NEW CONFIGURATION AND RESULTS WITH THE LPSC CHARGE BREEDER

T. Lamy, J. Angot, C. Fourel, T. Thuillier, LPSC, UJF, CNRS/IN2P3, INPG, Grenoble, France

Abstract

A 1+ thermo ionization source has been used to produce Sodium and Rubidium beams in order to compare the PHOENIX charge breeder capture efficiency for different ion masses but with the same beam optics. Yields of 1.9% for $^{23}Na^{6+}$ and 3.5% for $^{85}Rb^{15+}$, with charge breeding times of 8,6 ms/charge and 4,7 ms/charge respectively, have been measured. 1+ and n+ emittance measurements are presented along with the capture sensitivity to different parameters (DeltaV plots). Technical modifications have been performed to the charge breeder: replacement of the plasma chamber to allow a double frequency operating (14 + 18 GHz), modification of the injection magnetic plug to reinforce the axial magnetic field and correct its dissymmetry in the 1+ beam deceleration zone, insulation improvement to allow 60 kV operation for the SPIRAL2 project. First charge breeding experimental results at 14 and 18 GHz in the new configuration are presented and discussed for Rb beams.

INTRODUCTION

Improvement of ECR charge breeding characteristics (efficiency yield, charge breeding time, emittance) will immediately benefit to the physics performed with accelerated Radioactive Ion Beams (RIB's) allowing higher intensities (and/or brilliance) available to the experiments. There are two ways to reach such improvements: either to increase the 1+ beam capture efficiency, either to use the known methods that improve the intensity and charge state distributions delivered by Electron Cyclotron Resonance Ion Sources (ECRIS). The work presented here is intended to act on both ways.

RUBIDIUM AND SODIUM RESULTS

The experimental setup has already been extensively described [1] and will not be detailed here. A 1+ beam is produced, characterized, and then multi ionized into the charge state breeder, the n+ beam extracted is then characterized too. The three characteristics measured are efficiency, charge breeding time and emittance.

Rubidium

A 20 keV - 80 nA beam is produced with a thermo ionization source and injected into the PHOENIX charge breeder. Figure 1 shows the emittance plots for the $^{85}Rb^{1+}$ (left) and $^{85}Rb^{15+}$ (right) ion beams, on the latter the emittance scan excursion allows to see peripheral beams of higher and lower Q/A beams (Q and A being the charge and the mass of the ions respectively). The emittance values are 2 π.mm.mrad and 13.5 π.mm.mrad for the 1+ and 15+ beams respectively. However, when measuring emittances of different n+ ion beams, we always measure the same value, we suspect wrong entrance and exit angles with the n+ spectrometer. This can be clearly seen on the n+ picture, the emittance of the beams is strongly decreasing for increasing exit angles (yellow lines). With the present exit angle, we think the n+ emittance is overestimated by a factor 2 at least. So, the n+ beam line has to be realigned in order to measure the real emittance of the source.

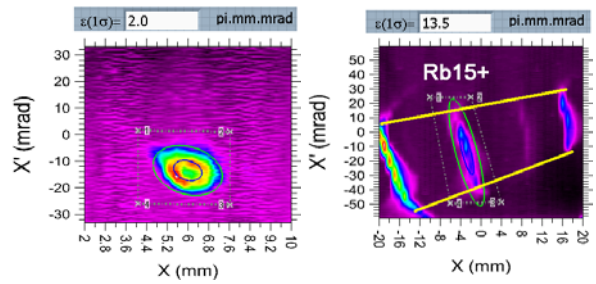

Figure 1: $^{85}Rb^{1+}$ and $^{85}Rb^{15+}$ emittances

Despite this problem, we have measured the transmission of the beam line to be 100% and we can then measure the charge breeding efficiency (1+→15+) which is η = 3.6% (result of the same order than in other laboratories, for example: [2], [3]).

The charge breeding time for this efficiency tuning was τ_{cbt} = 70 ms. Such a result has to be compared to ones which where obtained in previous experiments (η =5 %, τ_{cbt} = 225 ms). The charge breeder tuning (RF power, buffer gas flux and magnetic confinement) may give either low efficiency and fast process or higher efficiency but longer charge breeding time. In the context of radioactive ions the tuning will therefore be a compromise depending on the half life of the radioactive decay process.

Sodium

A 20 keV – 170 nA $^{23}Na^{1+}$ beam is produced with the same thermo ionization source as the one used for rubidium production, and injected. The emittance values for the $^{23}Na^{1+}$ injected and the $^{23}Na^{7+}$ produced are 1 π.mm.mrad and 15.6 π.mm.mrad respectively (Figure 2). The efficiency yield was 1.4 % and 1.9 % on the $^{23}Na^{7+}$ and $^{23}Na^{6+}$ respectively, with a charge breeding time of 52 ms for the 6+. In the case of light ions the tuning may be hard to find due to the capture sensitivity to the potential difference between the 1+ and the n+ sources (ΔV). However it seems that the ΔV width decreases for increasing charges, but not the potential value of the highest efficiency (Figure 3).

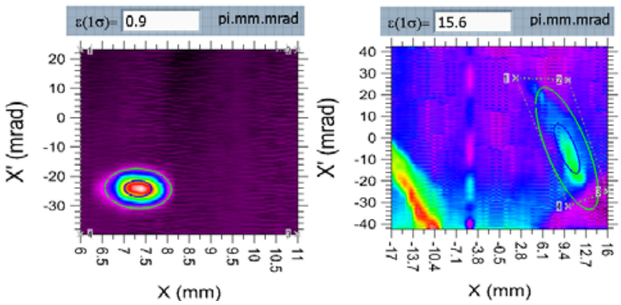

Figure 2: $^{23}Na^{1+}$ and $^{23}Na^{7+}$ emittances

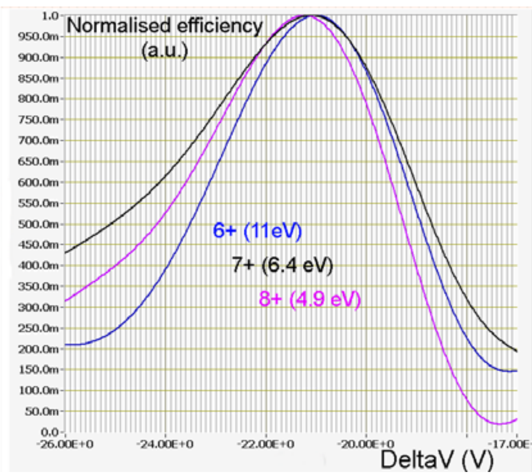

Figure 3: normalized deltaV plots for sodium 6+, 7+ and 8+.

IMPROVEMENT OF THE PHOENIX CHARGE BREEDER

High voltage insulation and rupture strength improvement

The central core (Figure 4) of the charge breeder is composed of a Fe-Nd-B hexapole H and two soft iron magnetic plugs (MPi and MPe) in which is inserted a plasma chamber.

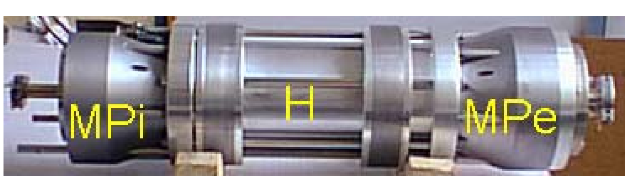

Figure 4: Photo of the central core of the PHOENIX charge breeder

This central core is inserted into a cylindrical insulator (Figure 5) and is maintained at the center of the charge breeder by the means of the blue part on the right and fixed by screws (in black).

For the SPIRAL2 project, this central core can be brought up to 60 kV with respect to the grounded body of the charge breeder (comporting 3 coils and soft iron to generate the axial magnetic field). On Figure 5, the lower part (under the axis) shows the original insulator shape (in green). On the right side the insulating cylinder was inserted into a slot machined in the blue part P. In case of a sudden breakdown of one of the 3 supplies of the coils, the central core undergoes a huge axial force (80 kN), the slot in the part P was inducing a mechanical weakness and the part P could brake. The insulator shape and the part P have been modified as shown on the upper part of the Figure 5, the slot has been suppressed in the part P and the recovering length of the insulator on the grounded body has been increased so the 60 kV insulation is insured and the resistance to tearing increased.

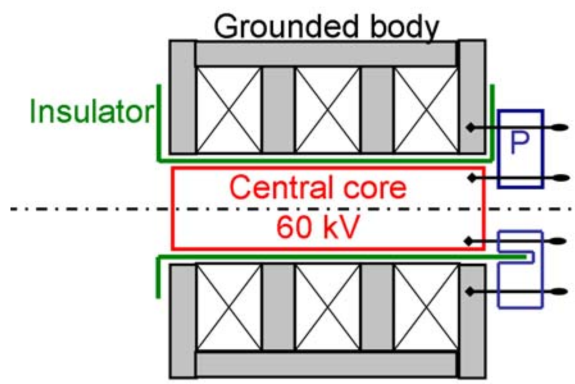

Figure 5: Charge breeder improvement scheme

Double frequency plasma chamber

Three modifications have been performed on the plasma chamber (Figure 6):

- An additional radial RF port has been soldered in order to permit the injection of 14 and 18 GHz microwave frequencies
- Two gas inlets have been added in order to directly inject the gas close to the plasma (in the previous version, it was flowing trough the grounded tube where the 1+ ions are injected)
- The inner diameter has been kept constant all along the chamber in order to be able to insert a liner where the ions will deposit. When working with radioactive ions it will facilitate the maintenance and limit the amount of radioactive wastes.

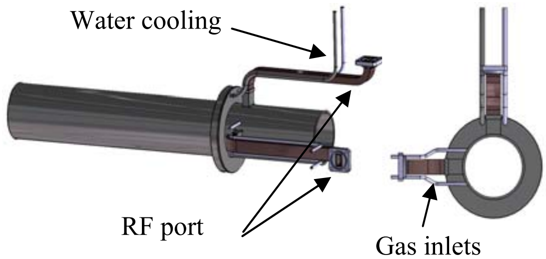

Figure 6: New 14 and 18 GHz plasma chamber

Magnetic field intensity and topology

The magnetic field intensity and topology at the injection side is of first importance for the efficient 1+ ions capture. The magnetic field characteristics are mainly due to a soft iron plug concentrating the flux lines of the injection coil and of the hexapole fringing field. The initial magnetic plug had a slot leaving a lot of spacefor the cooling tubes and the RF wave guide mounted on the plasma chamber. The redesign of this plug has been performed in order to increase the maximum axial induction and to correct the dissymmetry of the magnetic field lines due to the missing iron on the top of the plug. Additional parts have been added, to fill with iron as much empty space as possible (Figure 7).

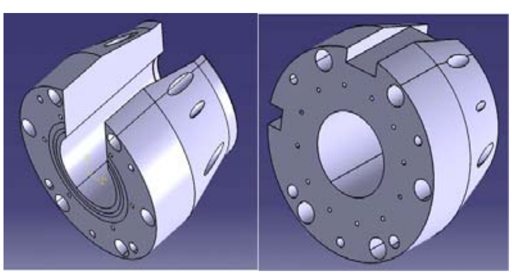

Figure 7: Initial and new magnetic plugs

Magnetic field calculations of the two configurations have been performed with RADIA [4] and Mathematica in 3D including the hexapole, the coils and the iron of the charge breeder. The current of the coils has been fixed to the typical experimental ones when tuned for charge breeding: 1100 A at the injection, 400 A at the middle and 600 A at the extraction side. The iso-B lines obtained for the old and new plugs, on a horizontal plane passing through the axis of the charge breeder, are shown Figure 8. For a better reading, only one half (injection side) of the charge breeder magnetic field calculation result in the plasma chamber is shown. The center of the charge breeder is at the coordinate 0, the grounded tube permitting the injection of the 1+ beam is the black line on the right. These calculations clearly show that the goals of the modifications have been fulfilled, the maximum induction at the injection side is 1.13 T after the modification (1.1 T before) and the dissymmetry of the magnetic flux is corrected. The pink and the red lines are the resonance zones for 14 and 18 GHz respectively.

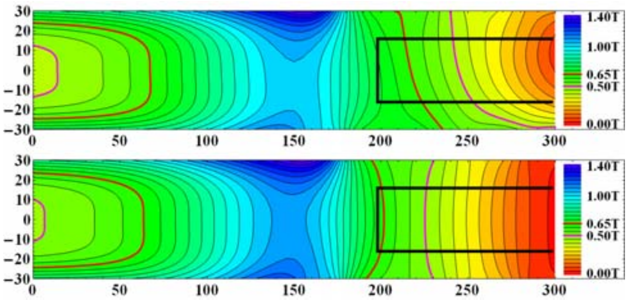

Figure 8: old and new magnetic configurations on the injection side of the charge breeder.

FREQUENCY MIXING EFFECT

In order to evaluate a frequency mixing effect, a first experiment has been performed. The relative variation of the $^{85}Rb^{13+}$ charge breeding efficiency has been measured for different total RF input powers varying the proportion of 14 and 18 Ghz powers. The results are presented Figure 9. The reference point has been chosen to be 400 W of pure 14 GHz injection because it is a rather usual tuning. One can see that the 18 GHz injection permits to improve the efficiency especially at higher powers and that the best effect is obtained for a mixing of 10 % of 14 GHz with 90% of 18 GHz . These preliminary results have to be confirmed, but we can conclude that frequency mixing can help to the charge breeding tuning process.

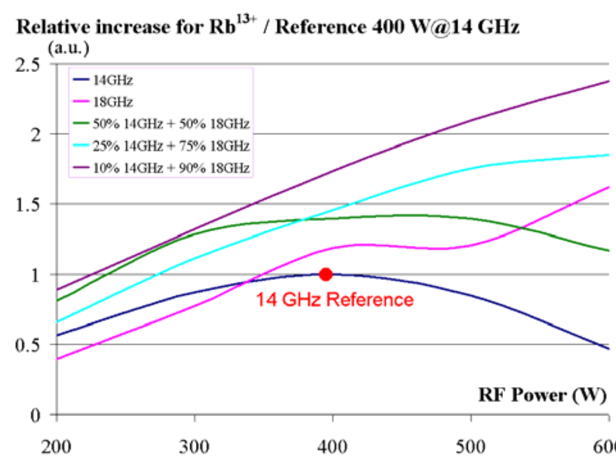

Figure 9: Frequency mixing effect on $^{85}Rb^{13+}$ production efficiency

REFERENCES

[1] T. Lamy, R. Geller, P. Sortais, and T. Thuillier Rev. Sci. Instrum. 77, 03B101 (2006).
[2] F. Ames et al., in these proceedings (WECO-A02)
[3] R. Vondrasek, J.R. Carr, R.C. Pardo, in these proceedings (WECO-A03)
[4] O. Chubar, P. Elleaume and J. Chavanne 1998 J. Synchrotron Rad. **5** 481 – 4 (1998)