# Latest Developments on Multicharged E.C.R. Ion Sources at GANIL

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## *Abstract*

Since now ten years, the field of multicharged ECR ion source shows a continuous development in order to improve performances, technology and reliability of sources. A review of the very last developments made at GANIL and useful for accelerator applications is given. A new method of source tuning, called afterglow tuning, for the production of pulsed currents begins to be operational on the copy of ECR4 source for its application on CERN accelerators. A new type of multicharged ECR ion source, called NANOGAN made entirely with permanent magnets is presented. Very first results of multicharged stable and radioactive ion production are also reported.

## 1. INTRODUCTION

Multicharged ECR ion sources are now well-known for their applications to cyclotron injection or low energy beams for atomic physics[1]. These ion sources have shown a very good long term stability for the production of continuous beams. After the realization of sources like MINIMAFIOS 16 GHz [2] or CAPRICE [3] where the role of frequency and magnetic field has been shown, the realization of a superconducting ECR is a logical development in order to produce highly charged ions[4]. However in the same time the necessity of simplifying the technological structure has induced the realization of the first ECRIS made entirely with permanent magnets: NEOMAFIOS [5]. Recent developments like the use of electron gun [6][7] or polarized probes [8][9] have shown that it is possible to improve ECRIS performances without changing the global structure of the source but the reliability of such system remains to be demonstrated. With the technological improvements of ECRIS, their applications on high voltage platforms [10][11] or on line isotopic separator [12][13] are now possible. This paper will give a more exhaustive description of recent developments on the pulsed operating mode and the new compact ECRIS made entirely with permanent magnets, NANOGAN operating at 10 GHz.

## 2. PULSED OPERATION WITH ECR4 14.5 GHz

ECR ion sources can produce C.W. current but at the same time and without any physical modification they can be tuned to produce short pulses of intensity much higher than during the C.W. tuning and called "afterglow pulsed currents". This phenomenon can be understood as a plasma potential disruption inducing a rapid diffusion of highly charged ions of the plasma[14]. With the realization of a copy of the ECR4 14.5 GHz source from GANIL for its application on the CERN Lead injector[15], it is now possible to study the beam characteristics of the afterglow currents. Figures 1 and 3 show the time dependence of typical afterglow and UHF power pulses for $Ar^{13+}$ ions.

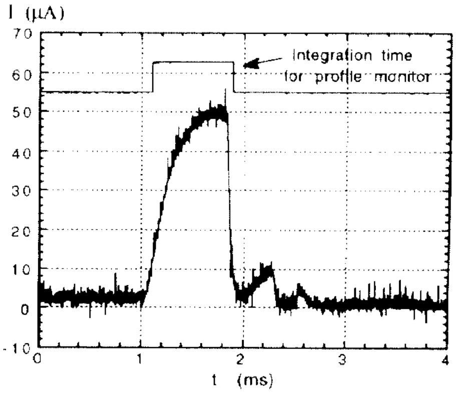

Figure 1. Afterglow peak current for $Ar^{13+}$

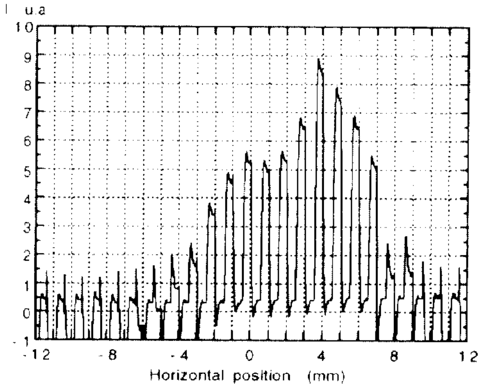

Figure 2. Beam profile during the afterglow for $Ar^{13+}$

The synchronization signal (figures 1 and 3) is used as integration time for profile monitor so figures 2 and 4 show the beam profile for one pulse respectively during the afterglow and the UHF power pulse. The observation of a classical ECRIS beam profile during the afterglow shows that this current is useful for accelerator applications. The horizontal profile during the afterglow seems slightly different than during the steady state. The optical characteristics or the beam energy may be modified during the afterglow due to a plasma sheath potential perturbation which induces the horizontal shift observed between figures 2 and 4. We plan now to install a rapid pulsed high voltage generator on the beam line in order to make precise emittance measurements with an arbitrary time integration window.

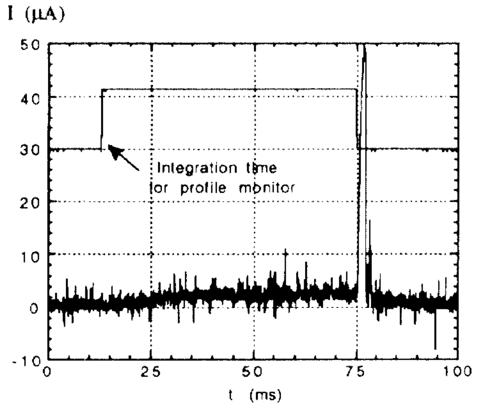

Figure 3. Beam current during the UHF pulse for $Ar^{13+}$

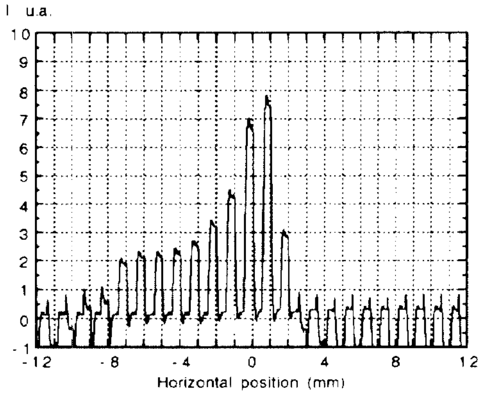

Figure 4. Beam profile during the UHF pulse for $Ar^{13+}$

## 3. NANOGAN 10 GHz : A MULTI-PURPOSE MULTICHARGED ECR ION SOURCE

### *3.1 General characteristics*

With the demand for production of radioactive species and the perspective of their post-acceleration, at high energy, GANIL decided to build a new small and purely permanent magnet ECRIS just in order to test the possibility of production of multicharged radioactive ions. This source, called NANOGAN, is made of FeNdB permanent magnets. This device is associated to a nuclear physics experiment intended to determine production rates of radioactive isotopes produced with a high energy heavy ion beam (up to 100 MeV/A). The choice of an ECR device is due to the very good gas efficiency of this kind of ion source associated to the production of multicharged ions [16]. Another important property is the production of "metallic" species without any fundamental limitation[17].

The design of the as small as possible ECRIS is made in order to minimize the distance between the target production and the ionization volume and also to simplify the technical implantation near the highly radioactive target. The outer diameter of the source is only 13 cm, the plasma chamber has a diameter of 30 mm and the distance between the resonance zone and the target is typically 10 cm. The axial mirror magnetic field is created with several slices of UGISTAB 300H FeNdB permanent magnets and the minimum |B| magnetic structure shows magnetic values very similar to the ECR3/CAPRICE ones [18]. The UHF coupling system is a rectangular to coaxial wave guide transition, like on CAPRICE or ECR4 14.5 GHz [19][20], but smaller and no pump is necessary so the total weight of the source is typically 10 Kg.

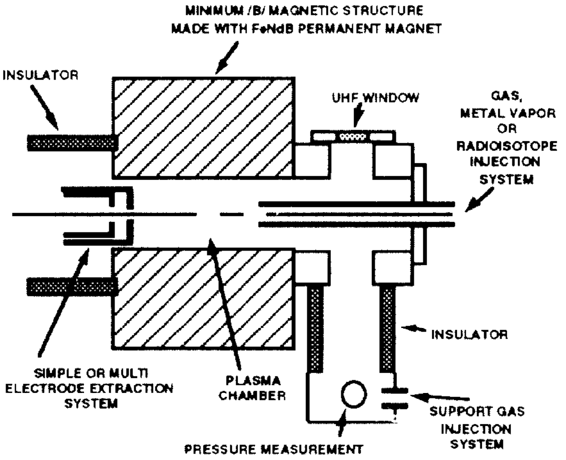

Figure 5. Nanogan 10 GHz schematic drawing

The NANOGAN project at GANIL began in April 1991, the assembly of the source has been made in December 1991 and the first beam was produced in January 1992. Figures 6 and 7 show very preliminary results obtained with Nanogan during its two first weeks of functioning. The production of typical ECRIS spectrums of multicharged ions shows that Nanogan is a simple, easy to run and reliable ion source. The typical UHF power consumption is 70 W. A power of 25 to 50 W is enough for producing low charge states like $Ar^{1+}$ to $Ar^{4+}$ and 100 W are better for high charge states like $O^{6+}$, $O^{7+}$, $Ar^{8+}$, $Ar^{9+}$ or $Xe^{17+}$. The production of an Ar spectrum where the highest electrical current is obtained on

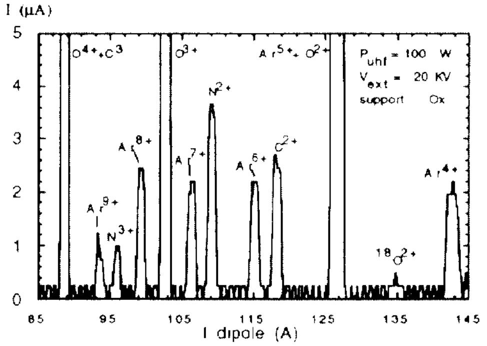

Figure 6. Nanogan 10 GHz:Argon charge state distribution optimized for highly charged ions

the charge $8^+$ (fig. 6) shows that it is possible to maintain a typical ECRIS spectrum even in a much smaller and simplified ion source. With the reduction of the plasma volume by a factor of about 20, it seems that the reduction of the extracted current is the most important effect compared to the weak decrease of the average extracted charge state ($Ar^{6+}$: 22 µAe with Nanogan and 300 µAe with ECR3 /CAPRICE) [19]. Beams of 1.3 mAe of $He^{1+}$ ,0.3 mAe of $N^{2+}$, 60 µAe of $Ar^{4+}$ and 22 µAe of $Ar^{6+}$ were also produced.

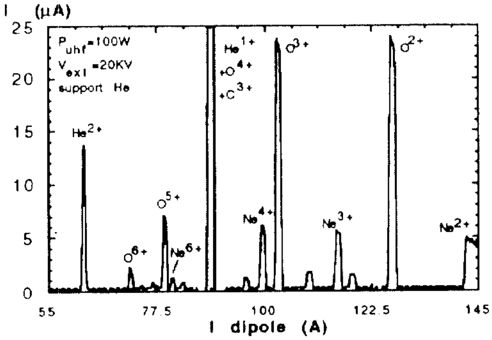

Figure 7. Nanogan 10 GHz:Neon charge state distribution optimized for $Ne^{6+}$.

*3.2 Preliminary on line characteristics*

A first on line experiment with NANOGAN has been performed during March 92 on the new isotopic separator at GANIL [21] (collab. GANIL/IPN ORSAY/CSNSM/LPC CAEN). The primary beam of 20 nAp of $^{20}Ne$ (200 nAe on charge $10^+$) at 96 MeV/A hits a target of sintered MgO of 15 mm in diameter, 20 mm in length, and divided in 30 slices of 0.3 mm in order to increase the outgassing surface. The target has been heated at about 550 °C with an ohmic heating (300A / 1.8V) and the beam power deposition was 40 W. The results of table 1 show very clearly that it is now possible to maintain a typical highly charged ion distribution of an ECR ion source during an on line experiment and that a very minority species of the plasma ($^{19}Ne$) has the same kind of charge state distribution than a most abundant one ($^{20}Ne$ or $^{16}O$, Fig.7). A first estimate gives a beam intensity of $^{19}Ne$, on the nuclear detection device (primary beam 40 nAp), greater than 6 $10^5$ p/s on the charge state $1^+$ and for a beam obtained without any optimization. Beams of $^{13}N$, $^{23}Ne$ and $^{24}Ne$ were also observed.

Table 1
Charge state distribution of stable and radioactive Ne ions obtained with NANOGAN

| | $1^+$ | $2^+$ | $3^+$ | $4^+$ |
|---|---|---|---|---|
| $^{20}Ne$ µAp from Fig. 7 | ≈3.8 | 2.4 | 1.9 | 1.5 |
| $^{19}Ne$ counting rate | 78235 | 63062 | 38982 | 17419 |

## 4. CONCLUSION

These new results associated with new applications of ECR ion sources show that it would be now possible to design new ECR devices especially adapted to pulse operation or highly charge radioactive ion production.

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