Metallic beam developments for SPIRAL2

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**CONTENT:**

I - Presentation of Phoenix V2, the SPIRAL 2 beam line, and the different production methods

II - Results with nickel and calcium
Q/A=1/3 at 60 kV (LPSC) -> 14 MeV/A

Ion source:
ECR ion source Phoenix V2 (LPSC) Commissionning & first physics experiments Later ..... Superconducting 28 GHz ECRIS

SPIRAL 2 beam line:
Phoenix V2

- 18 GHz (0.64 T)
- Axial magnetic field: 2.0 T / 0.50-0.56 T / 1.2 T (room temperature coils)
- Radial magnetic field: 1.2 T at plasma chamber wall (permanent magnets)
- ECR dimensions (L, D): (54-68mm, 33-37mm)

- Aluminum plasma chamber: $\phi 63\text{mm}, L \approx 200\text{mm} \Rightarrow V \approx 0.65 \text{ L}$
- Aluminum plasma electrode: $\phi 10\text{mm}$

- Beam extraction: 60 kV with 2 gaps

- Good gaz performance: 1.7 mA He$^{2+}$, 1.3 mA O$^{6+}$, 50 µA Ar$^{14+}$


A: Plasma chamber inner diameter (63mm)
B: Access ($\phi 13\text{mm}$) to inject gas, metal vapor
C: Ta biased disk
D: 18 GHz wave guide

C. Barué
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To get the best intensity for high charge states, we should control the metal flow injected into the source independently of the other source parameters.

- Avoid Production method like: sputtering, plasma heating
- Avoid metal compounds: NiO, MIVOC

The oven method seems to be the best suited method
Vapor pressure of metallic elements

Too low temperature (evaporation dominated by plasma)
Too high oven temperature
Too high vapor pressure
Too low vapor pressure

Operating area
~ 90% of SPIRAL 2 beams can be done with the oven method
The GANIL Oven

The LCO (Large Capacity Oven) used for Ca and Ni evaporation.

Load capacity ~ 400 mm³ ⇔ 300 mg ⇔ ~ 10 days with a consumption of 1 mg/h

**For nickel:**

Pur natural metal was used (64% 58Ni) and is melt « off line » in its container

**For calcium:**

Pur natural metal was used (99% 40Ca) and its oxyde layer is removed before placing in the source
No saturation for the $^{58}\text{Ni}^{19+}$ intensity with the RF power
1.7 kW RF power ⇔ 900 W injected into the source (1.4 kW/L)

Good beam stability over hours
To be confirmed over a longer period

Good reproducibility
Starting the source in the morning, the nominal intensity of 20 µA is obtained after 1 hour only!
**Strong getter effect:**
- Keeping constant source parameters number, the total number of ions decreases as the nickel evaporation increases.
- During optimisation, the $O_2$ gas flow has to be increased together with the nickel evaporation.

**Ionization efficiency measurement:**
20 $\mu A$ $^{58}\text{Ni}^{19+}$ during 2 hours (7 $\mu A$ for all nickel charge states $\leftrightarrow 0.015\text{mg/h}$) 
nickel consumption measurement by weighting the sample 0.25mg/h

$\Downarrow$
6% total ionization efficiency for nickel

**Source performance in gas were not degraded by the nickel contamination, on the contrary:**
$^{40}\text{Ar}^{14+}$ increased from 35 $\mu A$ to 50 $\mu A$
better neutral pressure inside the plasma chamber?
Intensity $^{40}\text{Ca}^{14+}$ increases with the RF power up to 700 W:

700 W RF power $\Leftrightarrow$ 560 W injected into the source (0.9 kW/L)

Above 700 W RF power, the calcium evaporation becomes too high and degraded the CSD

200°C off line $\Leftrightarrow$ 10$^{-9}$ mbar vapor pressure $\Leftrightarrow$ no calcium evaporation off line
oven heated either by RF / plasma losses / X rays?

Good beam stability over hours, but very sensitive to the helium flow

Intensity too small for charge state 16+ ($^{48}\text{Ca}$):

$\Rightarrow$ decision to change the buffer gas into $\text{O}_2$
CSD much better than those obtained with the buffer gas He
$^{40}\text{Ca}^{16+}$ increased from 1 µA to 6 µA

- Same RF power limitation as with He buffer gas
Ca + O₂

- Very strong getter effect:
  ~ disappearance of the O₂ buffer gas

![Graph showing ion current over time for Ca and O₂](image)

![Graph showing ion current over time for O₂ only and Ca only](image)

Spontaneous evolution (1 hour)
April 9th, 2013
RF power: 800W
560 W injected (0.86 kW/L)
Biased disk: -9 V
30 kV / 1.2 mA
Coils currents: 1170A / -810A / 1250A
Extraction pressure: 1.1E-7 mbar
Oven position: -16 mm
Oven T° off line: ~ 50° C
(v.p. < E-9 Torr)

► Good CSD distribution (as with O2)
► No measurable getter effect => good stability over hours
► Same RF power limitation

► Ionization efficiency measurement:
16 µA $^{40}$Ca$^{16+}$ during 7 hours (25 µmA for all calcium charge states ⇒ 0.037mg/h)
calcium consumption measurement by weighting the sample 1.0 mg/h

↓
4% total ionization efficiency for calcium
Best metallic beam intensities from Phoenix V2

Q/A = 1/3 (other room T sources, f ≤ 18 GHz)

SPIRAL 2 requests

19F7+ (200 μA)
32S11+ (80 μA)
36S12+ (≤ 32S12+ 55 μA)
40Ca13+ (40 μA)
48Ca16+ (≤ 40Ca16+ 16 μA)
58Ni19+ (19 μA)
Conclusion

**Calcium, nickel:**

- Very good CSD (1 pμA for Ni19+ and Ca16+) with a room T ion source

  *better neutral pressure inside the plasma chamber?*

- Good beam stability over hours *but* has to be confirmed over days.

- Increase more the intensity => superconducting ion source working at high frequency

**Calcium:**

- RF power limitation at 800 W (calcium evaporation dominated by the source)

  *oven heated by RF losses? plasma losses? X rays losses?
SPIRAL 2 building progress

July, 2011

September, 2012

August, 2013
Thanks for your attention