Stable and Intense $^{48}\text{Ca}$ Ion Beam Production with a Microwave Shielded Oven and an Optical Spectrometer as Diagnostic Tool

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„Poster“ Outline

- Optical emission spectroscopy diagnostics implemented at the high charge states injector of GSI
- Microwave shielding of Standard Evaporation Oven for stable metal ion beam production and operation
- Achievements in Ca ions beams production
High Charge States Injector (HLI)

CAPRICE ECRIS MAIN PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hexapole field</td>
<td>1...1.2 T</td>
</tr>
<tr>
<td>Solenoid field</td>
<td>0.8...1.5 T</td>
</tr>
<tr>
<td>μW-power</td>
<td>10...800 W (CW mode)</td>
</tr>
<tr>
<td>μW-frequency</td>
<td>14.5 (12.4...16) GHz</td>
</tr>
<tr>
<td>Extraction Voltage [kV]</td>
<td>≤ 22</td>
</tr>
<tr>
<td>Ion Species</td>
<td>Gas + Metal</td>
</tr>
<tr>
<td>Mode</td>
<td>CW or Pulsed</td>
</tr>
</tbody>
</table>

24th ECRIS Virtual Workshop, FRIB-MSU, 28-30 September 2020
Evaporation technique for metal ion beam production

Standard Temperature Oven (STO)

**LAYOUT**
- Central current entry
- Heating helix on ceramic body
- Water cooled support tube
- Crucible or aperture ring

**OPERATING PARAMETERS**
- Power: 2-120W
- Temperature: 400 - 1550°C
- Consumption: 0.2 – 5 mg/h
- Lifetimes days: $^{48}\text{Ca} \leq 30$, $^{64}\text{Ni} \leq 6$
**48Ca charge states distributions and plasma images**

Spectrum of $^{48}$Ca + He optimized on $^{48}$Ca$^{10+}$

A CCD camera looks through the straight beam line and the extraction aperture into the plasma chamber.
Spectrum of $^{48}\text{Ca} + \text{He}$ optimized on $^{48}\text{Ca}^{10+}$ after an excessive oven power increase

Plasma image recorded with the CCD camera
**48Ca charge states distributions and plasma images**

Spectrum of $^{48}$Ca + He optimized on $^{48}$Ca$^{10+}$ during an over heating of the oven

Plasma image recorded with the CCD camera
$^{48}\text{Ca}$ charge states distributions and plasma images

Spectrum of $^{48}\text{Ca} + \text{He}$ optimized on $^{48}\text{Ca}^{10+}$ after a power reduction of the oven

Plasma image recorded with the CCD camera
Spectrum of $^{48}$Ca + He re-optimized on $^{48}$Ca$^{10+}$

Plasma image recorded with the CCD camera

Hours of beam time wasted, consumption increase of expensive material and experimentalist disappointment.
Optical diagnostic devices at HLI

Telephoto Lens ➔ Optical Beam Splitter and Glass Fiber ➔ CCD Camera

OCEAN OPTICS QE Pro
- Entrance slits: 25 µm
- Wavelength Range 449-833 nm
- Resolution 0.95 nm

https://www.oceaninsight.com

..to the Optical Emission Spectrometer
HLI diagnostic devices set-up
Optical Emission Spectroscopy on a Standard Temperature Oven

Oven heating: CCD Camera images and Optical Emitted Spectrum
MICROWAVE SHIELDING

- Material: Tungsten
- Mesh 100 (149 µm) – 25.4 µm wire

OES measurements for different oven powers without and with mesh at the oven head

- Measurements carried out with the shielded empty oven inserted inside the ECRIS.
- Helium plasma generated by coupling up to 650 W microwave power.
- Oven power settings: 8.4, 12.5, 17.4 W.
- Up to 69% shielding due to the mesh.

Optical spectroscopy as a diagnostic tool for metal ion beam production with an ECRIS
- $^{48}\text{Ca}^{10+}$ beam (19 February – 04 March)
  - Beam intensity: 90-120 $\mu$A
  - Stable beam for the entire beam time and no on-call or intervention necessary

- $^{48}\text{Ca}^{10+}$ beam (17-31 March)
  - Beam intensity: 70-90 $\mu$A
  - Two on-call intervention necessary

- $^{48}\text{Ca}^{10+}$ beam (02-15 April)
  - Beam intensity 90-100 $\mu$A
  - Two on-call intervention necessary
  - Beam unstable after source recovery due to software reset (12.04.20)

- $^{48}\text{Ca}^{10+}$ beam (19 April -15 May)
  - Beam intensity 100-110 $\mu$A
  - Non on-call intervention necessary

Spectrum of $^{48}\text{Ca} + \text{He}$ optimized on $^{48}\text{Ca}^{10+}$

$^{48}\text{Ca}^{10+}$ intensity at the current transformer for 10 days
OES diagnostic during the $^{48}$Ca beam-run 02-15 April 2020

Counts

Counts

Wavelength [nm]

Wavelength [nm]
OES diagnostic during the $^{48}$Ca beam-run 02-15 April 2020
Conclusions

- For $^{48}$Ca operation it is difficult to find a working point to guarantee a long-term stability as the oven response time and the ECRIS reaction are relatively slow.

- The use of an optical spectrometer as a diagnostic tool for routine operation helps to recover the source performances much faster during the metallic ion beam production whenever optimizations are required or instabilities occur.

- The grid shielding of the oven head improved the Ca ion beam production in terms of stability, intensity and material consumption since the parasitic heating of the ceramic insulating material inside the oven head is strongly reduced.
THANK YOU FOR YOUR KIND ATTENTION

THE ECRIS TEAM

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Jan Mäder
Patrick Tedit Patchakui
Aleksandr Andreev
Me
SPARES SLIDES
Evaporable solids (metals) – vapor pressure of $\approx 10^{-2}$ mbar at $T < 1600^\circ$C for Standard-Oven (STO), and at $T < 2000^\circ$C for High-Temperature-Oven (HTO).
GSI Oven Types: STO and HTO

Oven models used at GSI – length 70 mm, diameter 14.5 mm

**Standard Temperature Oven (STO):** yellow = Al$_2$O$_3$; green = Ta; orange = Mo; violet = CuBe$_2$; black = WRe(26%)

**High Temperature Oven (HTO):** yellow = Al$_2$O$_3$; green = Ta; orange = Mo; violet = WL20
Hot screen for Ca, Mg (, Sr)

- Made of Tantalum
- Screen thickness: 0.1 mm
- Length = 165 mm
- Diameter = 62 mm
- Plasma chamber diameter = 64 mm
- Gap to cold plasma chamber: 1 mm
- Ca consumption without hot screen: ~ 10 mg/h
- Ca consumption with hot screen: ~ 0.2–0.5 mg/h
- Crucible filling: ~ 300 mg
- Material costs: ~ 50.000 €
- Screen used only once
- Caps are cleaned and reused