EXPERIMENTAL STUDIES ON THE ALISES ION SOURCE AT CEA SACLAY

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Abstract

The ALISES ion source was originally designed to reduce beam emittance at RFQ entrance by shortening the length of the LEBT. A wide opened magnetic coil at ground potential produces the fringe field needed for the ECR heating at 2,45 GHz frequency. The first part will describe the commissioning of the source: Penning discharges inside the accelerating column make the high voltage power supply collapse. Experimental tests with kapton films while discharges occur and simulations with the OPERA-3D code have shown great similarities to detect the location of those discharges and allow us to make the ion source work. The second part of this paper will present the result of low intensity light ion beam production versus the plasma chamber length and radius. Those very preliminary tests give us indications to reduce the ion source dimensions.

INTRODUCTION

At CEA Saclay, light ion sources are generally designed for accelerator purpose. Since mid-90's ECR ion sources have been developed for high intensities: the SILHI source produces up to 100 mA of proton or deuteron beams routinely [1] for the IPHI accelerator and the IFMIF ion source [2] producing up to 120 mA of deuteron is under commissioning. Recently the need of smaller size ion sources had increased, capable to deliver 50 mA of proton beams with the lowest emittance. In order to work on this need, an internal R&D work was scheduled on several years to study several criterions: what are the relevant parameters that can reduce the size of an ion source?

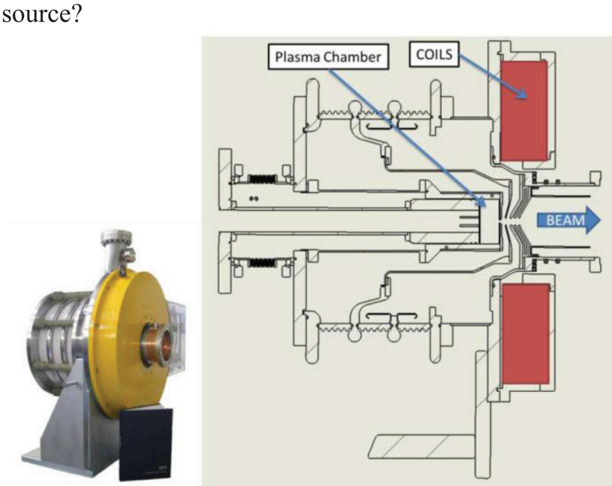

Figure 1: ALISES Ion Source, extraction side.

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This paper will show the first experimental results of the ALISES ion source installed on the BESTI test bench [3] and how we solved partially Penning discharges inside the source. The second part will show the preliminary results at low bias voltage for low extracted currents when changing the plasma chamber length and diameter.

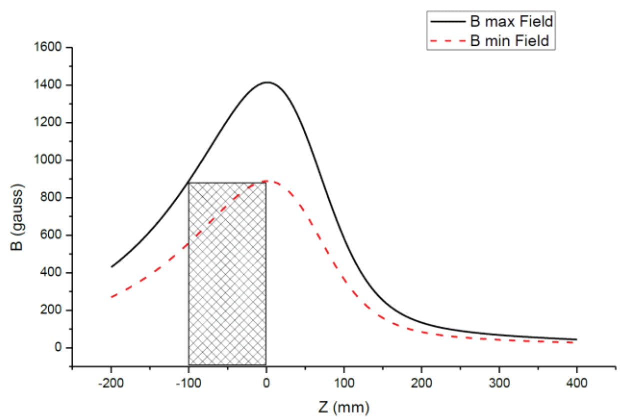

Figure 2: Fringe field of the source coil. The dash zone represents the plasma chamber

COMMISSIONING

The ALISES ion source has been described in ref [4] and [5]. This source is not intended to be a small size source but allows us to test several size parameters in order to miniaturize the next generation of ion sources. The ALISES concept consists in reversing the position of the insulating structure with the magnetic field generation material (coils or permanent magnets), in order to shortened the LEBT and keep the extracted beam focalized at source exit.

The commissioning of the ion source was made in several steps. First we applied 50 kV of bias voltage on the source body and the puller electrode independently in order to detect some grounding problem or sparking. No sparking was detected on either electrode. For the second step, we switched off all HV power supplies of the source and switched on the magnetic field of the source coil in order to produce the 875 Gauss resonance zone at 100 mm behind the plasma electrode. With a 3 sccm of H2 gas and 300 W of HF power delivered by the magnetron, a pink colored plasma was observed through a window along the LEBT axis, characteristic of the hydrogen Balmer lines.

When the electric and magnetic field were simultaneously on, the HV power supplies dropped down

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with a maximum current flow. This behavior occurs every time and is different than a spark. We suggest that it could be a Penning discharge occurring inside the accelerating column. With the OPERA-3D code [6] we could simulate the whole system, applying the right bias potential (40 kV on the plasma electrode and -2 kV on the repeller and ground potential on all the others) and the right magnetic field. We added also several free electrons (10-5eV of initial kinetic energy) in the space between electrodes. At several locations, electrons were accelerated up to several kilovolts and trapped by the combination of electric and magnetic field lines. Theses electrons have their energy and life-time increased and are able to ionize the residual gas, thus ignite a plasma: the Penning discharge.

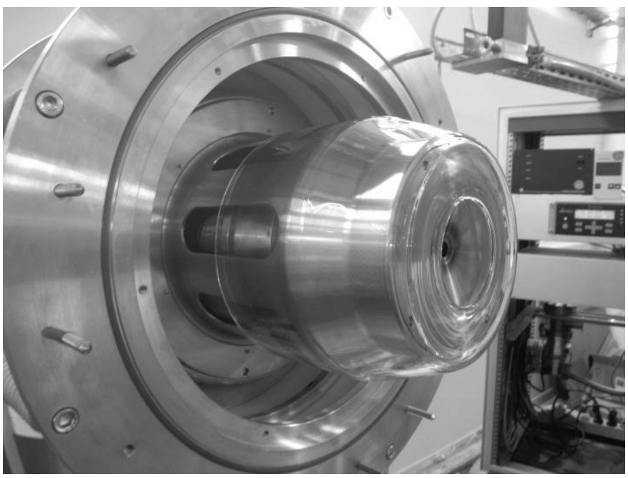

Figure 3: External glass-tube around the puller electrode.

To comfort our idea, we placed around the electrodes several foils of Kapton. We applied simultaneously the HV and the magnetic field several millisecond. We compared the locations of the marks on the foils with the trapped electrons zones simulated with the code: they showed a good agreement.

In order to reduce the Penning discharge occurrence, three tubes made of glass where positioned around the electrodes. That allowed us to apply simultaneously HV and magnetic field in order to ignite the ECR plasma and extract the H+ particles out of the source.

The gaps between electrodes were set for 23 kV (maximum potential reach with spark) of 20 mA beam extracted with a 6 mm diameter extraction hole. Now beam can be extracted at 23 kV and measurements with plasma chamber dimensions were started.

PLASMA CHAMBER REDUCTION

Plasma Chamber Length

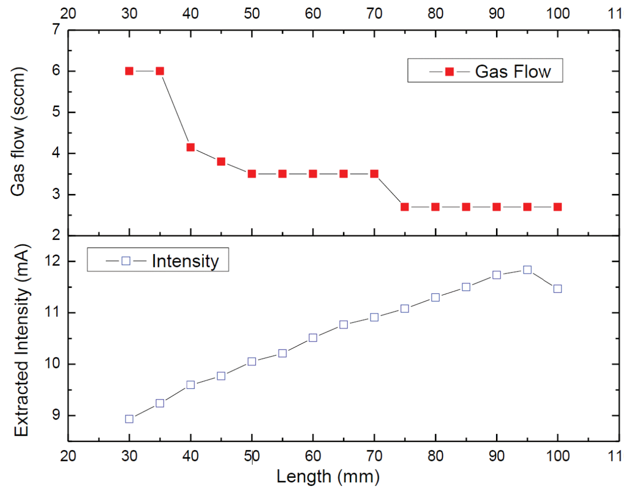

Figure 4: Intensity extracted and injected H_2 gas flow versus plasma chamber length.

The ALISES plasma chamber length can be modified from 100 mm to 30 mm. The extraction hole remains fix and the RF ridge part moves toward extraction hole. As the plasma chamber length get reduce, the intensity of the magnetic field produced by the source coil must also be decreased in order to keep the 875 Gauss at the ridge exit. On Fig.4 we report the optimized extracted intensity and the injected H2 gas flow rate versus the plasma chamber length. It shows that from 30 to 95 mm the intensity increases regularly as the gas flow decreases.

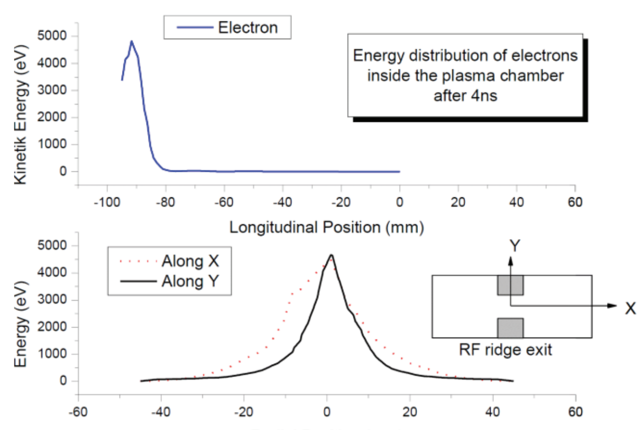

Figure 5: Spatial-energy distribution of electrons in the plasma chamber calculated with SOLMAXP.

One explanation of those behaviors can be advanced if we look at the longitudinal energy distribution of electrons in a 100 mm plasma chamber. This was simulated with SOLMAXP [7]. Highly energetic electrons are produced and concentrated around 10 mm of the ridge exit located at position -100 mm on Fig.5 upper curve.

The maximum of total cross section for producing H+ from H or H_2 by electron bombardment is around 60 eV

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[8-9], low value compare to the 5 keV of the hot electrons produced at the resonance zone. In order to lower the kinetic energy of those hot electrons, the gas in the rest of the plasma chamber is used as a "thermalizer". That explains also the behavior of the gas pressure to obtain the maximal value of extracted current for a shorter plasma chamber: as the thermalizer length is reduced the pressure must be increased to cool down with a better efficiency hot electrons in order to increase the cross section values for ionization.

Plasma Chamber Diameter

With ALISES ion source we can also reduce plasma chamber diameter by inserting a metallic tube and fix it on the RF ridge side of the plasma chamber. The nominal diameter of the chamber is Ø90 mm. Two metallic tubes of 100 mm long were manufactured with internal diameter of 45 and 30 mm. On the result Fig.6 the extracted current seems to be quite constant all over the 3 different diameter values.

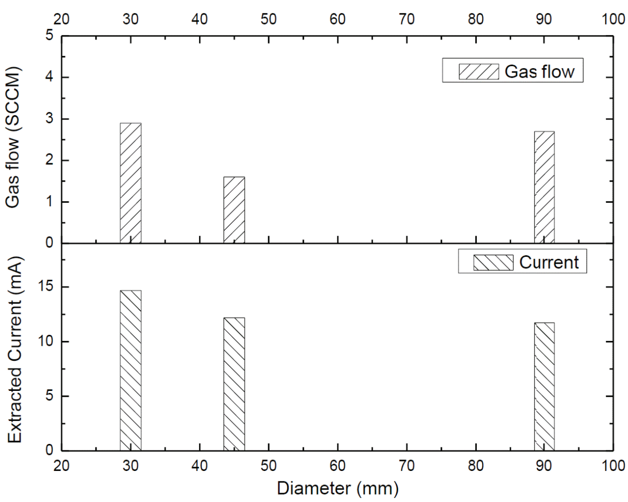

Figure 6: Extracted current intensity and injected gas pressure versus plasma chamber diameter.

On the lower part of Fig. 5 the radial simulation of kinetic distribution of hot electrons is centered on the ridge steps, where the electric field is concentrated. The radial dimensions of the distribution are around 20 and 30 mm respectively for vertical (Y) and horizontal direction (X). Compare to the waveguide dimension, the small distance between ridge steps in the vertical dimension (Y) makes the kinetic distribution narrower in this direction than in the horizontal plane: it seems evident that reducing plasma chamber radial dimension from 90 to 30 mm would not affect as much the heating zone where hot electrons are produced.

That means that plasma chamber internal diameter for future ion source can be reduced to 30 mm, giving the possibility of decreasing the dimension of the magnetic system and accelerating column radial dimension also.

This experiment was also carried out on the IFMIF ion source with a more intense proton beam, and gives the same results: for a 50keV of beam energy, extracted current intensity remains constant. For higher extraction potential a 10% decreased of current seemed to be observed as one reduces the internal diameter to 30mm.

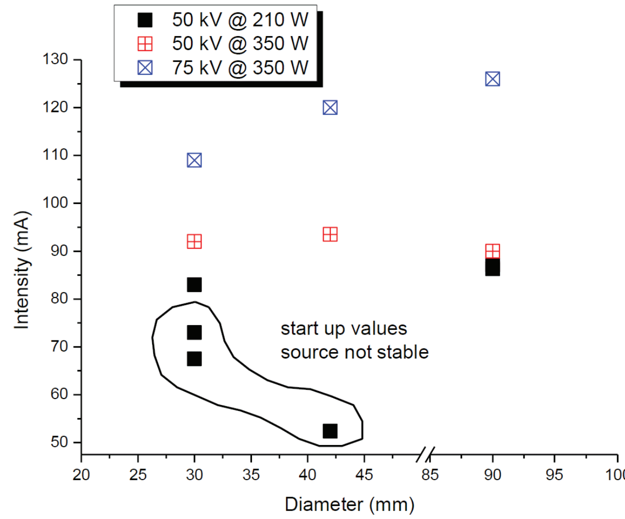

Figure 7: Preliminary results on IFMIF source, intensity vs plasma chamber diameter, bias voltage and bean extraction energy.

CONCLUSION

The commissioning of the ALISES ion source made us create a new tool to test our accelerating columns in order to find electrons traps that give rise to Penning discharges. This code was also tested on other source and helped us to understand some marks inside accelerating column of the IFMIF source for example.

Plasma chamber radial reduction on two ion sources (ALISES and IFMIF) showed the same behavior: up to Ø30mm internal diameter no dramatic changes on beams intensities were observed.

ALISES ion source Patent n°

REFERENCES

[1] R. Gobin, et al., Rev. Sci. Instrum. **81**, 02B301 (2010).

[2] R. Gobin, et al., Rev. Sci. Instrum. **83**, 02A349 (2012).

[3] O.Tuske, et al., Rev. Sci. Instrum. **79**, 02B710 (2010).

[4] O. Delferrière, et al., Rev. Sci. Instrum. **83**, 02A307 (2012).

[5] S. Nyckees, et al., Rev. Sci. Instrum. **83**, 02A349 (2012).

[6] Opera-3D, Cobham Technical Services 24 Bankside Kidlington, Oxford OX5 1JE, UK.

[7] The SolMaxP code, IPAC 2012, New Orleans (MOPPC056).

[8] Y.-K. Kim and M.E. Rudd, Phys. Rev. A **50**, 3954 (1994).(T).

[9] Y.-K. Kim and M. E. Rudd, Comments At. Mol. Phys. **34**, 293 (1999).

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