ECR Group Activity Report

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INTRODUCTION

The activity of the ECR group in 2011 was mainly devoted to the development of new metallic ion beams and the delivery of beams for the PIAVE-ALPI complex to perform nuclear physics experiments. A new technique to produce metallic beams by sputtering was explored and some preliminary results will be described. Nuclear physics experiments with a $^{136}$Xe$^{3+}$ beam were successfully performed showing excellent stability of the ion source over a long period of time. In 2011 INFN and in particular of the LNL/LNS ECR group have joined the European project EMLIE (Enhanced Multi-Ionization of short-Lived Isotopes at EURISOL). EMLIE was approved by NuPNETT and aims at improving the performance of the ECR-based charge breeder ‘PHOENIX’, installed at LPSC (Grenoble), that will be used in the SPES project for post-acceleration of radioactive beams. The project was approved in the EURISOL framework.

BEAM DEVELOPMENTS AND EXPERIMENTS

Since the ion source LEGIS was put into operation [1], several metallic species were tested using either the method of the resistive oven or the sputtering one [2,3]. Unfortunately, the sputtering yield with the LEGIS source is not so high and this prevented us from producing beams of Zr and Mo, due to the huge number of isotopes in a natural abundance sample that lowers the measurable current of the selected A and A/q. Moreover, these elements are always in powder form when an enriched isotope is requested, adding difficulty in the preparation of a proper sputtering target. For what concerns Mo, we overcame this difficulty by using a compound, MoO₃, which is highly volatile and which can be evaporated by our resistive oven. Preliminary tests were performed in November: the source easily produced currents higher than 2 μA in the M/q range between 4 and 5; a spectrum acquired during the tests is shown in figure 1.

The extracted current showed a very low ripple but a slow oscillation of the intensity, with time of ±50% impeded us to let this beam be available for experiments. This was probably due to bad thermal stability of the oven, worsened by the additional heat load given by the plasma. Further tests are needed and will be performed in 2012. About the Zr, we tried to develop a new method to produce a sputtering target starting from an element in powder form. The idea was the following: first of all, we melt the powder by electron bombardment in a properly shaped graphite container, then we put some aluminum slices on top of it in the same crucible and let them melt.

In this way, after cooling the sample, we obtain a single piece having on the front side a layer of the element to be sputtered and on the rear one an aluminum layer to be drilled and screwed to the sputtering rod. The element chosen for the first tests was Si, because already available in powder form and almost monoisotopic. A description of the method is shown in figure 2.

However, although the sample production was successful, the tests with the source revealed some drawbacks of this technique: first of all, Si is not the best element to be sputtered, because it is a semiconductor with a low sputtering yield for any kind of incident particle; moreover, it was not possible to screw properly the sample to the water cooled sputtering rod in order to have a good thermal contact and the two layers of different material separated during an experiment. Further tests, with a different element, are necessary to verify the usefulness of this method.

Another development regarded the production of Calcium from the LEGIS source. Calcium beams are often
requested by the nuclear physics community, especially the rather expensive isotope of mass 48. This beam is already being produced at LNL with the negative ion source but, due to the difficulty of producing negative ions of Ca because of its very low electron affinity, the current delivered to the experiment is usually rather low. In order to be competitive, the Calcium beam extracted with the LEGIS source and accelerated with the PIAVE-ALPI complex with charge state 11+ should be quite intense (up to 10 pnA at the experiment) keeping consumption rate within reasonable values. Following the experience of the Ions Source Group at GSI, we decided to adopt the technique of the tantalum liner. The liner consists of a very thin tantalum cylinder mounted inside the plasma chamber by means of two supports that avoid any thermal contact with the cooling circuit. Scope of this technique is to let the liner being heated by microwaves and plasma, so that it reaches high temperature (500-600 °C) and prevents the sticking of the metallic vapor not captured by the plasma on the source walls and its resulting loss. This will allow not only a stable production of a Calcium beam but also a drastic reduction of the consumption rate. Figure 3 shows a sketch of the liner mounted inside the LEGIS plasma chamber. The liner was machined and will be tested in 2012.

The months of July and October were dedicated to the nuclear physics experiments with $^{136}$Xe$^{20+}$: a current close to 1 μA was produced by applying the so called “frequency tuning” and was kept constant for a long period, injecting an intense and stable beam in the PIAVE-ALPI complex. A spectrum acquired at the end of the experimental campaign is showed in figure 4.

**THE EMILIE PROJECT**

As the most advanced concept of ISOL facility, EURISOL aims at producing unprecedented intensities of post accelerated radioactive isotopes. The charge breeding technique [4], which transforms the charge state of radioactive beams from 1+ to an n+ charge state prior to post-acceleration, is a key technology which has to overcome the following challenges: high charge states for high energies, efficiency, rapidity and purity. During FP6 the two techniques of ECR and EBIS charge breeding were compared and were found to be complementary. However they still require dedicated R&D: ECRIS are able to charge breed at a high rate ($\gg 10^{10}$ pps) for moderate charge states, but suffer of low efficiency for condensable elements.

![Image](image_url)

**Fig. 4. Xenon spectrum acquired at the end of the experimental campaign.**

On the other hand, EBIS sources provide high charge states, but they are limited by their low rate ($< 10^{10}$ pps) and they can work only in pulsed mode. The EMILIE [5] project, approved before summer 2011, foresees the involvement of different European countries and includes three Work Packages (WP): to INFN the WP of Deputy Coordinator of the project is assigned as well as that of leader of WP3, concerning the improvement of the performance of the ECR-based charge breeder ‘PHOENIX’, installed at LPSC. The activity of INFN will concern two important issues: the optimization of the microwave coupling to the PHOENIX charge breeder and the numerical studies of the capture of the 1+ beam by the ECR plasma. The first issue will help in improving the power transfer to the ECR plasma, allowing a faster ionization rate and a much more stable operation; the second issue will help in understanding the physics behind the capture process, allowing the improvement of the breeding efficiency for condensable elements that is widely known to be low (30% total) except for recent promising results obtained at Argonne National Laboratory.

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