MONOBOB II : LATEST RESULTS OF MONOCHARGED IONS SOURCE FOR SPIRAL2 PROJECT

M. Dubois, P. Jardin, O. Bajeat, C. Barue, C. Canet, M. Dupuis, J.L. Flambard, R. Frigot, C. Leboucher, N.Lecesne, P. Lecomte, P. Leherissier, F. Lemagnen, L. Maunoury, B. Osmond, J.Y. Pacquet, A. Pichard
GANIL, bd Henri Becquerel, BP 55027, F-14076 Caen cedex 05, France

Abstract

Among the sources which can be installed in the radioactive ion production module of SPIRAL II, a singly-charged ECRIS has been chosen to produce ions from gaseous elements. Its characterization is under way on a test bench at GANIL. Extraction, transport and response time results are presented.

INTRODUCTION

In the frame of the SPIRAL II project [1] (Système de Production d'Ions Radioactifs Accélérés en Ligne phase II), four techniques of ion source (IS) have been chosen to cover a large range of radioactive ions, *i.e.* FEBIAD and LASER [2] IS's for condensable elements, surface IS [3] for alkalis, and ECRIS [4] for gaseous elements. These sources can be installed in a vacuum chamber named "production module" which contains mainly the radioactive element production target and the IS. To limit the transient time of the atom from the target to the IS, the source is installed very close to the target. In this hostile environment, a standard ECRIS including permanent magnets and non mineral insulators cannot withstand the radiation dose more than few days, what must be compared to the three months of continuous operation expected. Then the techniques and materials available to design the sources are limited and only singly-charged IS can be built. To reach the charge states required by the post accelerator CIME [5] the delivered beams are then injected in a charge-booster [6].

The most interesting isotopes are the shortest lived ones; unfortunately, their production yields in the target decreases with their half-lives, and their losses tends to increase during the atom-to-ion transformation process as their half-lives decrease. The efficiency of each step of the process, diffusion of the isotopes out of the target, effusion up to the IS, ionization and transport must then be as high as possible to make the most of the isotopes produced in the target. By difference with stable elements, the process must also be as fast as possible to limit the losses by radioactive decay.

In this paper, we report the measurements of the beam transport from the exit of the ECRIS up to the Faraday cup situated after a magnetic mass spectrometer, the emittance measurement and the measurement of the atom-to-ion transformation time in the ECRIS.

DESCRIPTION OF THE SETUP

For gases, the production module includes a carbon converter, a uranium carbide target with its oven, a transfer tube and an ECRIS (Fig. 1). A primary beam of deuterons impinges the carbon of a wheel in front of the UC target, producing a flux of neutrons which induces the fission of the uranium. As the target is maintained at 2000°C, the fission fragments diffuse out of target material, effuse up to the ECRIS via the transfer tube and are ionized in a time and with an efficiency depending on the tuning of the source and of the element.

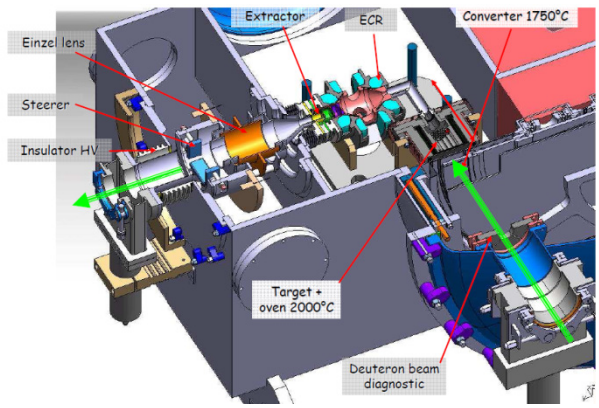

Figure 1 : Production module

The ions leave the IS trough the hole of the plasma electrode (7 mm in diameter) placed in front of the extraction electrode (14 mm in diameter, and with a tuneable position). The potential difference was maintained at 15 kV. After acceleration, the beam passes through an Einzel lens (with tuneable position), a magnetic mass analyser, an emittance meter (removable), before reaching a Faraday cup.

For safety reasons, in the frame of SPIRAL II operation, the TISS will be installed in a vacuum chamber where the pressure must be lower than 10^{-5} mbar after outgassing. During the present tests, the vacuum chamber reproduces these vacuum conditions, but the UC pills were replaced by carbon pills.

Two fast valves were installed on the TISS: one at the opposite of the plasma electrode hole to measure the response time of the source, and one on the target container, at the opposite of the aperture towards the IS to measure the contribution of the target to the response time of the TISS.

Fast valves were fed with a mixture of He, Ne, Ar, Kr, and Xe. Support gas was N_2, 0_2 being forbidden in case of carbon target at high temperature (max 1500°C).

TRANSPORT OPTIMISATION

The optimal distance between the extraction and plasma electrodes has been found equal to 31 mm. The transport of the beam from the exit of the ECRIS up to the Faraday cup has been estimated by comparing the total

current of the peaks present on the spectrum and the total current delivered by the ECRIS. The position of the lens and of its voltage were tuned to maximize the current of the N_2^+ beam in the Faraday cup, as this ion beam is the most abundant and then mainly govern the value of the transport (Fig. 2).

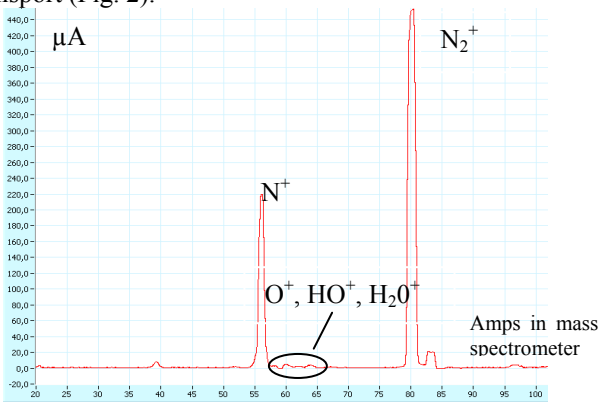

Figure 2: typical spectrum of the source after mass spectrometer after outgassing.

The total current delivered by the source was maintained between 640 µA and 810 µA, what is close to the maximum of this source. Once a transport close to 100% has been obtained, the emittance has been measured for Ar^+ (Fig. 3) and N_2^+ beams. More than 85% of the beam is included in an ellipse of 80 π.mm.mrad, which corresponds to the acceptance of the low energy beam line.

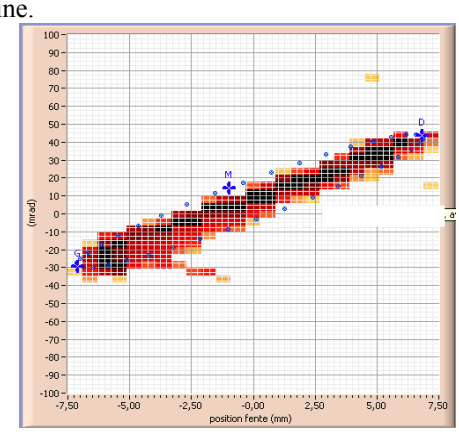

Figure 3: Emittance of the $^{40}Ar^+$ beam for a total current extracted from the source of 735 µA. The ellipse corresponds to the geometrical acceptance of the low energy beam line (80 π.mm.mrad).

This result should be improved by increasing the magnetic field of the ECRIS in the extraction region. During the tests, this magnetic field was not optimum owing to a limitation of the power supplies, and will be improved during the next tests. The emittance of the ECRIS being considered as the most important among the IS chosen, all the beams extracted from these ISs should be easily transported in a 80 π.mm.mrad beam line.

RESPONSE TIME

The source was fed with N_2 and ~50 W of RF power (less than 5 W of reflected power) to reach a total current between 640 µA and 810 µA at the exit of the source. Gas pulses of ~1.4 ms long were injected in the source, containing natural He, Ne, Ar, Kr and ^{129}Xe (Fig.4). The magnitude of the electrical pulses controlling the aperture of the valve was tuned to limit the perturbation to value lower than 5 µA induced on the plasma and thus on the total current. The ion beam of interest was selected with the spectrometer and the shape of the ion pulses was recorded on the Faraday cup. The intensities of the ion pulses being of the order of 10 nA, several pulses were added to increase the statistic. To reject the 50 Hz noise, the repetition period of the pulses was different from a multiple of 20 ms.

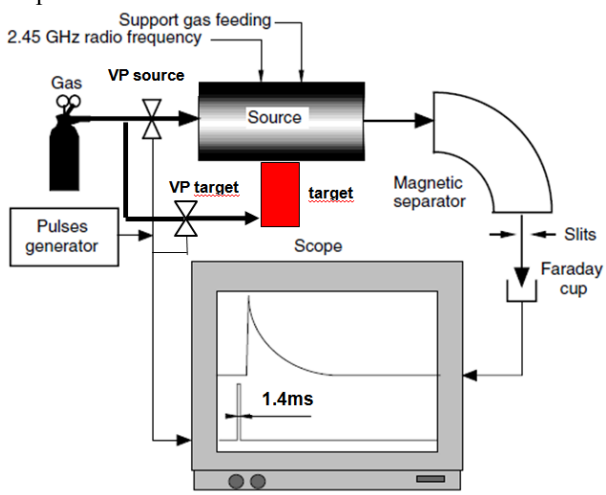

Figure 4 : Set up scheme

During the following measurements, the temperature of the target was equal to 1000 K. Owing to two half discs placed in the transfer tube, the target and the ECR plasma were not in direct regard. This TISS being dedicated to the production of isotopes of noble gases, this chicane stops the direct effusion of condensable element from the target to the source.

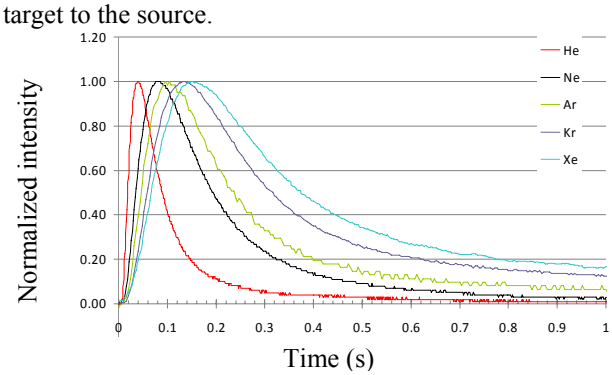

Figure 5: Time responses (s) of the TISS for He, Ne, Ar, Kr and Xe injected through the target. The target was the largest one, including 19 cylinders of 80 carbon pills each.

We recorded the response time of the atom-to-ion transformation for different gases in the same working

conditions of the source, as gases were simultaneously injected (Fig. 5). The response time increases with the mass of the gas.

This effect is mainly attributed to the effusion of the atom in the whole cavity of the TISS, and should then depend on the square root of the mass of the element considered

If the time scale of each response is compressed according to the ratio $\sqrt{M_{He}/M_X}$ (where M_X corresponds to the mass of the gas X and M_{He} is the mass of He), the different responses should be identical if only effusion governed the time responses. In fact, within this compressed scale representation, the time response decreases with the mass of the element (Fig. 6).

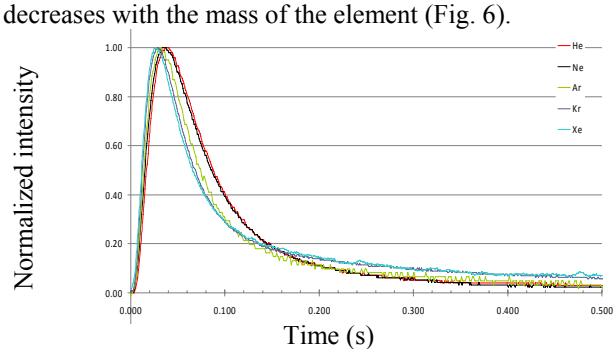

Figure 6: time responses of the TISS after time scale transformation. Injection has by the target (VP target).

To understand it, measurements were performed with injection of gas directly in the source (VP source). After time scale transformation (Fig.7), the result show is due to the first ionization potential which decreases with the mass and leads to ionization rates higher for heavier elements. In case of radioactive isotopes, this observation is of first interest since the global atom-to-ion transformation process of heavier elements will be shortened by ionization efficiency, increasing the ion production rate.

The contribution of this effect to the reduction of the global response time is relatively small (some tens or hundreds of ms) compared to the effusion time of the isotopes out of the target labyrinth (Fig. 5). But in case of short lived isotopes, the size of the target could be reduced to limit the inner-target effusion time.

TECHNICAL FEEDBACK

The TISS has been designed to withstand the dose around the UC target. Materials are only non-magnetic metals and mineral insulators. The TISS being installed under vacuum, the mechanical precision between the parts is sufficient to insure the tightness.

After several weeks of operation with a carbon target in its vicinity, the ECRIS still works but the total operation time has not been precisely measured. A layer of carbon appears on the wall of the plasma chamber but its thickness must be very low since the color of the wall metal is still visible. The carbon deposition is an important concern especially for RF window: if covered by carbon, the RF power will be reflected, and the window will be destroyed by temperature increase.

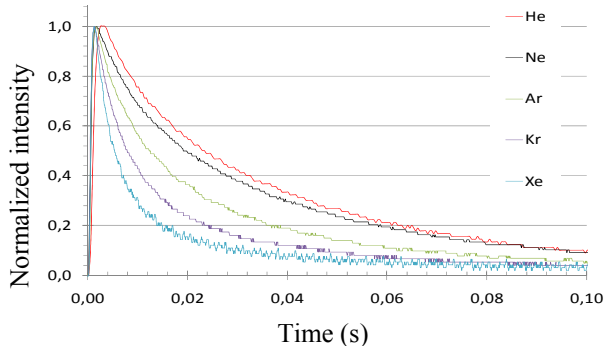

Figure 7: Time responses of the source for He, Ne, Ar, Kr and Xe in the same plasma conditions, after time scale transformation. Injection of gas in the source (VP source).

The carbon in the ECRIS comes from the target and its oven, which includes several parts in graphite. When the target is at high temperature, the carbon reacts with oxygen coming from the outgassing and is transported up to the source as CO or CO2 molecules, which are present in the source spectrum (Fig. 2, right part).

When the outgassing is less important, the presence of oxygen decreases and the carbon disappears from the spectrum. The system has then to be well outgassed before operation to avoid carbon concerns.

REFERENCES

[1] M. Lewitowicz, 'The SPIRAL 2 Project', Nuclear Physics A, Volume 805, Issues 1-4, 2008

[2] N.Lecesne et al., 'GISELE: A resonant ionization laser ion source for the production of radioactive ions at GANIL', Rev. Sci. Instrum. 81, 02A910 (2010)

[3] A. Pichard at al., 'Development of a surface ionization source for the SPIRAL 2 project', Rev. Sci. Instrum. 81, 02A908 (2010)

[4] C. Huet-Equilbec et al., 'MONOBOB: A radiation-hard and efficient 2.45-GHz ECRIS dedicated to radioactive ion production', Nucl. Instr. and Meth. in Phys. Res. B 240 (2005) 752–761

[5] Cime Working Diagram, 'http://pro.ganil-spiral2.eu/users-guide/accelerators/spiral-beams'

[6] T. Lamy et al., 'Charge breeding method results with the phoenix booster ECR ion source', Proceedings of EPAC 2002, Paris, France