On Line Isotopic Separator Test Benches at GANIL

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Abstract

A first version of isotopic separator on line test bench has been built in order to test the feasibility of the production of radioactive species from 96 MeV/u of ^{20}Ne impinging a thick target of MgO.This test bench was equipped with a very compact ECR ion source (Nanogan) entirely made from permanent magnets and operating at 10 Ghz.

We succeeded in producing and ionizing $^{18}Ne^{2,4+}$; $^{19}Ne^{1,2,3,4+}$ and $^{23,24}Ne^{1+}$.

We then decided to build a new more performing separator (SIRa) allowing the use of different types of ion sources. It will be completed by the end of 1993.

I. INTRODUCTION

From the first experiments at GANIL, fragmentation reactions have been used to produce and study exotic nuclei. Such a research made use of the large intensities obtained through the whole accelerator system. It was realized that these beams could also be used to produce nuclei at rest in thick targets and to adapt the ISOL method to primary heavy ion beams.

This program is now under consideration with the project of a RIB facility (SPIRaL project [1]).

An important R&D program has been implemented from mid 1991 to investigate the use of high energy ion beams provided by the GANIL facility to produce radioactive atoms by the ISOL method.

We present the first version of isotopic separator and the results we got with it in 1992. We are now building a new isotopic separator called SIRa (Séparateur d'Ions Radioactifs) which is therafter described.

II. THE FIRST ON-LINE SEPARATOR

The challenge is to continuously separate the producted nuclei from a huge amount of target nuclei and transfer them into the gas phase to the plasma of a ECR ion source. Such a transfer process is only governed by element specific diffusion, desorption ans chemical processes.

A - The target box

The target box, the same as the one constructed by the ISOCELE group at Orsay [2], has been connected to a new compact ECR ion source specially designed for that purpose[3]. Fig.1 shows a schematic cut of the target chamber and and its coupling to the source. The target is mounted on the rear flange of the target box and placed in a nickel container.

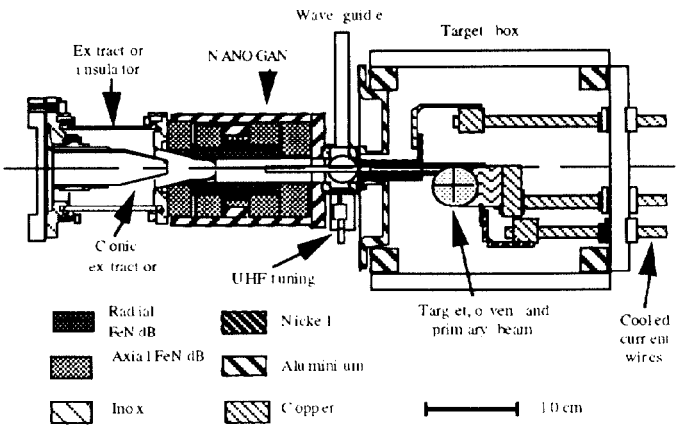

Figure 1. Cut of the target-ECRIS system.

The container is a 7.5 cm long cylinder heated by ohmic power up to 1200°C maximum. It is put at the source potential (15 to 20 kV). The transfer tube (25 cm long, 5mm inner diameter), also made of Ni, is welded on the container and inserted into the inner copper tube of the source.

B - The Nanogan source

The ionizer is a very compact ECR ion source (called Nanogan), entirely made of Fe.Nd.B permanent magnets for both radial and axial magnetic confinement. Its dimensions are 17 cm long and 13 cm diameter. This ECR ion source needs a rather small amount of microwave power:< 100W at 10 GHz.

C - The separator

Due to the short requested duration of realization and the limited budget alloted, the separator has simply been made up of available components : a 102° bending magnet (acceptance figure 150 π.mm.mrad), allowing a maximum mass resolution of 10^{-2}, a diagnostic box (with horizontal slits and beam profile monitor) followed by two electrostatic quadrupole doublets.

D - The detection system

The collection chamber at the end of the separator beam line is equipped with a Faraday cup and the tape transport system coming from ISOCELE experiment [2]. It is operated in primary vacuum, except for the collection point placed in secondary vacuum.

The collected ions are periodically moved to one of the two different detector locations. In the first one, two NaI detectors detect in coincidence the two gammas produced by the β^+ annihilation. At the second one, there are a plastic scintillator and a Ge detector.

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III - RESULTS AND DISCUSSION

Table 1 gives the measured parameters of different isotopes detected.

As predicted "light" Neon (^{19}Ne, ^{18}Ne) coming from projectile fragmentation process together with "heavy" Neon (^{23}Ne, ^{24}Ne) coming from target fragmentation have been observed. Charge states higher than 1^+ have been obtained (Ne $^{3+}$, Ne $^{4+}$) which corresponds to suitable Q/A values for postacceleration in the cyclotron of the SPIRaL project.

The last column but one of table 1 gives the production yield corrected from transmission and ionization efficiencies in order to compare real and calculated values.

This table shows also the rather poor transmission factor of this separator since the overall efficiency was only around 3,5 %. Nevertheless, tests made off-line with Nanogan operated with stable ions and calibrated leak have shown that a total ionization efficiency of 40 % was obtained in real experimental conditions.

	Separator		ECR I. S.		Target	
	Yield meas. pps/pμA	Trans. eff. %	Yield extract. pps/pμA	Ion. eff. %	Yield prod. pps/pμA	Yield Calc. pps/pμA
^{19}Ne^{1+}	4.8 10^7	3.5	1.4 10^9	25	5.6 10^9	
^{19}Ne^{2+}	8.9 10^6	3.5	2.5 10^8	7.5	3.3 10^9	
^{19}Ne^{3+}	1.6 10^6	3.5	4.6 10^7	4	1.2 10^9	
			Σ1.7 10^9	40	4.3 10^9	1.3 10^{10}
^{18}Ne^{2+}	1.9 10^6	3.5	5.4 10^7	7.5	7.2 10^8	
^{18}Ne^{4+}	1.9 10^5	3.5	5.4 10^6	3.5	1.5 10^8	
			*Σ2.7 10^8	40	6.8 10^8	2.7 10^9
^{23}Ne^{1+}	6.3 10^5	3.5	1.8 10^7	25	7.2 10^7	5.0 10^8
^{23}Ne^{1+}	1.5 10^5	3.5	4.3 10^6	25	1.7 10^7	1.0 10^8
^{13}N^{1+}	3.8 10^5	3.5	1.1 10^7	1(?)	1.1 10^9	1.5 10^9

Table 1. Experimental results for on line isotope production with ^{20}Ne primary beam at 95 MeV/u on a MgO thick target. (*)Assum. $I_{Ne^{1+}}$=4 x $I_{Ne^{2+}}$ and $I_{Ne^{2+}}$=2x$I_{Ne^{3+}}$ like ^{19}Ne.

The first version of separator has been useful for bringing out unacceptable drawbacks :

- the optics of the primary beam was not well under control (non achromatic focusing point),
- the detection system, located inside the experimental room, was not enough shielded from background noise and slow neutrons. As a consequence, the primary beam had to be pulsed which resulted in strong pressure variations in the source,
- the overall separator performance (resolution and transmission efficiency) was rather poor and not enough well controlled.

IV. THE NEW SEPARATOR

From 1992, September, a new separator called SIRa (Séparateur d'Ions Radioactifs) is under construction, according to the following specifications :

- the target will be put at the normal focusing point in the experimental room (achromatic point) ;
- the secondary beam line will be more sophisticated in order to have the possibility of creating an object point upstream the 90° dipole magnet, whatever the type of source in operation ;
- the collection point as well as the detectors will be installed outside of the room and concrete blocks added so as to strongly damp the background noise.

A - Target box

A new target box is under design An internal mecanism will automatically withdraw the transfer tube from the ECR source so as to shut 3 insulating vacuum valves (contamination problem). So the used target will be kept under vacuum in a confined volume, easy to be handled.

B - The source

A new source, called Supernanogan, is under study.. Its commissioning is expected in mid 1994. That is why the first ECR source of SIRa will be a classical one (Caprice type 10 GHz), already available at GANIL.

V. BEAM OPTICS OF SIRa

A. Primary beam

The beam radius on the target (T on figure 2) can be varied from 4 to 15 mm (for emittances ranging from 2.5 to 6π.mm.mrad) by means of a magnetic quadruplet. 2 steerers, 2 beam profile monitors (1 behind the quadruplet, 1 in front of the target) and a Faraday cup allow to adjust the beam on the target.

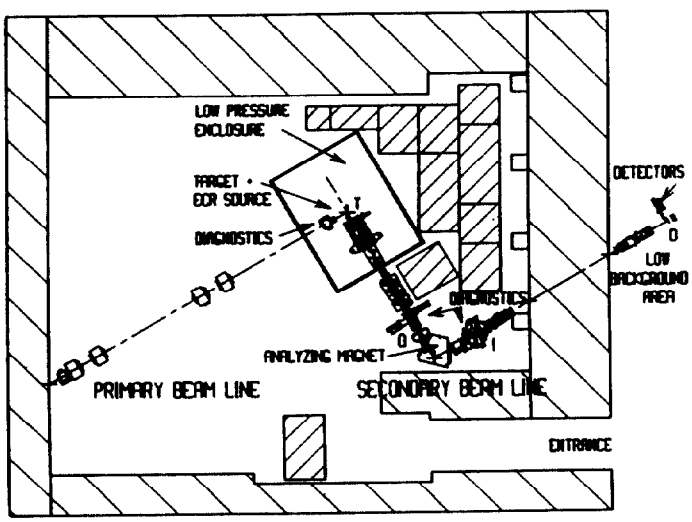

Figure 2. Layout of SIRa

B. Isotopic separator

The on-line isotopic separator follows the ECRIS ; it can be divided into two parts:

. A matching section composed of a solenoid and a magnetic triplet to focus the beam at the object point 0 of the analyzing magnet. For an emittance of 150 πmm.mrad (corresponding to the acceptance) and beam dimensions of ± 3 mm at the source puller the radial size at 0 can be adjusted between ± 1.5 and ± 10 mm. The type of source can easily be

changed -provided that the solenoid remains close to it- by adjusting the distance between the solenoid and the triplet.

The maximum rigidity of the line of 0.136 T.m corresponds to the maximum field of the existing dipole.

The characteristics of the elements are :

- Solenoids : max field = 6800 G, magnetic length = 400 mm, bore diameter = 70 mm.
- Quadrupoles (which provide in addition a dipolar component for a steering purpose) : max gradient 3.5 T.m, magnetic length = 210 mm, bore diameter = 80 mm.

. An analyzing section composed of:

- A 90° double focusing dipole (max field = 3400 G,, radius of curvature = 400 mm, gap height = 70 mm, max radial extent in the vacuum chamber = ± 120 mm, pole face rotation 27°, tilt of the focal plane with respect to the axis 27°).
- A sextupole (max field = 700 G, magnetic length 170 mm, bore diameter = 140 mm) is placed 230 mm in front of the dipole entrance to correct geometrical aberrations.

The calculated mass resolution is 4 10^{-3} for an emittance of 80 πmm.mrad (see figure 3) : the ZGOUBI code (4) was run with 200 particles uniformely filling a 4D hyperellipsoid ; a measured field map is used. A better resolution can be obtained by achieving a lower radial angle matching and then cutting with the slits located at 0. Vertical slits, as well as radial ones, can be used for stopping unwanted charge states.

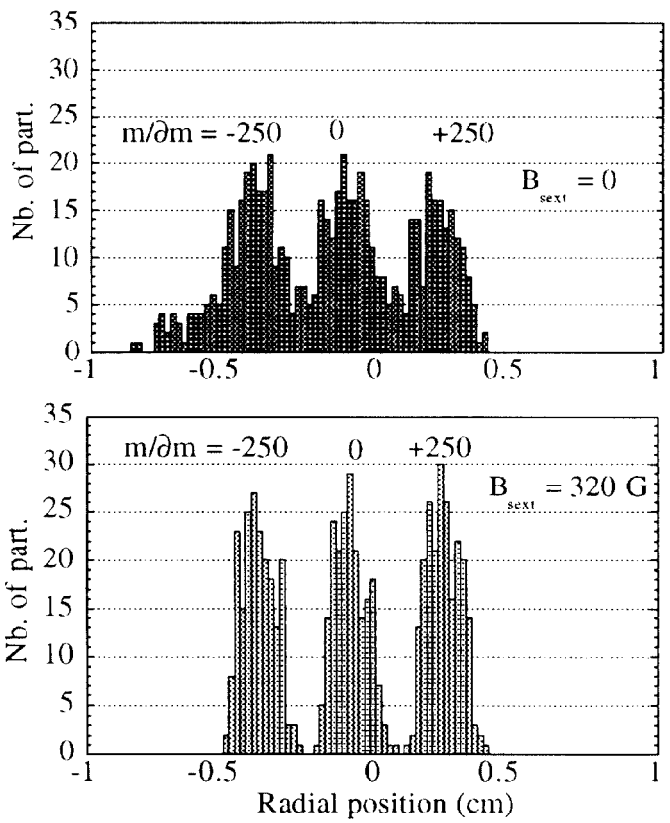

Figure 3. Mass resolution without and with sextupole

A special box for diagnostics is placed around the image point I. It contains a vertical wire moving parallel to the focal plane, 2 radial slits moving in the plane, a beam profile monitor and a faraday cup. The tilt of the first 3 diagnostics can be manually adjusted.

Transport to the detector:

A set of electrostatic quadrupole doublet and triplet is used to transport the whole emittance on the detector D located in a very low background area. The beam diameter at D is 10 mm. Since there is independant power supply per electrode for each quadrupole, horizontal and vertical steering can be achieved. The quadrupole characteristics are : max voltage = 2.5 kV,

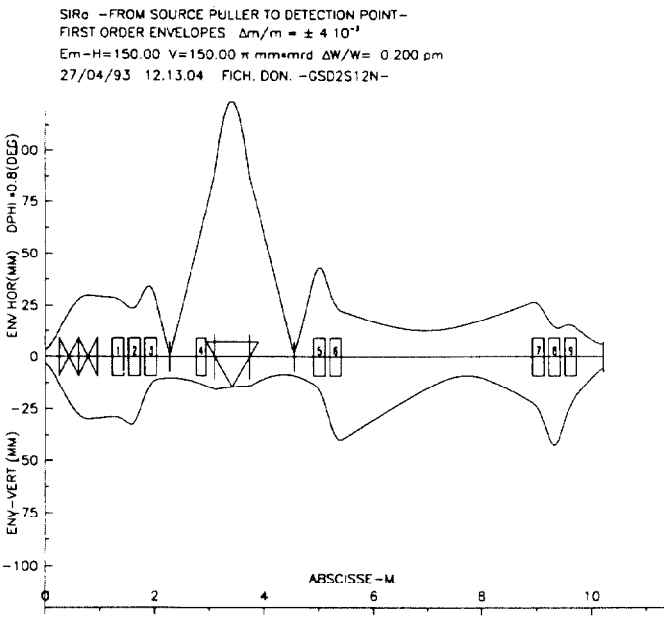

Figure 4. Beam envelopes from source to detector

VI. CONCLUSION

The first version of separator has allowed to establish the basic feasibility of the "ECR Source-close-to-target" concept for efficiently producing high charge state radioactive ions by the ISOL method.

With the new separator SIRa, high charge state and good transfer efficiencies are expected in a first step with gaseous radioactive ions like ^{19}Ne, ^{35}Ar or ^{78}Kr. First tests will take place by the end of this year.

In a second step, alcaline ions like ^{21}Na or ^{25}Na will be progressively tested together with a variety of research studies in the field of radioactive beam production.

VII. REFERENCES

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