THE FIRST TARGET ION SOURCE SYSTEM FOR THE SPIRAL PROJECT: RESULTS OF THE ON LINE TESTS

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The first radioactive ion beams of the SPIRAL facility will be produced by the nuclear reactions of the primary beam on an external target. In a first step, a target ion source system (TISS) has been developped with the goal to produce noble gas radioactive ion beams. This TISS is based on the coupling of a carbon external target with a permanent magnet ECR ion source called NANOGAN 2 and has been tested on the SIRa separator. The target is heated by the primary beam and by an extra ohmic heating up to 2000 K to allow a good diffusion of the radioactive atoms. The atoms are then ionised in the ECR ion source, extracted from the source, selected and driven to a collection point where they are identified. The results of these tests will be presented. A description of the TISS in the production cave will also be done.

Introduction

The radioactive ion beams (RIB) that will be accelerated by the CIME cyclotron will be produced by the interaction of a stable high energy (95 Mev/A) and high intensity (2 10^{13} particle/s) primary ion beam delivered by the GANIL cyclotrons with a target heated up to 2000°C. During this interaction, some radioactive atoms are created and diffuse out of the target before entering into an electron cyclotron resonance ion source where they are ionized and extracted.

1 Description of the target.

In a first step the SPIRAL project will deliver ion beams of radioactive noble gases produced by projectile fragmentation. This production mechanism needs the use of low Z material for the target that allows a long range and gives a reasonable production yield. However, the use of this mechanism implies to stop all the primary beam inside the target. The power deposition in this case is very inhomogenous and presents a sharp Bragg peak that can burn the target. These two reasons made graphite as a good candidate for the target material.

To solve the problem temperature, a theoretical code[1] has been developped that calculates the temperature in each point of the target taking into account the radiation of the different parts and the conduction in all directions.

Figure 1 shows a simulation made with a 2 kW Ar primary beam. The conical shape of the target (see figure 2) has been done in order to increase the stopping area of the primary beam and by this way to decrease the power density deposited inside the target. An extra heating can eventually be added in the case of a decrease of the primary beam intensity. Two configurations have been studied for this extra heating. The first one is dedicated to the experiments made on the SIRa test bench where the primary beam power is limited to 400 W while the second one has been developped for SPIRAL where the primary beam power will reach 6 kW.

In the first case, an ohmic heating is added arround the target with reflectors and allows to heat the target up to 2000°C with 2 kW of ohmic power.

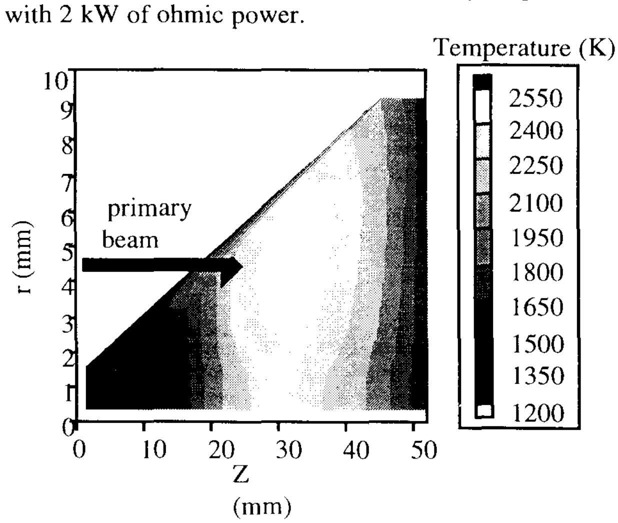

Figure 1: temperature distribution of a carbon target heated by a 2 kW Argon primary beam.

In the second case, the reflectors have to be removed when the 6 kW primary beam is on the target and the target diameter has to be increased to avoid the evaporation of the graphite. In this case a surrounding ohmic heating leads to an excessive electrical power consumption. In order to decrease this power consumption, the current will be feed through the axis of the target.This configuration has been successfully tested under 6 kW of a 30 MeV proton beam at Louvain La Neuve(1).

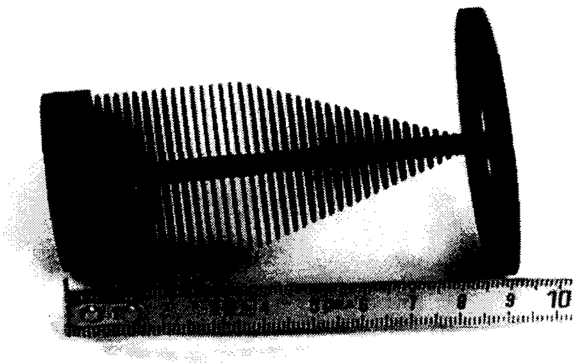

Figure 2: picture of the conical sliced target used during the Louvain la Neuve tests.

2 Description of the ion source.

The target is coupled via a transfer tube with a totally permanent magnet ECR ion source(2), called Nanogan II (see figure 3). This compact source has been designed with two goals in mind. The first one is to produce the same ionisation efficiency than the other classical ECR ion sources. The second one is to minimize the size of the target ion source system in order to decrease the volume of the lead container in which the system will be stored after irradiation and to simplify the connection-deconnection operations.

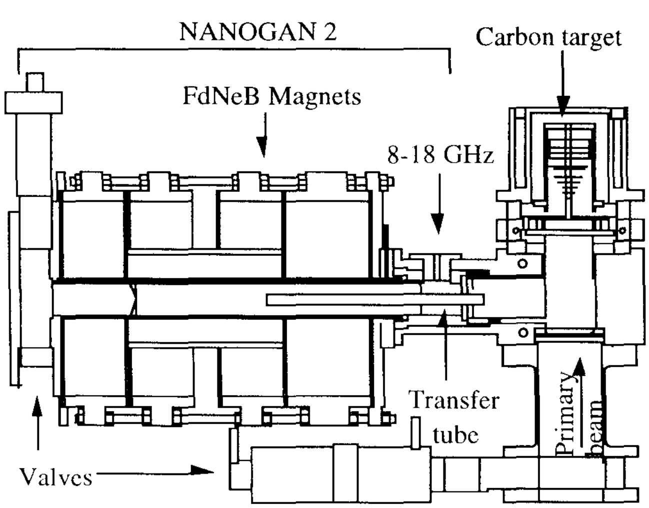

Figure 3: Schematic drawing of the first target ion source source system for the spiral project.

The axial magnetic field profile is shown on figure 4 where a relative ratio Bmax/Bmin of 2.36 is obtained. The radial confinement is assured by an hexapole.
A 8-18 GHz tunable microwave frequency transmitter with a maximum power of 200W available all over the frequency range assures the tuning of the ion source. The UHF is coupled to the source via a coaxial wave guide that is biased to a negative value compared to the source body. The extraction voltage given by the cyclotron parameters is between 7 to 34 kV and the distance between the plasma electrode and the extractor can be optimized without breaking the vacuum.

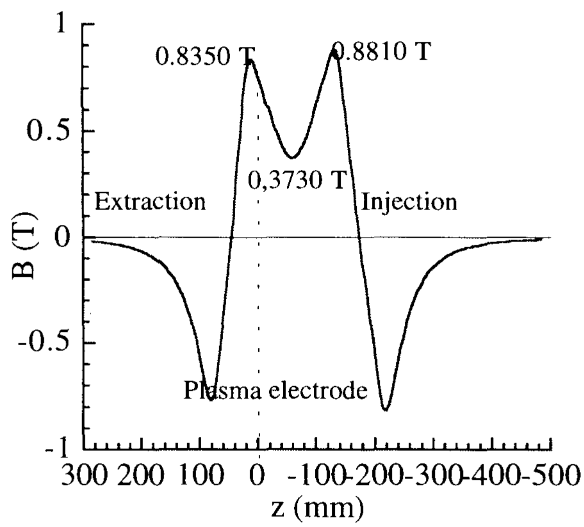

Figure 4: axial magnetic profile of the nanogan 2 ion source.

3 The ion source performances

3 a) off line performances

Figure 5 and 6 show the charge state distribution of Argon and Xenon when the source is optimised to produce Ar^{8+} or Xe^{23+}. In both cases a gas mixing with oxygen is used and the extraction voltage is 19 kV .

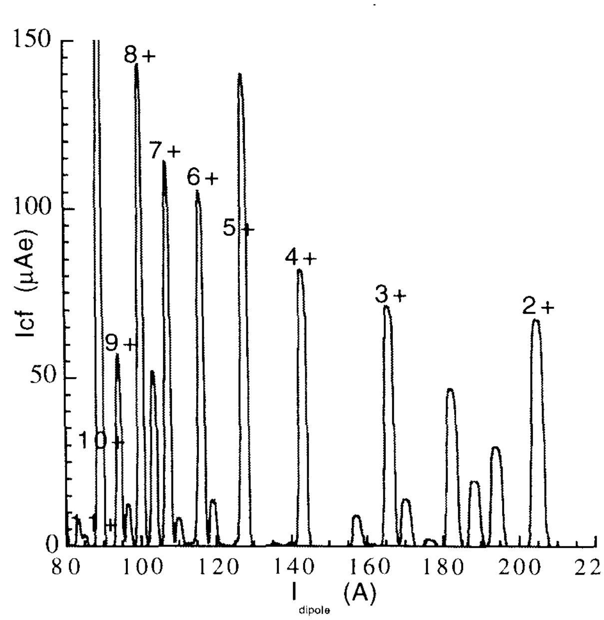

Figure 5: Charge state distribution of argon when the source is optimised to produce Ar^{8+}

The total efficiency has also been measured by injecting the argon gas through a calibrated leak of 7 µAp and by measuring the intensity of each charge state after the dipole to the flux of argon.

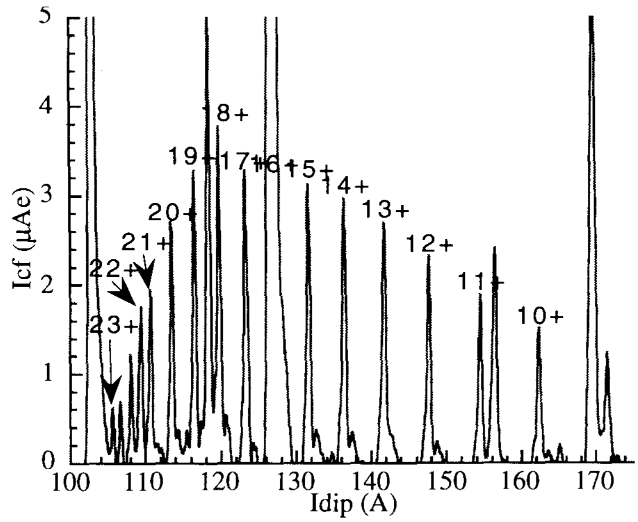

Figure 6: Charge state distribution of xenon when the source is optimised to produce Xe^{23+}

The figure 7 shows the result of this measurement. The transport efficiency is measured by dividing the current delivered by the extraction power supply by the sum of the currents of all peak of the spectrum. The ionisation efficiency can be deduced by dividing the total efficiency by the transport efficiency. An overall efficiency, defined as the sum of each charge state ionisation efficiency, of 100% can be achieved.

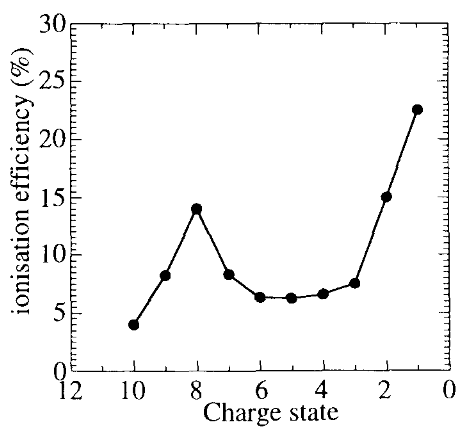

Figure 7: Ionisation efficiency of stable ^{40}Ar on the different charge states.

3 b) on line results

Different tests of the nanogan2 based target ion source system have been made on the SIRa test bench where the primary beam power is limited to 400 W. The first one consisted in measuring the production rate of radioactive isotopes of Kr and Ar by impiging the target with respectively a ^{78}Kr and a ^{36}Ar primary beam. The result of this test is given in table 1 where it can be pointed out that a multicharged $^{31}Ar^{3+}$ ion beam, that presents a very low life time (15 ms) has been produced.

exotic ion beam	primary beam	production rate (pps)
$^{81}Kr^{15+}$ (13.1 s)	$^{78}Kr^{34+}$ 73 A MeV 1.8 10^{11} pps	1.78 10^7
$^{79}Kr^{15+}$ (50.0 s)		4.21 10^7
$^{79m}Kr^{15+}$ (35.04 h)		2.21 10^8
$^{77}Kr^{15+}$ (74.4 mn)		6.76 10^8
$^{76}Kr^{15+}$ (14.8 h)		7.65 10^7
$^{75}Kr^{15+}$ (4.3 mn)		1.94 10^7
$^{74}Kr^{15+}$ (11.5 mn)		3.17 10^6
$^{73}Kr^{15+}$ (27.0 s)		4.49 10^4
$^{72}Kr^{15+}$ (12.7 s)		2.38 10^3
$^{35}Ar^{8+}$ (1.775 s)	$^{36}Ar^{18+}$ 95 A MeV 7 10^{11} pps	3.02 10^8
$^{34}Ar^{7+}$ (844 ms)		7.68 10^6
$^{33}Ar^{8+}$ (173 ms)		1.62 10^5
$^{32}Ar^{7+}$ (98 ms)		1.00 10^3
$^{31}Ar^{3+}$ (15 ms)		15

Table 1: Production rates of radioactive isotopes of Krypton and Argon with the nanogan2 based target ion source system.

The second test consisted in measuring the charge state distribution of a short life time element and to compare it with the stable isotope distribution. Figure 8 gives the comparison of ^{31}Ar charge state distribution with the ^{40}Ar distribution. It can be seen that there is no difference between the stable and the radioactive element. This result proves that the source was not perturbated during the production and that the time needed to ionize the high charge state is lower than the half time of ^{31}Ar (15 ms).

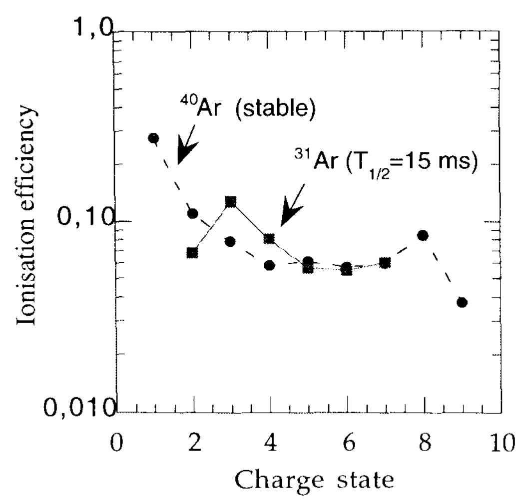

Figure 8: Comparison of ^{31}Ar charge state distribution with the ^{40}Ar distribution.

References

1) R. Lichtenthäler et al, to be published in NIM B

2) L. Maunoury et al, Proc. of the 13th International workshop on ECR Ion Sources, 26-28 February 1997, College Station, Texas, USA.