Cluster Results on Ion Emitter Operation

Klaus Torkar
Space Research Institute, Austrian Academy of Sciences, Graz, Austria

Mats André (Swedish Institute of Space Physics, Uppsala Division / EFW), Andrew Fazakerley (MSSL, Holmbury St. Mary, United Kingdom / PEACE), Henri Rème (CESR, Toulouse / CIS), and the ASPOC Team: W. Riedler, G. Fremuth, H. Jeszenszky, F. Giner, G. Laky (IWF); C.P. Escoubet, M. Fehringer, R.J.L. Grard, R. Schmidt, H. Arends (ESTEC), B. Narheim, K. Svenes (FFI), A. Pedersen (Univ. Oslo), F. Rüdenauer (IAEA), W. Steiger (ARCS), E. Whipple (Univ. Washington), R.B. Torbert (UNH), R. Goldstein (SwRI)

5th SPINE Workshop, ESTEC, 16–17 September 2003
Contents

- Instrument set-up
- Principle of operation
- Ion beam properties
- Cluster operations summary
- Effect on spacecraft potential
  - Comparison between spacecraft
  - Histograms of potential
  - Beam current – spacecraft potential characteristics
- Effect on PEACE electron measurements
- Effect on CIS ion measurements
- Effect on EFW electric field measurements
- Conclusion
- Liquid Indium (heated to \(\approx 200 \, \text{C}\)) covers needle
- Field emission of ion beam
- Four emitters integrated in "module"
Instrument ASPOC

- Active Spacecraft Potential Control
- Mass: 1.9 kg
- Power: 2.1 ... 2.7 W
- Lead: IWF Graz
- Major partners: RSSD/ESA, ARC/Seibersdorf, FFI/Norway, UNH/USA
Location of ASPOC and electron / ion sensors on spacecraft
Ion Beam Properties

- Energy width at 10 µA: ≈150 eV; low intensity, low energy tail down to ≈500 eV below nominal beam energy
- Species: >90% single charged In⁺, Minor contributions of other charge states and clusters
- Isotopic composition: 115 amu (95.7%), 113 amu (4.3%)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Salsa</td>
<td>5.4, 7.4</td>
<td>10</td>
</tr>
<tr>
<td>Samba</td>
<td>7.7</td>
<td>12.2, 13.7, 14.5</td>
</tr>
<tr>
<td>Tango</td>
<td>5.5, 6.8</td>
<td>10, 14.5</td>
</tr>
</tbody>
</table>
Development of Beam Energy
## Cluster operations summary

Table shows status of 21 August 2003

<table>
<thead>
<tr>
<th></th>
<th>Salsa</th>
<th>Samba</th>
<th>Tango</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total operation time (hours)</td>
<td>234</td>
<td>2543</td>
<td>2115</td>
<td>4892</td>
</tr>
<tr>
<td>Maximum total operation time of a single emitter (hours)</td>
<td>128</td>
<td>2525</td>
<td>1468</td>
<td></td>
</tr>
<tr>
<td>Number of operations</td>
<td>107</td>
<td>450</td>
<td>373</td>
<td>930</td>
</tr>
<tr>
<td>Average duration of single operation (hours)</td>
<td>2.4</td>
<td>5.9</td>
<td>5.8</td>
<td>5.5</td>
</tr>
<tr>
<td>Maximum duration of single operation (hours)</td>
<td>7.8</td>
<td>36.4</td>
<td>35.8</td>
<td></td>
</tr>
</tbody>
</table>
Operational status

- Operations on all even-numbered orbits
- Typical sequence with Cluster apogee in magnetotail:
  - 7 hours around outbound cusp crossing
  - 7 hours centred at neutral sheet
  - 7 hours around inbound auroral zone crossing
- Ion current: between 10 and 15 µA
Example of ASPOC ion beam turn-on
ASPOC Operations on Cluster 3 in 2001: Measured Potential Before and After

- Lines show operation times.
- Spacecraft potential measured by double probes (EFW) shown as colored triangles.

Bryant Plot before and after beam, S/C 3

Perigee

Orbit Time [hours]

S/C Potential [V]

Day in Year 2001

Solar wind

Magnetosphere
Spacecraft Potential on Cluster 2,3,4 in Comparison with Cluster 1 During Active Periods of ASPOC on Cluster 2,3,4
Example of current–voltage characteristics, Spacecraft potential (EFW), Cluster 2

ASPOC Operations on 25 September 2000 10:35 - 16:42

Ion Current [µA]

Potential of S/C 2 [V]
Histograms of Spacecraft Potential

- Prime Parameter data of s/c potential measured by EFW
- Covering year 2001
- Data from the same s/c for different times
Comparison of Spacecraft Potential Between Cluster 1 and 2, ASPOC OFF

Simultaneous data from different spacecraft

2001, Histogram of EFW Potential, ASPOC OFF, SC1 & SC2

Occurrence

Spacecraft Potential [V]
Comparison of Spacecraft Potential Between C1 and 2, ASPOC ON for C2

2001, Histogram of EFW Potential, ASPOC ON, SC1 & SC2

Spacecraft Potential [V]
The following pages show the effect of ion beam operation on PEACE electron measurements, in various regions of the magnetosphere (polar cap, magnetotail, high-altitude cusp).

Electron measurements not only benefit from the improvement of the data, but also from the increased lifetime of micro-channel plates, when photo-electron count rates stay low.
Polar Cap

Mar. 21, 2001
AE< 50 nT
Kp=1-

Location:
X = -1Re,
Y = 2.6 Re,
Z = 5 Re,
19–20 LT,
L > 50
(Vs/c=25V –
Vaspoc=7V)

ASPOC ON
I = 10 µA

Field-aligned
electrons

ASPOC ON
I = 10 µA

Svenes et al., 2003

Svenes et al., 2003
Magnetotail

10 Sept. 2001
Sep. dist. 2000 km

Plasma sheet:
$ne=0.1-0.2 \text{ cm}^{-3}$
$Vs/c=20 \text{V}$

Tail lobe:
$ne=0.01 \text{ cm}^{-3}$
$Vs/c=45 \text{V}$

$V_{aspoc}=9 \text{V}$
$AE<50 \text{nT, Kp}=1$
23 MLT, close to apogee, near XY–plane

Svenes et al., 2003
Changes of the spacecraft potential between \(<10 \text{ V}\) and \(>20 \text{ V}\) clearly influence the measurements of cold ions by the Cluster Ion Spectrometer (CIS).

Effects can be seen in \(\text{H}^+\), \(\text{He}^+\), \(\text{O}^+\) and total ion density data.

This is demonstrated by examples on the following pages.
ASPOC SUPPORTS DETECTION OF LOW–ENERGY He+ AND He+ IONS IN LOW DENSITY REGIONS

The Cluster Ion Spectrometer (CIS) measures significantly higher flux of low–energy H+ and He+ in low density regions when the ASPOC is active.

The switch–off of ASPOC is clearly visible.

On S/C3 CIS stops to observe low–energy H+ and He+ after 15:19:57.

Effect is particularly clear on the He+ population (20 to 70 eV) on S/C4 from ≈16:40, and which was never observed on the other spacecraft on which ASPOC was off during that interval.
- Duskward/tailward streaming cold H\(^+\) appears only after ASPOC turn-on at 15:58 (with 12 µA)
ASPOC Support for EFW Electric Field Measurements

Cluster 1

EDIEFW

ASPOC ON

Cluster 3

EDI

ASPOC OFF

Ex (mV)

Ex (mV)

UT 04:00 04:10 04:20 04:30 04:40 04:50 14 Feb 2001
Conclusions – 1

- While ASPOC is emitting 10 µA ion current, the spacecraft potential does not exceed 8 to 9 V
- With 12 to 15 µA => 6 to 7 V
- Histograms peak at ≈7 V when ASPOC is active
- Significant improvement of low energy electron measurements, without compromising wave and electric field measurements
- At times when the ion beam turns on while the plasma environment remains constant one can nicely study the effect of spacecraft potential control
- The reduction of photo–electron counts in the measurements and the improvement of the effective energy resolution is most obvious in any low density environment
Conclusions

In spite of the low ambient density the ion beam does not appear to have a measurable effect on the incoming electrons at the present state of analysis; further work is to be done, including simulation.

Changes of the spacecraft potential between $<10$ V and $>20$ V clearly influence the measurements of cold ions; effects can be seen in $\text{H}^+$, $\text{He}^+$, $\text{O}^+$ and total ion density data, and on both spacecraft 3 and 4 the observations are not specific to a single instrument or spacecraft.

Electric field measurements by double probes may benefit in certain environments.