Development of 14.5 GHz ECR Ion Source at KAERI

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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
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.
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### Designed Specifications of KAERI ECRIS

<table>
<thead>
<tr>
<th>Device Parameters</th>
<th>EM-type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency</strong></td>
<td>14.5 GHz</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>2.0 kW</td>
</tr>
<tr>
<td><strong>$B_{ECR}$</strong></td>
<td>0.52 T</td>
</tr>
<tr>
<td><strong>$B_{inj}$</strong></td>
<td>1.7 T</td>
</tr>
<tr>
<td><strong>$B_{ext}$</strong></td>
<td>1.1 T</td>
</tr>
<tr>
<td><strong>$B_{rmax}$</strong></td>
<td>1 T</td>
</tr>
<tr>
<td><strong>$R_{inj}$</strong></td>
<td>3.3</td>
</tr>
<tr>
<td><strong>$L_{ECR}$</strong></td>
<td>90 mm</td>
</tr>
<tr>
<td><strong>$V_{plasma}$</strong></td>
<td>85 cm³</td>
</tr>
<tr>
<td><strong>$ID_{chamber}$</strong></td>
<td>68 mm</td>
</tr>
<tr>
<td><strong>$L_{chamber}$</strong></td>
<td>320 mm</td>
</tr>
<tr>
<td><strong>$D_{ext}$</strong></td>
<td>8 mm</td>
</tr>
<tr>
<td><strong>$V_{ext}$</strong></td>
<td>20 kV</td>
</tr>
<tr>
<td><strong>$I_{C6+}$</strong></td>
<td>20 eμA</td>
</tr>
</tbody>
</table>

![Drawing of the designed KERI ECR ion source](image)
Magnet System Design

Opening of the Input plug

Structure of the magnet system

Axial field distribution

- Could be controlled by trim coil current
Beam Extraction Optics (IGUN Simulation)

\[ V_{\text{extraction}} = 20 \text{ kV}, \quad V_{\text{einzell}} = 15 \text{ kV}, \quad D_{\text{gap}} = 24 \text{ mm} \]

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

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

- Hexapole Magnet/Plasma Chamber
- Axial Magnet/Yoke
- Beam Extraction System (high voltage insulation)
- Einzel Lens
- Microwave/Gas Injection Port
- Bending Magnet Port
- Vacuum Pumping System
A hexapole magnet

Assembled hexapole magnet
(N42SH, N45H)

Assembled solenoids

Beam extractor & beam lens
Plasma Chamber Fabrication

- 1T-SS304 COVER
- SS304 COOLING LINE (2.5W x 2.0D GROOVE)
- AL6061

WELD

friction welding
14.5 GHz RF System

2 kW Klystron
Assembled KAERI ECRIS

Before X-ray shielding

After X-ray shielding (20mm lead)
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Structure of $B_\theta$ 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 $B_\theta$ at the chamber wall position ($r = 34\text{mm}$)

- 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 $\theta$–component sensor.
Structure of $B_z$ and $B_t$ component by solenoid and hexapole

*B at a 30 mm radius layer in a chamber in 5 mm and 15° resolutions*
- The measured max. value is 1.7 T at the entrance and 1.1 T at the exit.
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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.
Conceptual design of KoRIA

1. High Energy RIB (In-Flight) ~150 MeV/n
   * Low energy (RIB)
2. Isol based RIB
3. Gas Catcher Based RIB 15~20 MeV/n
4. In-Flight Stopped RIB
   → Laser spectroscopy (Mass measurement)

Post Accelerator for RIB (50 %)
& Stable Heavy Ion Accelerator (50 %) + H, D, He irradiation
- Maximum energy ~10MeV/n, Bio~15MeV/n

Dispersive RI catcher (RIC)
- Material/Bio/Medical science
  * H, (D, He) cyclotron 70 MeV ~1 mA
  * ISOL RIB – probe
  * In-Flight RIC
  * Stable Heavy Ion Beam (ECR IS)

Future Extension
µ production
Medical application
## Needed Ion Sources for KoRIA at the conceptual design

<table>
<thead>
<tr>
<th>Needed Beam Species</th>
<th>Needed Beam Current</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>For Driver Acc.</strong>&lt;br&gt;- SC ECRIS</td>
<td>from p to U</td>
<td>&lt; 350eμA for U^{35+}&lt;br&gt;&lt; 500eμA for Xe^{20+}</td>
</tr>
<tr>
<td><strong>For Driver Acc.</strong>&lt;br&gt;- Proton (+) IS</td>
<td>proton positive</td>
<td>&lt; 10mA</td>
</tr>
<tr>
<td><strong>For Cyclotron</strong>&lt;br&gt;- Proton (-) IS&lt;br&gt;- or Proton H$_2^+$</td>
<td>Proton negative H$_2^+$</td>
<td>&lt; 1mA&lt;br&gt;&lt; 10mA</td>
</tr>
<tr>
<td><strong>For Medical or Other Application</strong>&lt;br&gt;- ECRIS</td>
<td>carbon, heavy ions</td>
<td>&lt; 70μA for C6+</td>
</tr>
<tr>
<td><strong>For ISOL</strong>&lt;br&gt;- target IS</td>
<td>heavy ions</td>
<td>- Single Ionization&lt;br&gt;- ECRIS</td>
</tr>
<tr>
<td><strong>For ISOL</strong>&lt;br&gt;- Breeding Booster</td>
<td>heavy ions</td>
<td>- Charge breeding</td>
</tr>
</tbody>
</table>
We hope your helps with advanced technologies and experiences!

Thank you very much for your attention.