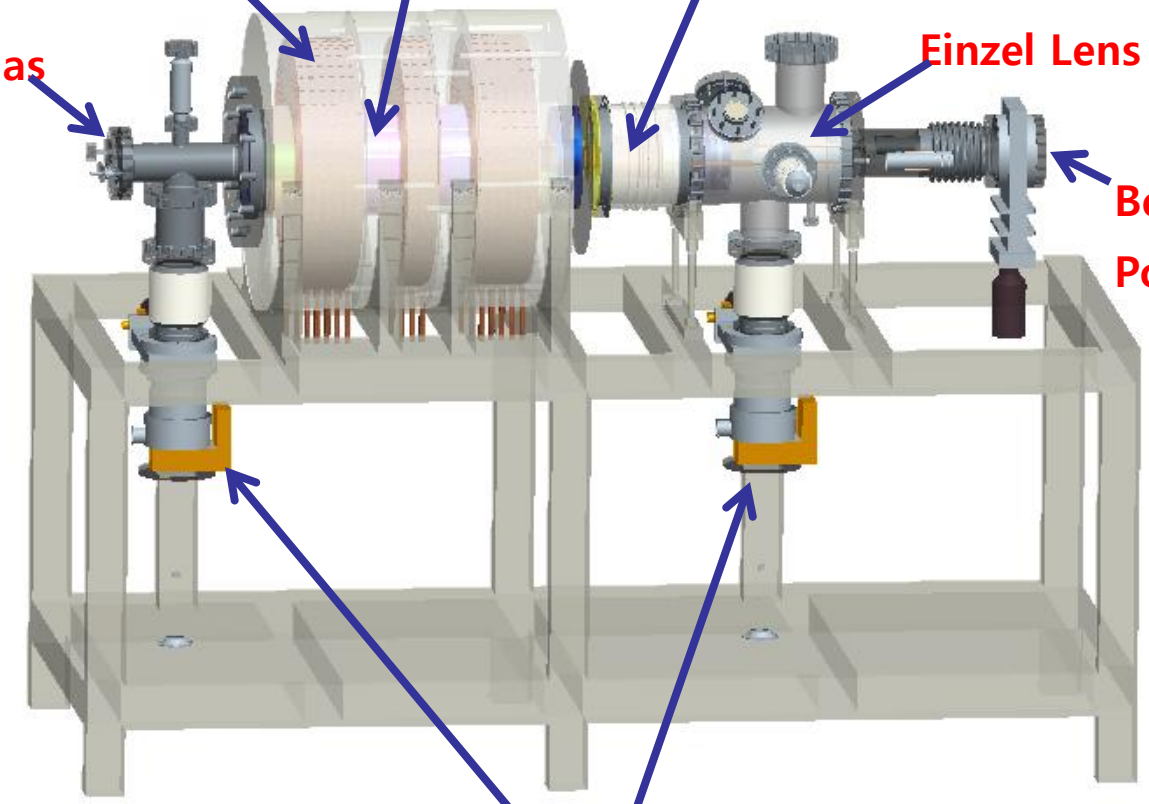
$V_{extraction}$ = 20 kV, V_{einzel} = 15 kV, D_{gap} = 24 mm

I_{beam} = C^{+2} 0.5 mA + C^{+4} 0.5 mA + C^{+6} 0.08 mA + H^{+} 4.0 mA

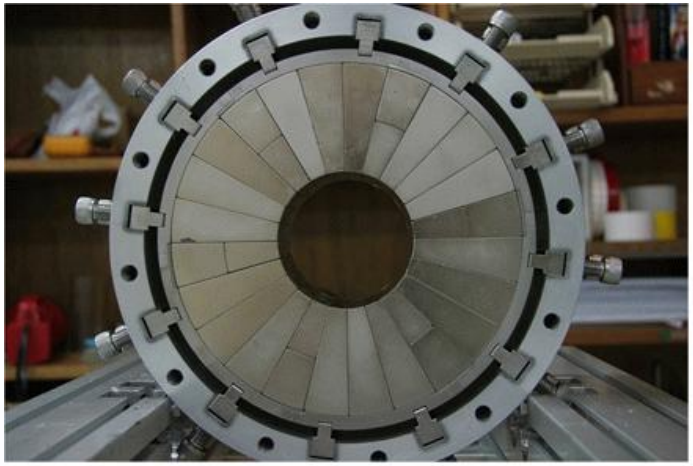
The acceleration gap can be adjusted within 0~50 mm, and the accelerating voltage in 0~50 kV.
The acceleration electrode is actively cooled.

- w/o deceleration grid
- einzel movement with beam extraction grid

Schematics of the assembled 14.5 GHz ECRIS

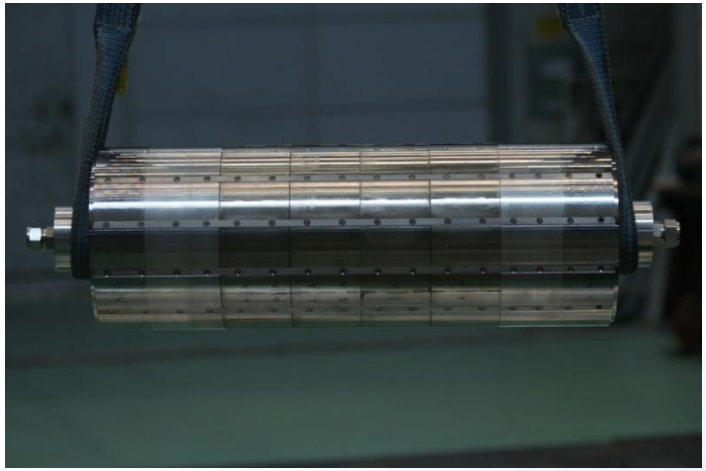


A hexapole magnet

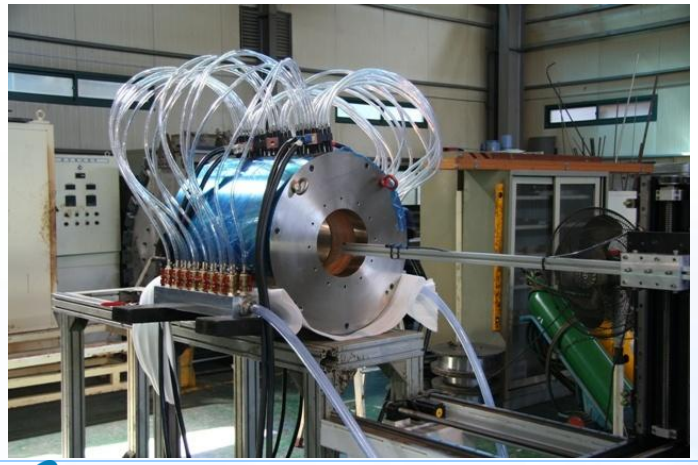


Assembled hexapole magnet

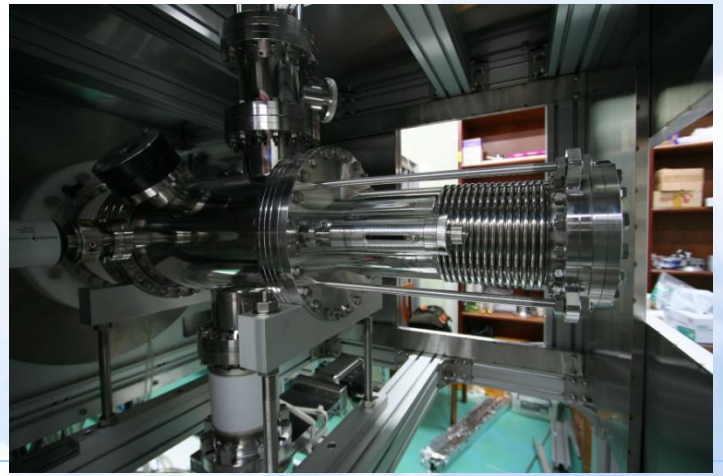
(N42SH, N45H)



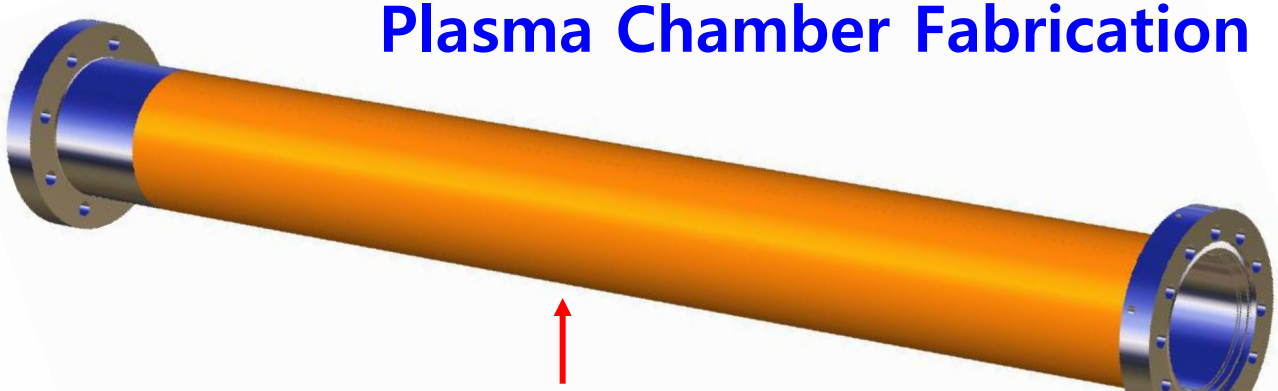
Assembled solenoids



Beam extractor & beam lens



Plasma Chamber Fabrication



1T-SS304 COVER

WELD

WELD

SS304

COOLING LINE

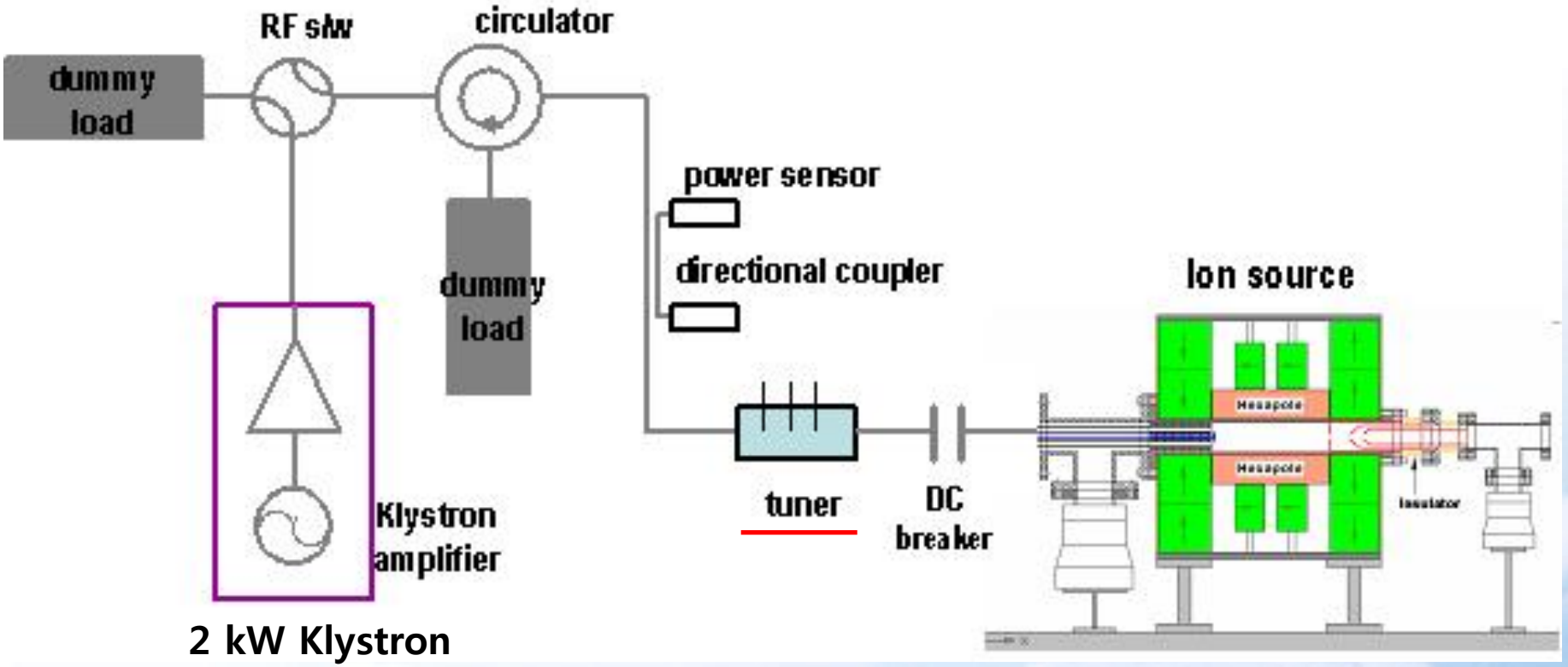
(2.5W x 2.0D GROOVE)

AL6061

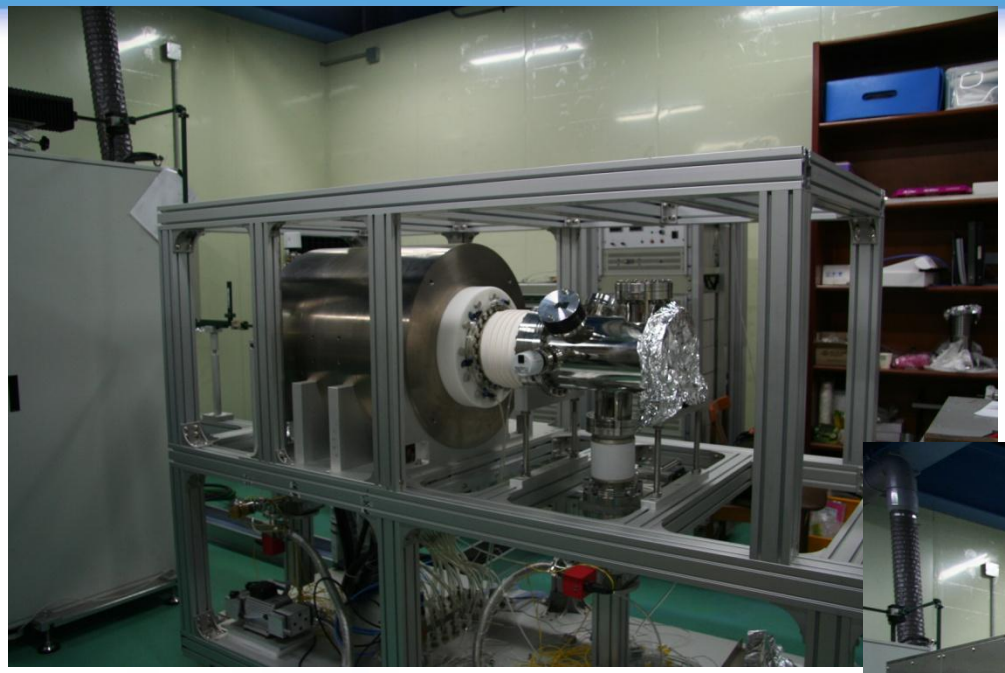
SS304

friction welding

14.5 GHz RF System



Assembled KAERI ECRIS

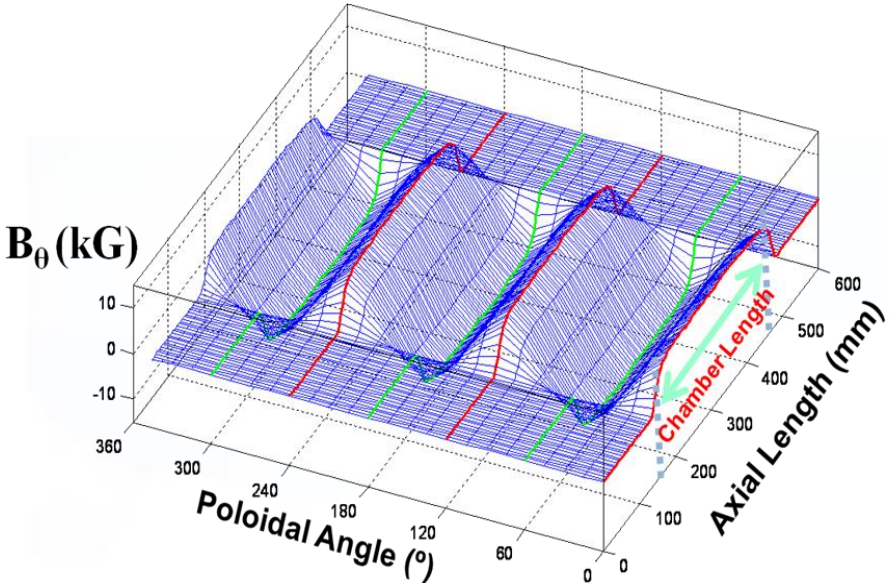


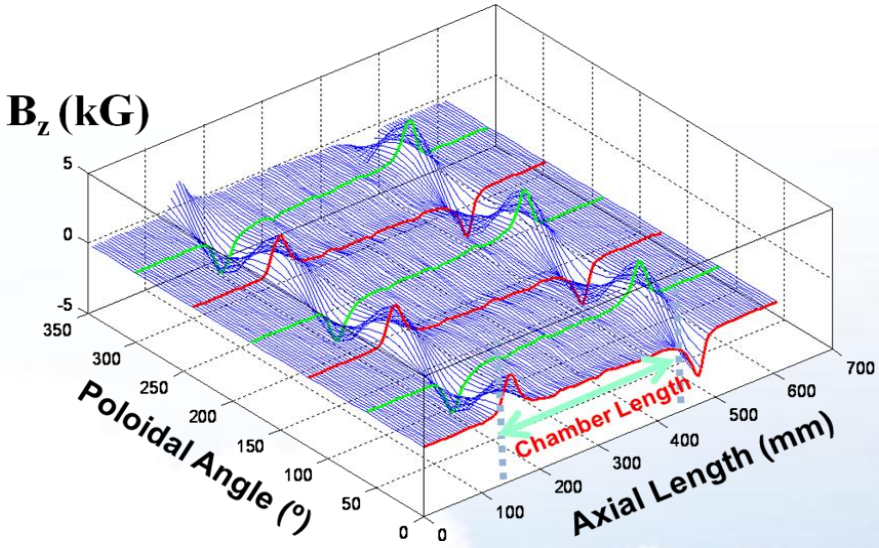
BeforeX-ray shielding

After X-ray shielding (20mm lead)

CONTENTS

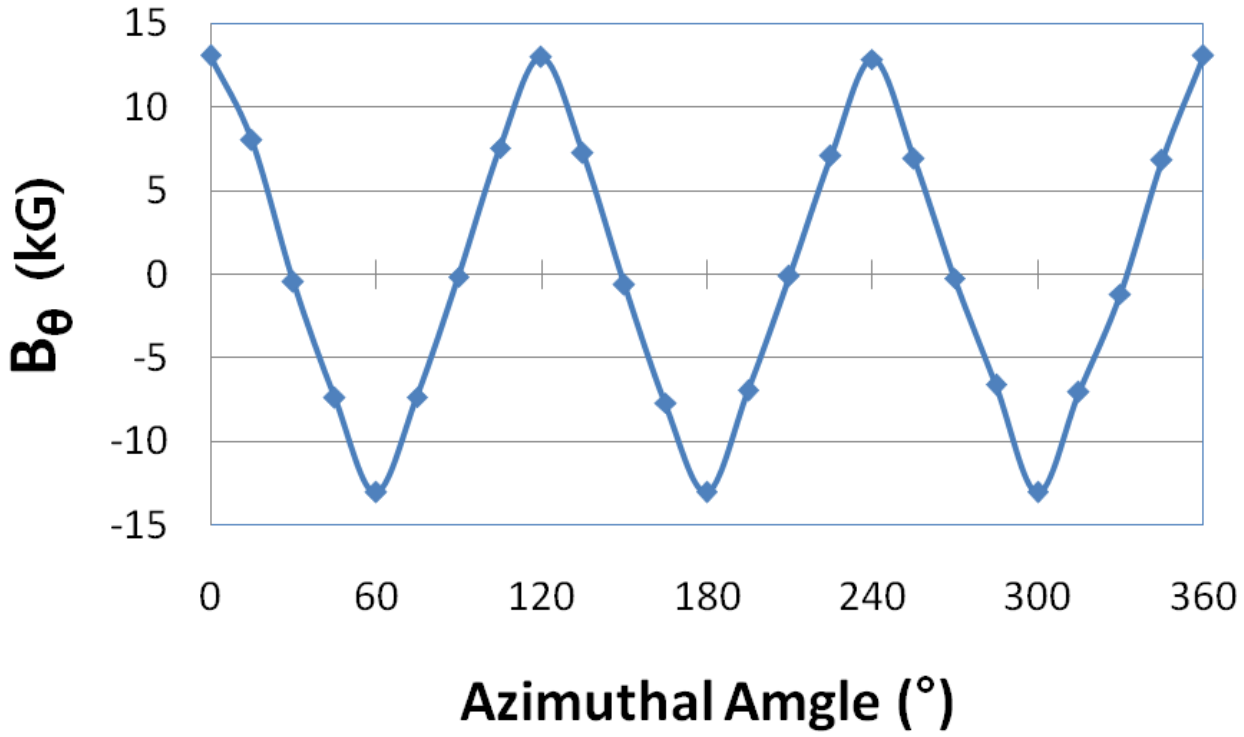
Structure of B_θ and B_z in the chamber by the hexapole





*** at a 30 mm radius layer in a chamber in 5 mm and 15° resolutions**

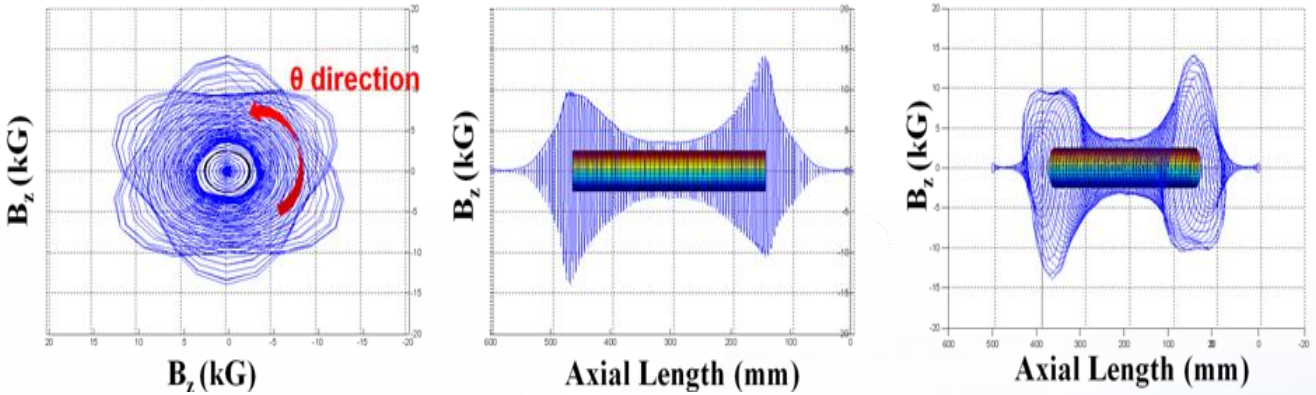
Measured B_θ at the chamber wall position (r = 34mm)



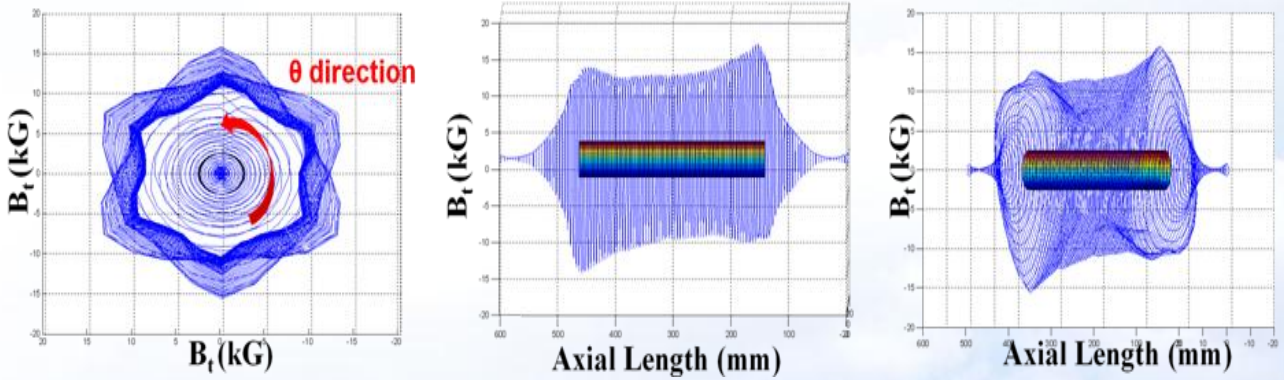
- The measured value (about 1.3 T) is higher than the estimated one (1.2 T) .
- The difference comes from the position shift of a θ–component sensor.

Structure of B_z and B_t component by solenoid and hexapole

B_z structures in different view points

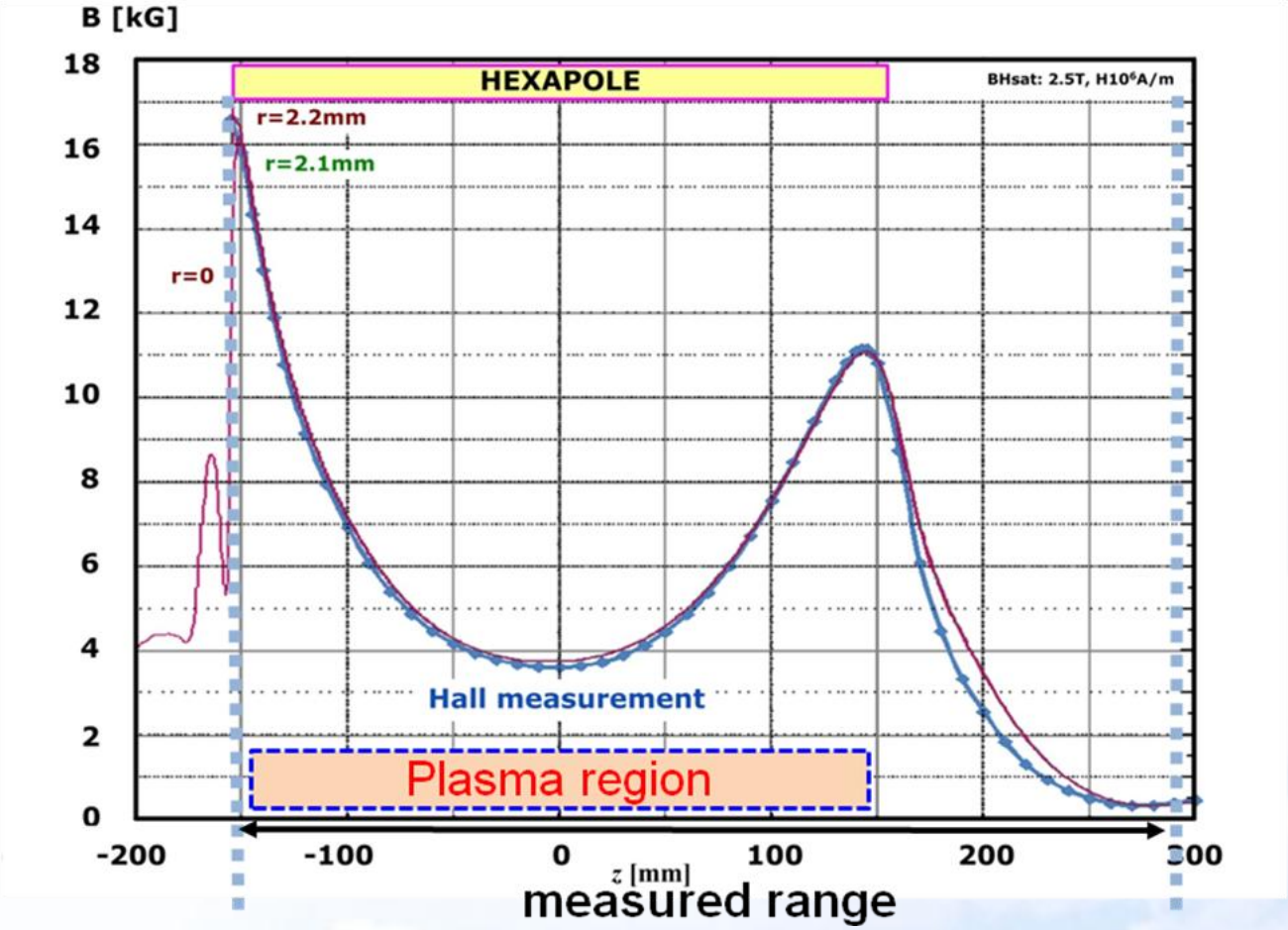


B_t ($B_t = \mathrm{sqrt}(B_r^2+B_0^2+B_z^2)$) structures in different view points



*** at a 30 mm radius layer in a chamber in 5 mm and 15° resolutions**

Measured B_z along the beam axis with the complete set of magnet



Pohang
S10C steel

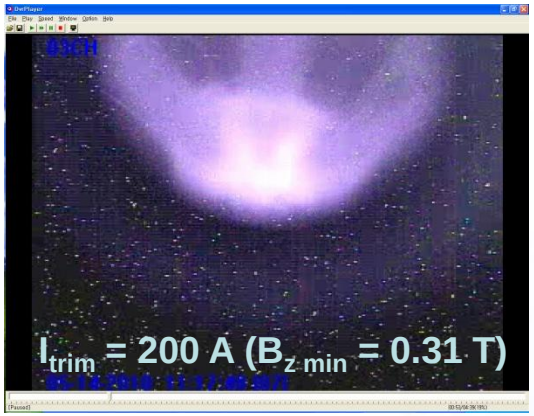
H(A/m)	B(T)
0	0
100	0.5
200	0.88
300	1.1
400	1.22
500	1.3
600	1.36
800	1.43
1000	1.47
1400	1.51
2000	1.55
4000	1.61
6000	1.66
8000	1.7
12000	1.76
16000	1.8
20000	1.84
30000	1.92
40000	1.97
1000000	2.50

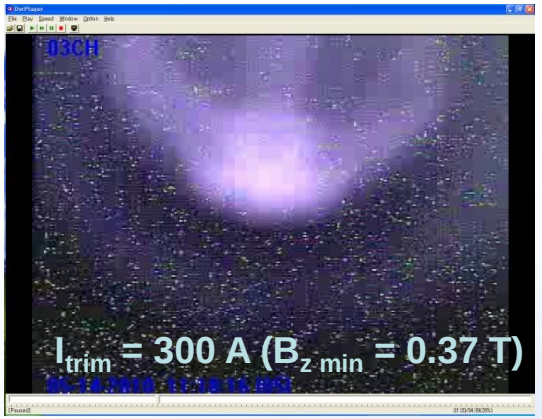
- The measured max. value is 1.7 T at the entrance and 1.1 T at the exit.

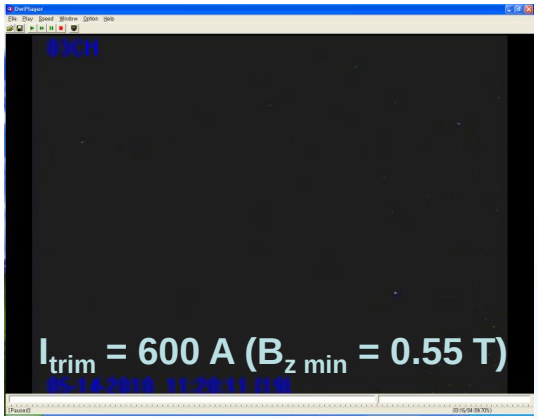
CONTENTS

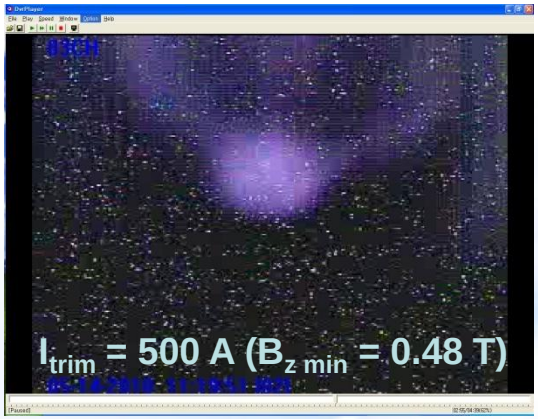
ECR Plasma Images with Different Trim Coil Currents

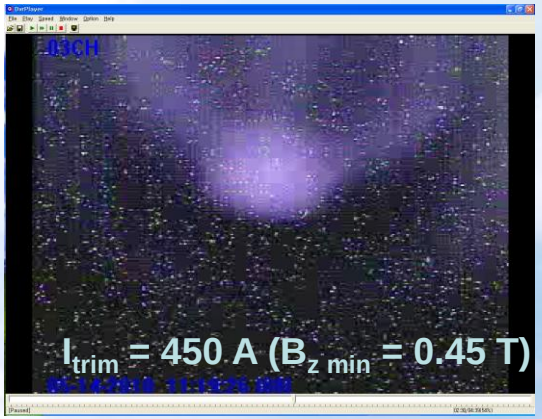
- be seen through the beam extraction hole
- at the beam extraction electrode position





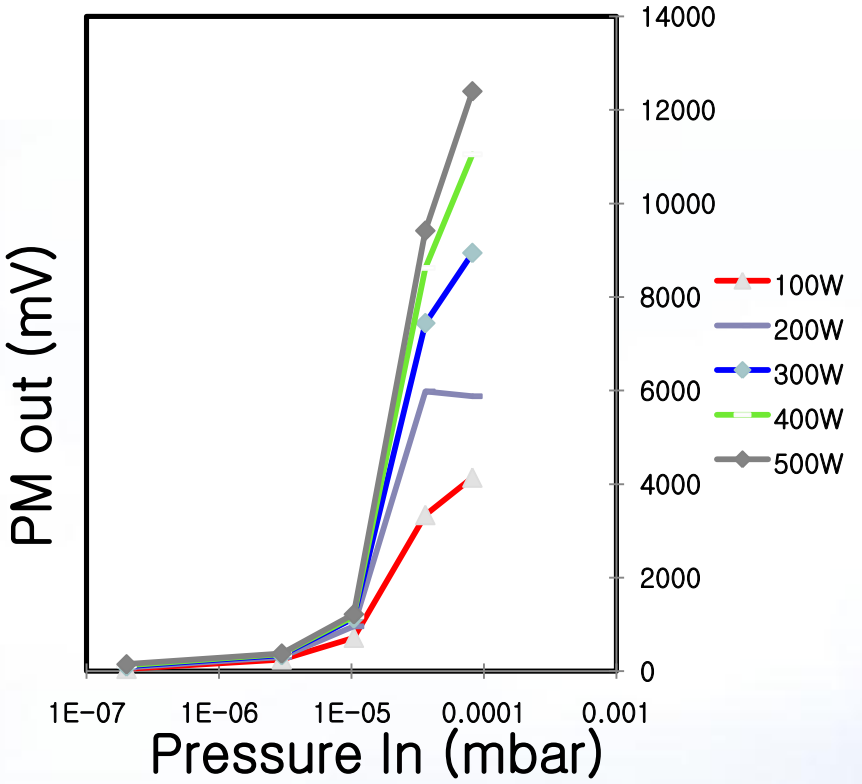




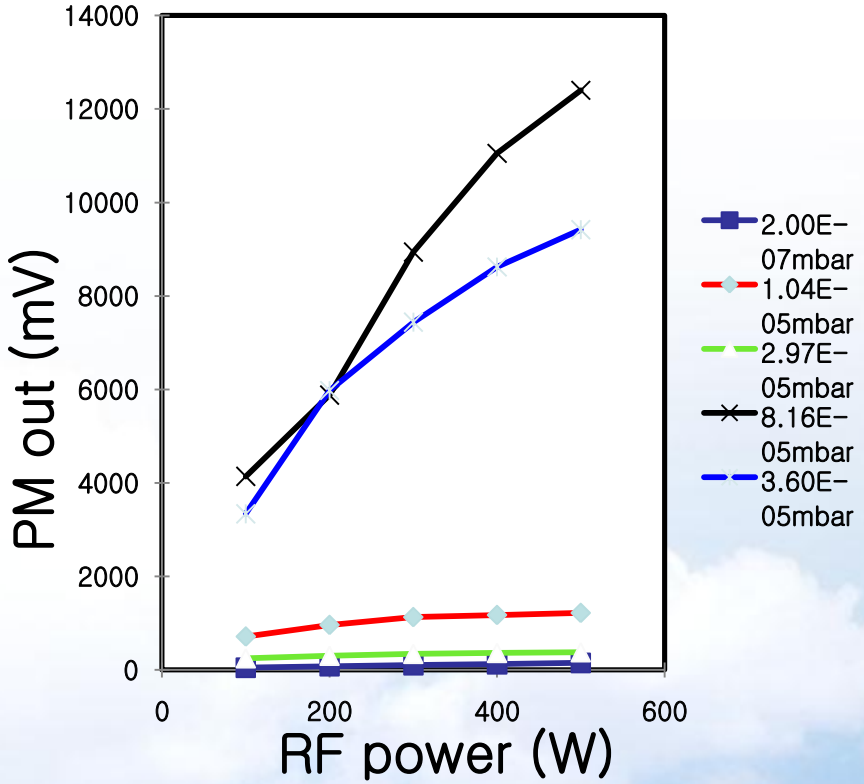


Light Strength depending on Plasma Conditions

- be seen with an optical sensor and a PM tube
- at the same position of the camera



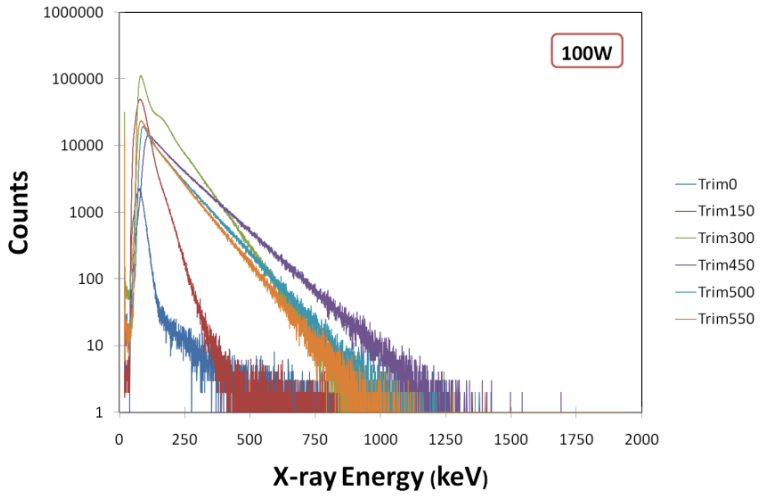
PM out with Argon gas pressure

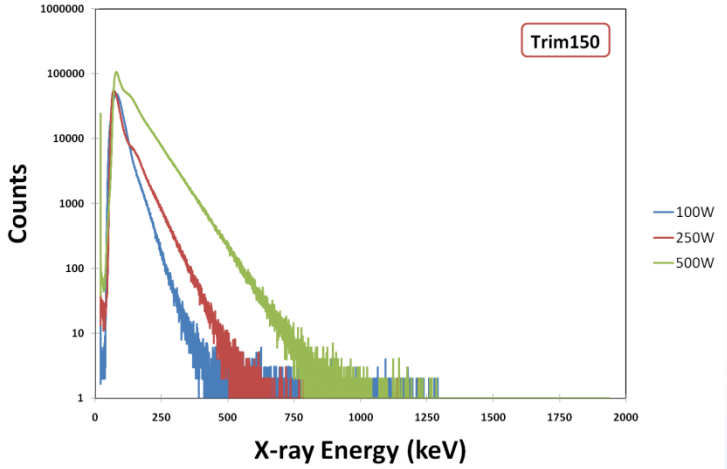


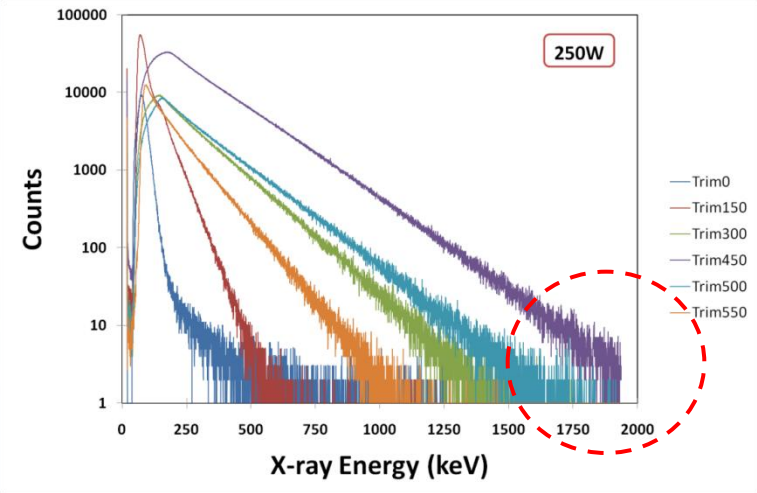
PM out with microwave input

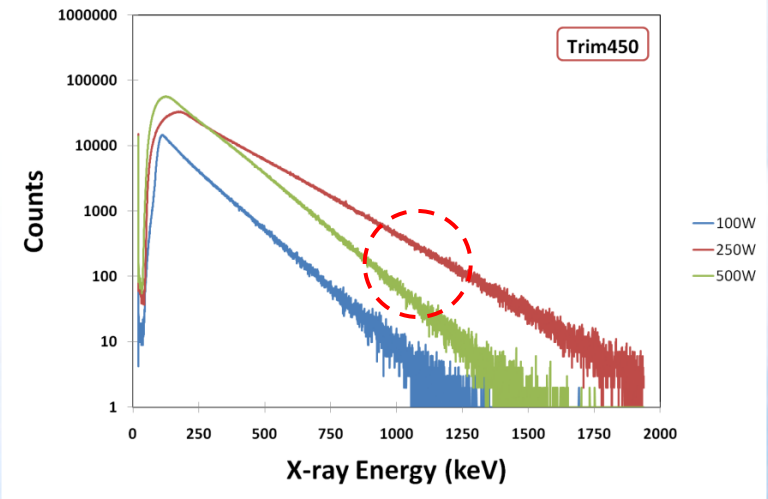
Bremsstrahlung X-ray Spectrum depending on operation conditions

- at the outside of the chamber / with Na(I) detector/ without any collimator







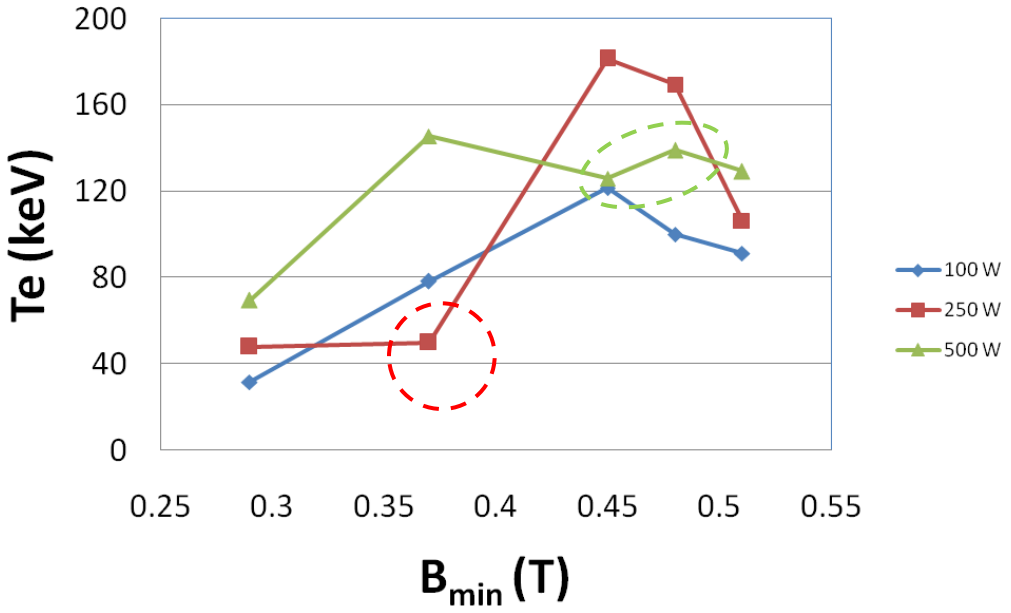


X-ray spectrum with trim coil current

X-ray spectrum with microwave power

Estimated Electron Temperature of the ECR plasma

- based on Gaussian distribution of the high energy tail



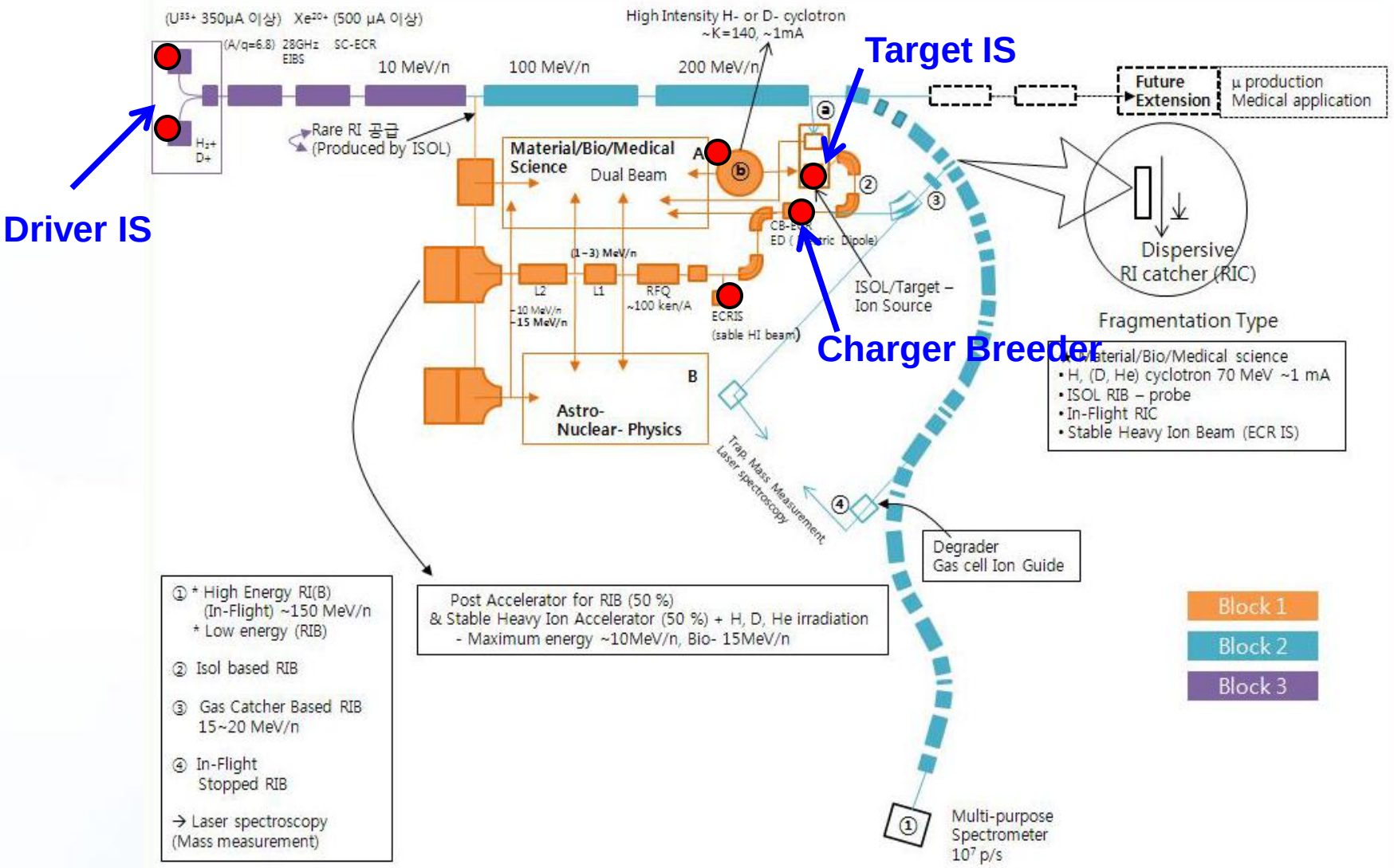
- ➢ **Looks like optimum condition is made;**
- **between 250 W and 500 W of RF input,**
- **and about B_m is 0.48 T.**
- ➢ **We need more data in order to be confirmed.**

Summary and Future Works

- The fabrication of 14.5 GHz KAERI ECR ion source had been finished.
- Clear ECR plasma characteristics was found during the initial test.
- Shielding structure for high intensity X-ray has been installed recently.
- Now we will start the following experiments as a next step;
  - more experiments to check the characteristics of the ECR plasma,
  - beam extraction and mass analysis,
  - upgrade for higher current beam of multi-charged ions.

- Also new activity on Rare Isotope Accelerator (KoRIA) is started in Korea, and we are engaged in this project with SM ECR ion source.

Korea Rare Isotope Accelerator Program



Conceptual design of KoRIA

Needed Ion Sources for KoRIA at the conceptual design

	Needed Beam Species	Needed Beam Current	Remarks
For Driver Acc. - SC ECRIS	from p to U	< 350eμA for U^{35+} < 500eμA for Xe^{20+}	- Stable ion beam - Multi-charged ions
For Driver Acc. - Proton (+) IS	proton positive	< 10mA	
For Cyclotron - Proton (-) IS - or Proton H_2^+	Proton negative H_2^+	< 1mA < 10mA	
For Medical or Other Application - ECRIS	carbon, heavy ions	< 70μA for C6+	- Stable heavy ions - Multi-charged ions
For ISOL - target IS	heavy ions	- Single Ionization - ECRIS	- Radioactive isotopes
For ISOL - Breeding Booster	heavy ions	- Charge breeding	- Radioactive isotopes - ECRIS/EBIS

➢ **We hope your helps with advanced technologies and experiences!**

Thank you very much for your attention.