C-PIMS based on a 2.45 GHz microwave ion source and a floating potential charge exchange cell

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1. Introduction

2. Carbon Positive-Ion Mass Spectrometry
   - Schematic view of the C-PIMS
   - 2.45 GHz microwave ion source
   - Floating potential Charge eXchange Cell

3. Summary and outlook
Accelerator Mass Spectrometry

- Advantages of AMS: high sensitivity, short measurement time, minor sample requirement
- \(^{14}\text{C}\) remains the most important nuclide, taking up more than 90% of AMS measurements.

What is PIMS?

Positive Ion Mass Spectrometry

Positive ion source $\rightarrow$ Charge exchange cell $\rightarrow$ Mass spectrometry

Molecular(CH$_2$,CH) interferences

$^{14}$N interference

Mass spectrometry $\rightarrow$ Tandem accelerator $\rightarrow$ Negative ion source

Conventional AMS
Advantages of PIMS

AMS
Accelerator
Cs sputter IS

PIMS
No accelerator
ECRIS

- Low-cost
- Maintenance easy
- Small footprint

- No memory effects
- No graphitization
- No cesium
- No cathodes
- Easy operation
Challenges of PIMS

- Is there any method to improve the overall efficiency of PIMS?
- Is there any possibility of using a 2.45 GHz ECRIS for PIMS?

<table>
<thead>
<tr>
<th>PIMS system</th>
<th>Ion source</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANSTO</td>
<td>ECR</td>
<td>7 GHz</td>
</tr>
<tr>
<td>ORNL</td>
<td>ECR</td>
<td>14 GHz</td>
</tr>
<tr>
<td>SUERC</td>
<td>ECR</td>
<td>10 GHz</td>
</tr>
</tbody>
</table>
Outline

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3. Summary and outlook
Conceptual layout of the C-PIMS

- Microwave ion source
- Pre-analyzer
- CXC
- HV platform
- Solenoid lens
- Double focusing magnet
- Electrostatic analyzers (ESA)
- Particle detector
- FCs

C-PIMS AT PKU
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2.45 GHz ECR ion source

- High intensity;
- Low emittance;
- High stability;
- Simple structure;
- Simple maintenance;
- Low cost;
- Long lifetime

\[ \frac{n_e}{n_0} < 1 \quad \left( n_e \tau_i, \quad T_e < 10 \text{ eV} \right) \quad \text{No MI whatever } n_e \tau_i \]

\[ \frac{n_e}{n_0} > 1 \quad 10^8 \sim (n_e \tau_i), \quad T_e < 100 \text{ eV} \quad \text{MI with low } Z \]

\[ \frac{n_e}{n_0} > 1 \quad 10^{10} \sim (n_e \tau_i), \quad T_e < 5 \text{ keV} \quad \text{MI with totally stripped very light species} \]

\[ \frac{n_e}{n_0} \gg 1 \quad 10^{13} \sim (n_e \tau_i), \quad T_e > 100 \text{ keV} \quad \text{MI with totally stripped heavy species} \]

\[ n_e \tau_i \text{ is in cm}^{-3} \text{ s.} \]

MI (Multiply charged Ions)

\[ \tau_q \sim \left[ \frac{B_{\text{max}}}{B_{\text{min}}} \right] \left\langle \nu^+ \right\rangle \exp \left( \frac{\Delta \phi}{q kT_i} \right) \]

Design of magnetic field

Minimum-B magnet structure

Axial mirror field

Hexapole field

<table>
<thead>
<tr>
<th>Parameters</th>
<th>High $B$ field</th>
<th>Reference ECR field</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B_{\text{max}}$ (Gs)</td>
<td>2700</td>
<td>940</td>
</tr>
<tr>
<td>$B_{\text{min}}$ (Gs)</td>
<td>880</td>
<td>761</td>
</tr>
<tr>
<td>$B_{\text{unj}}$ (Gs)</td>
<td>2700</td>
<td>924</td>
</tr>
<tr>
<td>$B_{\text{ext}}$ (Gs)</td>
<td>860</td>
<td>591</td>
</tr>
<tr>
<td>$B_{\text{unj}}/B_{\text{ECR}}$</td>
<td>3.09</td>
<td>1.06</td>
</tr>
<tr>
<td>Mirror ratio</td>
<td>3.07</td>
<td>1.24</td>
</tr>
</tbody>
</table>
Numerical examination

Electrostatic 3D PIC

- 100 × 100 × 207 cells
- 5 × 10^4 super particles
Numerical examination

• The magnetic field may be effective for plasma confinement!
Ion source configuration

microwave window flange
aluminium oxide
boron nitride
Preliminary test with CO₂

- More than 40 uA C^{2+} can be obtained with Aluminum liner.
- More results of this source (such as Ar^{4+}, O^{5+}, Li^{2+}) can be found in TueP24 by Dr. Tenghao Ma.
Preliminary test with CO$_2$/Ar

- He/Ar can decrease the intensity of CO$_2^+$, which is helpful to improve lower the consumption of CO$_2$ sample.
- The He/Ar will be chosen as carrier gas.

Ar($^3P_{0,2}$) + CO$_2$ → CO + O($^3P$) + Ar,
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Floating potential CXC

...the outgoing charge state after the cell is independent of the input charge state. If this is valid, then the charge exchange probabilities for multiply-charged ions could be comparable to that of singly-charged positive ions.

Summary and outlook

1. To improve the overall efficiency of the PIMS. We propose a new conceptual design of C-PIMS system based on a 2.45 GHz microwave ion source and a floating potential charge exchange cell (CXC).

2. At PKU, a 2.45 GHz microwave ion source with minimum-B magnetic field configuration is designed and operated. In the preliminary experiments, about 40 μA C$^{2+}$ beam can be obtained.

3. Next, the influence of gas pressure, microwave power, magnetic field intensity, source body configuration, ratio of CO$_2$ to helium, etc. on the generation efficiency of C$^{2+}$ ions will be investigated. The CXC will be designed and tested.

4. In the future, the ion source platform of PKU will upgrade to the PIMS system. The sensitivity of the C-PIMS system will be tested and optimized with $^{14}$C-labelled CO$_2$ samples.
Thanks for your attention!