Development of the NIM Mass spectrometer for Exploration of Jupiter’s Icy Moons Exospheres

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EGU Vienna 04.05.2020
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• JUICE*: Jupiter Icy Moons Explorer
  • Investigation of Jupiter and its environment
  • Characterisation of Jupiter’s icy moons Ganymede, Europa and Callisto

• PEP: Particle Environment Package
  • Investigation of the icy moons’ atmospheres and plasma environment
  • Determine global surface composition and chemistry

*http://sci.esa.int/juice
Neutral Gas and Ion Mass Spectrometer (NIM)

- 3 modes: thermal-, neutral- and ion-mode
  - Closed source: Thermalisation of neural gas. FoV of $10/3 \pi \text{ sr}$
  - Open source: Ions and neutral gas enter ion-source directly. FoV of $300^\circ$ azimuthal direction and $10^\circ$ elevation

- Electron ionisation
- Ion mirror to increase the flight distance
NIM ProtoFlight Model (PFM)

PFM integrated in the test setup

Transport to the vacuum chamber

Integration into the test chamber
Ion Storage Capability of NIM

Objective
• Investigation of the NIM ion storage capability

Conclusions
• \[ S \sim I_{\text{em}}^{3.2} \rightarrow \text{Ion storage capability is very good of this source. Usual storage values, } S \sim I_{\text{em}}^{2} \] (Abplanalp, 2009)
• Signal decrease for \( I_{\text{em}} > 500 \mu A \) due to space charge effects

Signal height depends on the electron emission current \( I_{\text{em}} \). Red curved is a fit with the function: \[ S = a + b \cdot I_{\text{em}}^{c} \]
Density enhancement behaviour of Antechamber

Objective
- Verification of the functionality of the antechamber by measuring the density enhancement behaviour of the antechamber

Conclusion
- Signal increase with increasing beam velocity as expected according to (Wurz et al., 2007)
Mass Range

Objective

• NIM is designed to measure masses up to 1’000 u. Expected masses up to ~100 u
• FC5311 was used as a test sample because it has tabulated masses up to 624 u. This was the sample with the highest mass range available.

Conclusion

• Masses visible up to 642 u which is even higher than the highest mass tabulated (624 u) of this test sample
Electronic Board Tests

- **Low Voltages (LVs)**
  - Used in the ion-source and around the electron emitting filament

- **High Voltages (HVs)**
  - Used for the focusing lenses in the ion-source, for the ion-mirror and the detector

- **Shutter Motor**
  - Located between the antechamber and the ion-source. Used when measuring in n-Mode to block particles coming from the antechamber
Low Voltage Board

Electronic Board Tests

Measurement configurations

- Lab electronics: all voltages were provided by lab electronics. In case separate electrodes are listed, the voltages of these electrodes are provided by the flight low voltage board.

<table>
<thead>
<tr>
<th>Configuration</th>
<th>m/Δm</th>
<th>SNR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>O₁₆</td>
<td>F₁₉</td>
</tr>
<tr>
<td>Fil 1</td>
<td>90 ±3</td>
<td>174 ±10</td>
</tr>
<tr>
<td>Lab electronics</td>
<td>103 ±4</td>
<td>156 ±8</td>
</tr>
<tr>
<td>Fil 1, 2, 3, IS 1, 2, 4</td>
<td>93 ±3</td>
<td>174 ±10</td>
</tr>
<tr>
<td>Lab electronics</td>
<td>105 ±4</td>
<td>164 ±9</td>
</tr>
<tr>
<td>IS 1, 2, 4</td>
<td>107 ±4</td>
<td>164 ±9</td>
</tr>
</tbody>
</table>

Conclusion

- Same mass resolution for all different configurations
- LV board not calibrated → lower SNR
High Voltage Board

Electronic Board Tests

Measurement configurations

- Lab electronics: all voltages were provided by lab electronics. In case separate electrodes are listed, the voltages of these electrodes are provided by the flight high voltage board. Tested electrodes were electrodes from the ion-mirror
- R2 reaches -7 kV, R15 is a bipolar high voltage electrode reaching up to +2.3 kV

Conclusion

- Same mass resolution and signal-to-noise ratio for the different configurations

<table>
<thead>
<tr>
<th>Configuration</th>
<th>m/Δm</th>
<th>SNR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N₂</td>
<td>CO₂</td>
</tr>
<tr>
<td>R15</td>
<td>307 ± 25</td>
<td>330 ± 23</td>
</tr>
<tr>
<td>Lab electronics</td>
<td>295 ± 23</td>
<td>330 ± 23</td>
</tr>
<tr>
<td>R2</td>
<td>295 ± 23</td>
<td>330 ± 23</td>
</tr>
<tr>
<td>R2, R15</td>
<td>295 ± 23</td>
<td>330 ± 23</td>
</tr>
<tr>
<td>Lab electronics</td>
<td>295 ± 23</td>
<td>319 ± 21</td>
</tr>
</tbody>
</table>
Motor Boards
Electronic Board Tests

Measurement configurations
- Shutter open/ closed: neutral particle beam enters the ion source through the antechamber;
- Background: neutral particle beam points on the antechamber outer wall and scatters into the ion-source
- N₂ and CO₂ are residual gas and not part of the beam

<table>
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<th>m/Δm</th>
<th>SNR</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>N₂</td>
<td>CO₂</td>
</tr>
<tr>
<td>Shutter open</td>
<td>307 ±25</td>
<td>330 ±23</td>
</tr>
<tr>
<td>Shutter close</td>
<td>307 ±25</td>
<td>330 ±23</td>
</tr>
<tr>
<td>background</td>
<td>307 ±25</td>
<td>330 ±23</td>
</tr>
</tbody>
</table>

Conclusion
- Same mass resolution for all different configurations
- Shutter performance lower than expected due to differences between laboratory and flight environment
Redesign of IS

Objective

- Redesign of ion-source due to mechanical failure during vibration test
- New design:
  - ring to narrow the entrance hole of the electron beam had to be removed due to mechanical reasons
  - IS 7 was shifted to increase its distance to the entrance (IS 3) to increase high voltage stability
  - In red the redesigned electrodes IS 3 and IS 7
Redesign of Ion Source

Objective
• Simulations to evaluate the impact of the redesign on the performance of the ion source

Conclusion
• The redesign did not change the flight path of the electrons significantly, therefore expected performance of the ion source should be the same
Test Results

- Mass resolutions could be improved by a redesign of the old source

thermal Mode

neutral Mode
Next Steps

- Finalise work with PFM
- Commissioning, testing and calibration of the Proto Flight Model (PFM) sensor with flight electronics
- Integration and final testing completed by end of July 2020
Have a nice day