First results –
H⁻ ion beam extraction in ROBIN in surface mode

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Outline

• Introduction about ROBIN
• Diagnostic and Monitoring system implemented in ROBIN.
  ✓ Langmuir probe (plasma parameter)
  ✓ Optical Emission Spectroscopy (Cs and plasma impurity trace)
  ✓ Residual Gas Analyser (Gas impurity)
• Parametric study of ROBIN
• Results from probe study.
• Preliminary results of beam characterization using
  ✓ thermal differential calorimeter
  ✓ Doppler Shift Spectroscopy
• Summary
• Future plan
1MHz, 100kW, ICP type negative ion source with 6.5 turn water cooled coiled antenna, having 3 grid beam extraction and acceleration system.

Cs delivery system (1gm Cs ampules) is attached in the lower side of the expansion region.

Source body temperature is maintained @ 40°C.
Open Extraction aperture number = 146 out of Total 776; 
Open extraction area = 73.38cm²

Plasma grid temperature is maintained at 150°C

Expansion chamber
30cm × 58cm × 19cm
High voltage power supply system (APSS: -35kV, 15A DC; EPSS:-11kV35A DC) commissioned in NNB HVPS Facility
- Maximum duration of a shot: 4 second shot
- Maximum power couple in surface mode: 70kW.
- Maximum HV applied: 24kV (EPSS 10kV, APSS 14kV).
<table>
<thead>
<tr>
<th>Diagnostic</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Langmuir probe (uncompensated) installed in extraction region</td>
<td>To estimate the plasma potential, floating potential, electron temperature and plasma density</td>
</tr>
<tr>
<td>Optical Emission Spectroscopy</td>
<td>For monitoring of the impurities and Cs lines</td>
</tr>
<tr>
<td>Residual Gas Analyser (RGA)</td>
<td>To measure the partial pressure of residual gases, water vapour etc.</td>
</tr>
<tr>
<td>Doppler shift spectroscopy</td>
<td>For beam velocity, stripping loses and beam divergence</td>
</tr>
<tr>
<td>Thermal Differential Calorimeter</td>
<td>For the measurement of beam profile, beam position, beam divergence and power deposition</td>
</tr>
<tr>
<td>Extensive current measurements</td>
<td>To examine the source optimization</td>
</tr>
</tbody>
</table>
Complete system of ROBIN

Source
DSS ports
Cryopump
TMP
RGA
Electrical current measurement
Source performance in surface mode

Different RF Power level.
All other parameters are varied.

Max. beam current density
~13mA/cm²

Min. e/H- ion ratio ~ 2
Source performance in surface mode

Different gas pressure level.
All other parameters are varied.

- Max. beam current density $\sim 13\text{mA/cm}^2$
- Min. e/H- ion ratio $\sim 2$

Cs conditioning?
Source performance in surface mode

RF Power scan in ROBIN

Almost Linear relationship with power

**saturation effect?**
Source performance in surface mode

Pressure scan in ROBIN

Gas cooling down effect in Electron part?
Source performance in surface mode

Grid bias voltage scan

Optimum PG bias voltage ~ 24V.
Source performance in surface mode

Acceleration voltage scan

- Electron current nearly unaffected.
- GG current decreases.
  - Is Beam quality getting improved ??
Current in Beam dump has decreasing trend in higher voltage.
  - Any other effect (2ndary electron emission) ??
Fixed voltage (HV) ratio scan

- Electron current increases linearly.
- Current in Beam dump has decreasing trend in higher voltage after 5-6kV extraction voltage.

Is Beam quality getting affected??
Thermal Differential Calorimeter

Thermal calorimeter used for investigation of beam position, power deposition, beam divergence and beam optics study.

IPP design

Beam facing side of the calorimeter
Preliminary results from calorimeter

<table>
<thead>
<tr>
<th>Shot#</th>
<th>High voltage DC</th>
<th>Beam divergence</th>
</tr>
</thead>
<tbody>
<tr>
<td>26135</td>
<td>EPSS: 5kV, APSS: 7kV</td>
<td>5.8°</td>
</tr>
<tr>
<td>26137</td>
<td>EPSS: 5kV, APSS: 11kV</td>
<td>5.6°</td>
</tr>
<tr>
<td>26139</td>
<td>EPSS: 5kV, APSS: 15kV</td>
<td>3.7°</td>
</tr>
</tbody>
</table>

Source operation pressure: 0.6 Pascal, RF power: 40kW, Bias voltage: 24 V, Grid temp. 150°C, Source compo. Temp. 40°
Beam diagnostics

Doppler shift Spectroscopy with EMICON MC spectrometer

**Specifications**

<table>
<thead>
<tr>
<th>Specification</th>
<th>EMICON MC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of spectrometer channels</td>
<td>1-4</td>
</tr>
<tr>
<td>Wavelength range [nm]</td>
<td>200 - 1100</td>
</tr>
<tr>
<td>Spectral resolution [nm]</td>
<td>1.5</td>
</tr>
<tr>
<td>Signal resolution</td>
<td>16 Bit</td>
</tr>
</tbody>
</table>

Light from the Beam
Beam diagnostics

Doppler shift Spectroscopy with EMICON MC spectrometer

Unshifted peak

Shifted peak

Beam divergence

Intensity (counts)

$\lambda$ (nm)

26431 $V_{ex}: 5\text{kV}, V_{acce}: 7\text{kV}$

26437 $V_{ex}: 7\text{kV}, V_{acce}: 8\text{kV}$

26440 $V_{ex}: 10\text{kV}, V_{acce}: 12\text{kV}$
Beam diagnostics

DSS with high resolution spectrometer

- Preliminary calculation suggests divergence is in the range 4-5 degree in beam total operational HV (EPSS+APSS) range 10 – 20 kV.
- Stripping observed
  - Further calculation on going.
Online data analysis during each shot.

Plasma parameter variation with bias voltage

RF power: 60kW, Pressure: 0.6Pa

Plasma non-uniformity observed ~ one order difference in density?

Plasma density ~ (Top) $10^{16}$ m$^{-3}$ – (Bottom) $10^{17}$ m$^{-3}$.

Plasma temp ~ 2 – 4eV.

Cs distribution in the source and its conditioning?
Plasma monitoring - OES

Typical Optical Emission Spectrum

Cs lines observed.

Impurities like Oxygen and OH indicates presence of moisture or vacuum leak..

Leak detection ensures leak rate $\leq 10^{-8}$ mbar l/s
Residual Gas Analyser scan

- Moisture level high! $10^{-7}$ torr.
- Increases when $H_2$ gas is injected.

Effect on Cs conditioning?
• RF generator and matching circuit is not behaving properly more than 70kW – Improved matching circuit to be connected.

• Cryopump operation (14000 l/s) reduces the moisture level 5 times between the shots compare to only TMP case (effective - 3500 l/s),
  - However, beam dump current and DSS signal goes down. beam blowup ??

• Cryopump operation needs almost double gas throughput to maintain same pressure in the source compare to only TMP case.

• Gas feed starts behaving erratic due to large reflected radiation.
  New MFC installed which shows better behaviour.

• PG bias interlock is as reliable as H-alpha interlock for RF generator during the initial plasma breakdown impedance mismatch condition.

See poster - MonP12
• Extraction grid (EG) rise in temp ~ 3°C only in 4 sec shot in spite of with higher e/H ratio – ~ 2 A electron current (42 lpm total flow rate in two grid halves).
  – Is it correct??
• EPSS is riding on APSS, so during breakdown, EPSS voltage shoots up
  – To protect special spark gap based arrangement is made.
• Metallic valve bellow leakage in Cs oven (due to Cs corrosion?)
  Valve is removed at present.
• Source is kept in Ar environment when not operational.
  – How it affects Cs conditioning?

Concern over Quality of Cs conditioning in presence of impurities
• Operation with Improved matching circuit to raise the power coupling further.
• Integration of a directional coupler to measure reflected power.
• Use higher purity gas along with a gas purifier in the gas feed line.
• Integration of RF shield around RF coil.
• Integration of a high resolution spectrometer including into DACS.
• Integration with Laser Photo-detachment diagnostics.
• Integration of dedicated Cs absorption line diagnostic system.
• ROBIN is upgraded by integration of EPSS, APSS, Cs oven, Cryopump, RGA and a thermal calorimeter.
• Cs oven is integrated and source is operated in Hydrogen in presence of Cs injection.
• Maximum current density is observed as ~ 13mA/cm$^2$
• Minimum e/H- ion ratio observed as ~ 2.
• Needs improvements in many fronts
  (RF coupling, Cs conditioning, Gas impurities, Diagnostics).
Thank you