ISBN: 978-3-95450-257-8 ISSN: 2222-5692 doi:10.18429/JACoW-ECRIS2024-MOP04

ALISES v3 ION SOURCE IN VARIOUS CONFIGURATION ALONG THE YEAR

O. Tuske*, O. Delferriere, A. Dubois, Y. Gauthier, Y. Sauce
Université Paris-Saclay – CEA–Irfu, Gif/Yvette, France

Abstract

ALISES v3 is a very compact light ion source that has been developed at CEA Saclay in 2018. The easy maintenance procedure of this source allowed us to test many different configurations. On the BETSI test bench equipped with a single Alisson Scanner and a pair a solenoid/deviator, we studied the extraction energy influence, we changed the number of electrodes in order to extract different kind of ions other than protons. This paper will describe briefly the ALISES v3 ion source and will present all the results that we gathered in a year with all those modifications

INTRODUCTION

The ALISE v3 ion source, developed at CEA Saclay in 2018, represents a significant advancement in light ion source technology using ECR heating process. It aims to achieve the same performance as the original SILHI source, known for its high intensity proton and deuteron beams, but with a smaller and more user-friendly design. This new iteration incorporates the best aspects of previous ALISE versions, resulting in a more compact and practical configuration. The manufacturing of ALISE v3 coincided with the upgrade of the BETSI (Banc d'Etudes et de Tests des Sources d'Ions) test bench, allowing for thorough testing and analysis of its beam characteristics. This innovative source holds promise for various applications requiring high-intensity light ion beams, offering improved efficiency and ease of maintenance. This article will summarize all the evolution and changes that were made to the original model of the ALISES v3 to increase the availability of the ion source at different energy.

ALISES v3 ION SOURCE ON BETSI TEST BENCH

The BETSI test bench, located at CEA Saclay [1], is a crucial facility dedicated to the optimization and characterization of high-intensity light ion sources. Operational since 2009, it has played a pivotal role in the development and testing of various ion sources, particularly those used in large-scale accelerator projects like Spiral2 and some component of various project (emittance measurement unit and Wien filter). Also this test bench is used for educational purposes with students for Paris-Saclay University. The core of the BETSI test bench is a versatile platform capable of accommodating and testing different ion source types, primarily those based on Electron Cyclotron Resonance (ECR) heating.

The ALISE v3 ion source uses several key technical advantages. Its compact design, with a ceramic diameter of only 150 mm and a length of 300 mm, makes it significantly smaller than traditional high-intensity ion sources. This allows for easier integration into existing accelerator facilities and reduces the overall footprint of the system. Additionally, the simplified structure of the source facilitates maintenance and reduces the risk of operational issues.

A single coil at ground potential provides the magnetic field and is located around the source ceramic. This unique coil was used on both IPHI project (SILHI source [2]) and FAIR project ion source. On this latter project, a single coils was enough to heating up electrons to ignite the plasma source [3].

The gas injection system allow to control the mass flux of the injected gas (hydrogen or helium) that is needed to inject inside the plasma chamber, independently of the temperature in the experimental hall. The PR4000 MKS brand was chosen because of its good behaviour against sparks. The use of metallic capillaries with metallic gasket decrease the possibility of tiny leaks polluting the plasma with air and its components.

The energy id provided by a microwave generator at 2,45 GHz delivered by SAIREM company. Free electrons inside the magnetic field have at a moment the same gyration frequency than the magnetron generator and leads to an efficient energy transfer from the microwaves waves to the kinetic electrons velocity, causing them to get accelerated (heat up) and collide with neutral atoms of the injected gas. These collisions result in the ionization of the atoms of the gas, forming a plasma which contains the desired positive ions, electrons and also some ionized molecules in some cases.

The positive ions are extracted trough the plasma chamber extraction hole, focused and accelerated using a multi-electrode extraction system.

Extraction energy was designed to be 100 kV but unfortunately this value was never reached in normal source operation with the first design of the ceramics. With the second design [4], maximum extraction voltage reach the value of 80 kV but sparks occurs too frequently and did not allow to increase more because the risk of damaging any equipment.

INFLUENCE OF THE COIL POSITION

The single coil of the source can be moved easily. As the position changed, the current value of the Coil Power Supply (C-PS) must also be adjusted in order to keep the resonant zone at the same location to ignite the plasma. As the coil gets further away the RF ridge, the value of the C-PS must

* olivier.tuske@cea.fr

increase. This has an influence on the magnetic profile in the plasma chamber. In Fig. 1, we show the increased of the extracted proton beam intensity versus the extraction voltage for two positions of the source coil. Electrons seemed to be more efficient for the same RF power to ionized the hydrogen gas and thus produces a higher beam current. From that result, we defined the position of the Coil that delivers the highest extracted intensity.

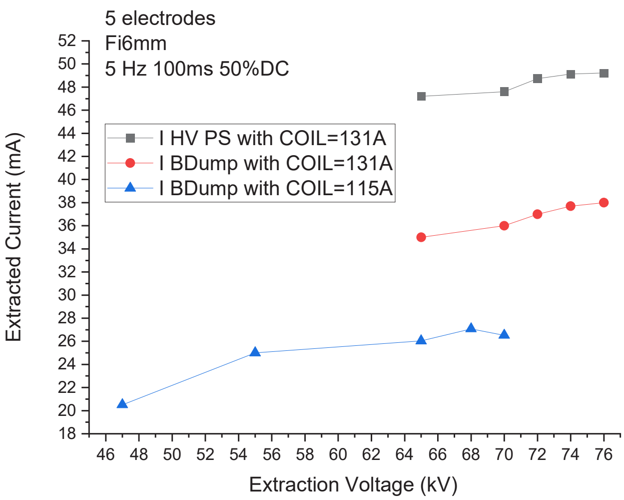

Figure 1: Evolution of Extracted Proton current vs extraction voltage for 2 Source Coil Power Supply (C-PS) value.

Number of Electrodes

On the ALISE v3, the accelerating column can be modified very easily. As the extraction voltage of 100 kV seemed to be impossible to reach even with the second ceramic design, we decide to fix the extraction voltage value around 60 kV and the plasma hole diameter at 6 mm. While the puller electrode was removed, to optimize the beam extraction with 4 electrodes configuration, the extraction gap was reduced by moving the plasma electrode toward the first ground electrode.

On Fig. 2 we can compare the extracted beam (the drain current of the high voltage power supply "I HV PS") with the collected beam intensity at the end of the LEBT (I BDump). With 5 electrodes, I HV PS drain current is higher than with the 4 electrodes configuration. That means that in the first case with a two gaps accelerating system has a better efficiency to pull out particles out of the plasma. But the measured current at the end of the LEBT seemed to higher with the 4 electrodes accelerating configuration, showing that with a single accelerating gap of 12 mm at 60 kV the beam divergence is lower, increasing the transmission of the beam. This behaviour was simulated with IBSIMU code [5] while optimizing the acceleration gap length in order to lower beam divergence.

In order to increase even more the extracted total beam current, the use of a larger diameter plasma electrode aperture hole will be tested soon: from 7 to 9 mm aperture plasma diameter hole.

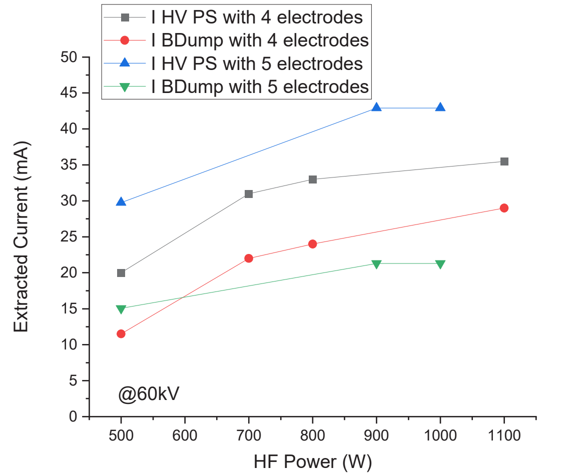

Figure 2: 4 and 5 electrodes configuration, respectively single and double acceleration gap extraction.

Helium Gas in ALISES v3

In order to increase the panel of possibilities of the ALISES v3 ion source, we fed it with helium gas. Helium has a lower ionization level: that means first ionization is possible. Extraction simulations at 60 kV extraction voltage showed that with the same gap length, beam divergence is bit larger because of the space charge effect as Helium atom (He) is four time heavier than hydrogen. Also helium gas is a noble gas: there won't be any "ionized molecules" in the extracted beam and no helium pollution once hydrogen gas will be use again. On Fig. 3 He^+ particle are plotted for various magnetron power. Helium beam is not well transported in BETSI's LEBT, more adapted for hydrogen beam but a constant transmission around 80 % at 60 kV extraction energy for all RF power is observed.

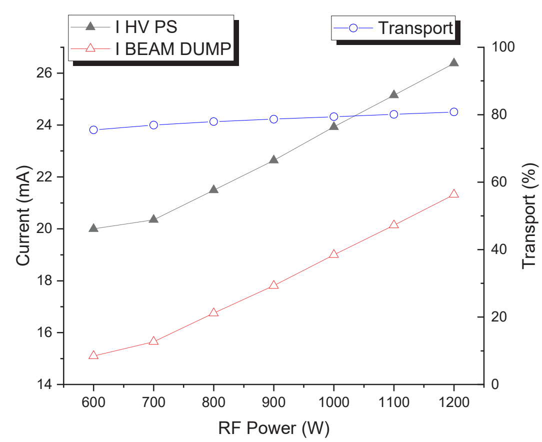

Figure 3: Helium Beam extracted and transported.

Those measurement were done in a single day and we emittance measurement at 900 W after the first solenoid (Fig. 4) were also carried out. The use of TRACEWIN/PLOTWIN code [6] estimates the normalized RMS emittance value around $0.19\,\pi \cdot \mathrm{mm} \cdot \mathrm{mrad}$. The beam shape in the phase space is not really what we expected and some simulations are needed to try to reproduce this shape under those conditions.

ISBN: 978-3-95450-257-8 ISSN: 2222-5692 doi:10.18429/JACoW-ECRIS2024-MOP04

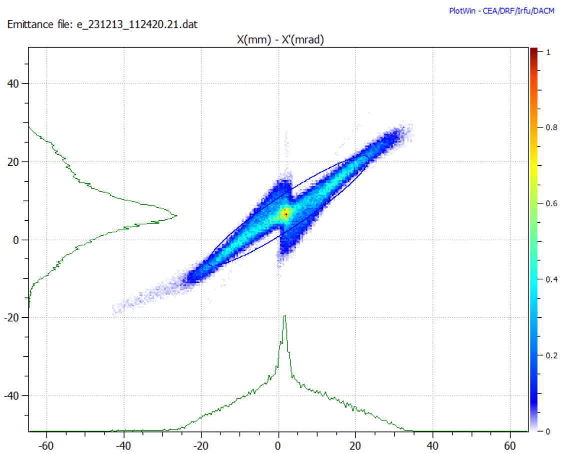

Figure 4: Emittance measurements at 900 W of magnetron power after the 1st solenoid of the LEBT.

CONCLUSION

ALISES v3 is a very compact source, with a easy maintenance procedure. The source can produce routinely up to 50 mA of proton beam, with simple some adaptations. The position if the single source coil has been optimized. The 4 electrodes configuration has demonstrated its versatility up to 60 kV extraction voltage and we continue to reduce beam divergence in order to transport as much particle as possible. Some measurements with helium gas showed interesting results that we will pursued.

REFERENCES

[1] O. Tuske *et al.*, "Experimental Studies on the ALISES Ion Source at CEA Saclay", in *Proc. 20th Int. Workshop on ECR Ion Sources (ECRIS'12)*, Sydney, Australia, Sep. 2012, paper WEPP16, pp. 143-145.

[2] P. Ausset *et al.*, "Status Report on the Saclay High-Intensity Proton Injector Project IPHI", in *Proc. 7th E. Part. Accel. Conf. (EPAC'00)*, Vienna, Austria, Jun. 2000, paper THOAF202, pp. 283-285.

[3] O. Tuske, N. Chauvin, O. Delferriere, J. Fils, and Y. Gauthier, "Commissioning of the ECR ion source of the high intensity proton injector of the Facility for Antiproton and Ion Research (FAIR)", *Rev. Sci. Instrum.*, vol. 89, no. 5, p. 052303, May 2018. doi:10.1063/1.5017783

[4] A. Dubois, O. Delferriere, Y. Gauthier, Y. Sauce, and O. Tuske, "Evolution of ALISES 3 Light Ion Source at CEA Saclay", *J. Phys.: Conf. Ser.*, vol. 2743, no. 1, p. 012058, May 2024. doi:10.1088/1742-6596/2743/1/012058

[5] T. Kalvas, O. Tarvainen, T. Ropponen, O. Steczkiewicz, J. Ärje, and H. Clark, "IBSIMU: A three-dimensional simulation software for charged particle optics", *Rev. Sci. Instrum.*, vol. 81, no. 2, p. 02B703, Feb. 2010. doi:10.1063/1.3258608

[6] D. Uriot and N. Pichoff, "Status of TraceWin Code", in *Proc. 6th Int. Part. Accel. Conf. (IPAC'15)*, Richmond, VA, USA, May 2015, pp. 92-94. doi:10.18429/JACoW-IPAC2015-MOPWA008