INSTALLATION OF ECR2 AT LNS AND PRELIMINARY TESTS

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Abstract

The source ECR2 has been built in 1998 by Pantechnik; it is an ECR4M, modified according to the suggestions of the Ion Source Team of LNS. The main improvements are:

a) a higher magnetic field (up to 1.58 T axial, 1.1 T radial) is used, to operate the source at 14 GHz in High B mode and at 18 GHz with a quite good confinement;
b) two frequency heating can be used, by means of a mixer;
c) an aluminum made plasma chamber is used in place of the stainless steel one;
d) the maximum voltage is 30 kV.

The main features of ECR2 along with a review of the preliminary tests will be outlined.
The installation of the source at LNS has been completed recently and some details will be given.

1 THE SOURCE DESCRIPTION

The source ECR2 is the latter upgraded model of the well-known CAPRICE ECR ion source [1] which evolution throughout the years have marked the development of the ECR sources, with different versions, CAPRICE 14 GHz at Grenoble [2], ECR4-M at GANIL [3], Hypernanogan at Manne Siegbahn Laboratory, built by Pantechnik.
With respect to these sources, ECR2 has some major improvements, as described in the abstract: in particular, the Al chamber, which has been used during the acceptance tests, has significantly increased the currents, as observed in other laboratories [4,5].

Operating frequency	14 and 18 GHz
Maximum radial field on the wall	1.1 T
Maximum axial field	1.25 T (for 14 GHz)
at injection	1.58 T (for 18 GHz)
Maximum axial field	1.0 T (for 14 GHz)
at extraction	1.35 T (for 18 GHz)
Minimum axial field	0.4 T (for 14 GHz)
	0.5 T (for 18 GHz)
Coils supply	Two 1300 A – 60 V
Hexapole	NdFeB made
Extraction system	Accel-decel,
	35 kV/12 kV max
Plasma chamber	St. steel or Al made

Tab. 1 – Design parameters of LNS-ECR2.

The three-electrode extraction system has not been used extensively with the plasma during the preliminary tests at LNS, but it is ready to be used, while 18 GHz operations and two-frequency heating can be tested only in the second part of this year. The axial field profile can be scaled with the frequency and the magnets allow operating at 18 GHz with one of the highest confining field yet achieved by conventional ECR ion sources. The maximum field is 1.58 T, as a compromise between the requirements of high axial field for High B mode operations and the maximum power from the supply (which is quite large, about 180 kW). A higher field would have been useful for 18 GHz operations, as observed for SERSE [6], but the requirements in terms of power would have been prohibitive.
In tab. 1 the main parameters of the source are given. Two photos of the source are shown in fig. 1 and 2.

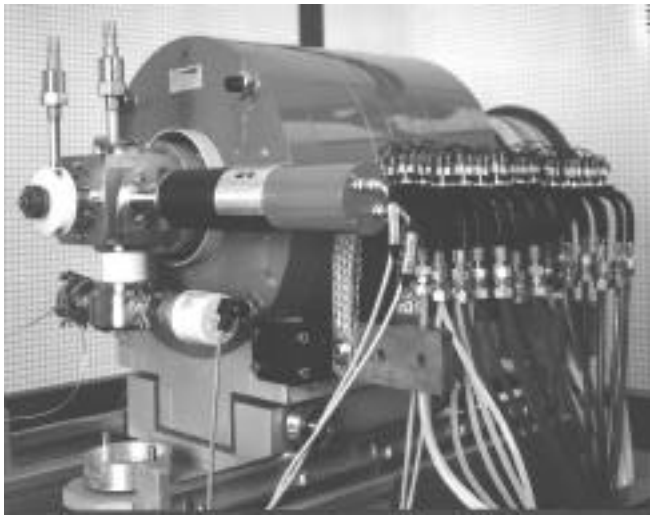

Fig. 1 – The LNS- ECR2 source.

2 THE TESTS AT GANIL TESTBENCH

We carried out on the testbench a first set of tests with stainless steel chamber, for gaseous elements (Ar, O, Kr), and metals, by oven (Ca) or by sputtering (Ta, Ni); the stability over 4 hours was measured for Ta and Ni and emittance measurement were carried out for Ar, O, Kr and Ta. A second set of tests was carried out with an Aluminum chamber, only with gaseous elements (Ar, O, Ne, ^{15}N)

including some emittance measurements, in presence of a large extracted current.
The optimum magnetic field used for these tests (at 14 GHz) was slightly different for the different ion species, being higher on the injection side, for the highest charge states (about 1.2 T) while at the extraction it was about 0.8 T.

2.1 – Tests with the stainless steel chamber

The tests with Argon were carried out with the goal to achieve currents exceeding 80 eμA of Ar^{11+} and 10 eμA of Ar^{14+}, which are the typical performances of Hypernanogan for routine operations.
These value were obtained after a short optimization and this was really encouraging, being these species considered as reference ions for the production of medium charge states and high charge states respectively.

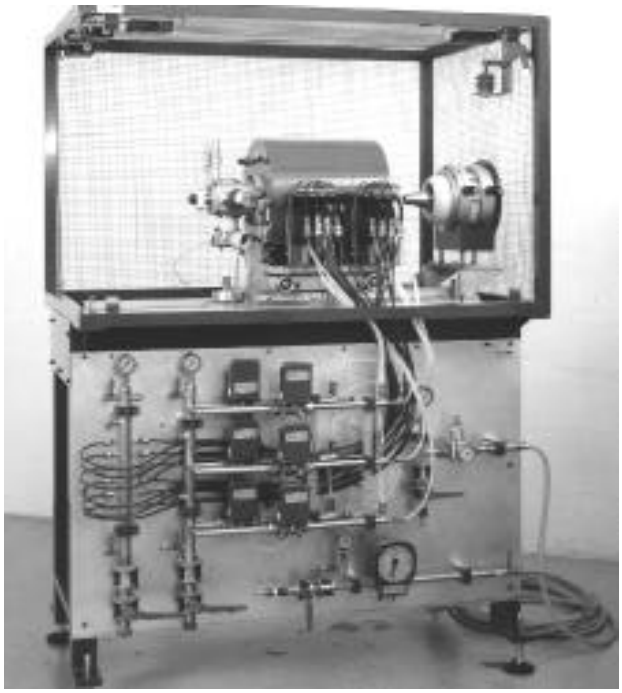

Fig. 2 – The ECR2 source on its support stand.

Similar results were obtained for Oxygen, which currents of 80 eμA for O^{7+} and 530 eμA for O^{6+} were largely above the specifications and close to optimum performance for Caprice-type source. In fig. 3 one of the best charge state distribution for Krypton high charge states is shown; it can be observed that 22 eμA of Kr^{20+} and 10 eμA of Kr^{22+} were produced, that is a relevant result with respect to the other CAPRICE-type sources. Emittance measurements were carried out for O^{7+} and Kr^{22+}, that have given values of ε_{RMS} in the order of 60 to 80 π mm mrad for 90% of the beam in both cases, in good agreement with the results in literature [7,8]. Fig. 4 shows a typical emittance plot for O^{7+}.
The source was opened, in order to insert an oven on axis, able to get a maximum temperature of 1500 °C. It was operational (vacuum was in the mid 10^{-7} mbar) after one night and a stable beam was obtained after six hours of conditioning with plasma. For sake of brevity, tests were carried out only with Calcium ions, for which is quite complicate to obtain a stable oven regime.
The optimization gave stable currents of 30 eμA for Ca^{12+} and 3 eμA for Ca^{14+}. A trial to further enhance the currents of the highest charge states led to values exceeding 50 eμA for Ca^{12+} and 5 eμA for Ca^{14+} but the source was not stable.

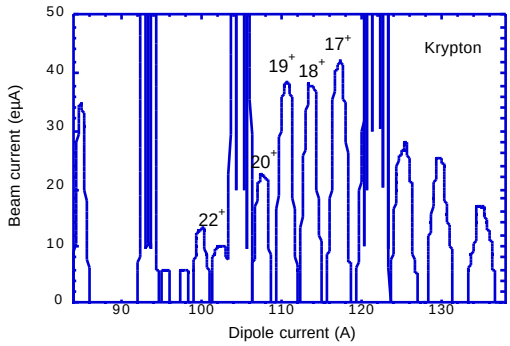

Fig. 3 – A charge state distribution, optimized for Kr^{22+}.

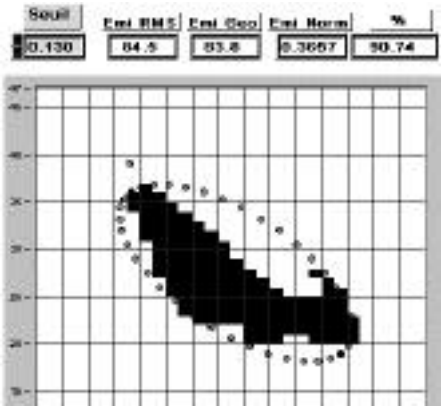

Fig. 4 – Emittance plot for O^{7+}.

Tests for Tantalum ions were prepared initially with the evaporation method, but we observed that a bias voltage on the Tantalum wire allowed to increase significantly the currents, especially for the highest charge states, according to the sputtering method elsewhere developed [9].
The measured current for Ta^{28+} was above 7 eμA and for Ta^{31+} it exceeded 3 eμA (fig. 5), which is a larger value than CAPRICE best results. The stability over 4 hours was excellent (better than 5%) but the emittance was high (about 150π mm.mrad). Tests for Nickel were not so satisfactory, because the peak current was larger than expected (7 eμA for Ni^{19+}) but the beam was not stable and after one hour only it was necessary to tune the source again. The wire consumption was too large, then the distance between the plasma and the wire is to be increased and a larger wire (to stabilize the sample temperature and limit the emission of clusters) must be used.

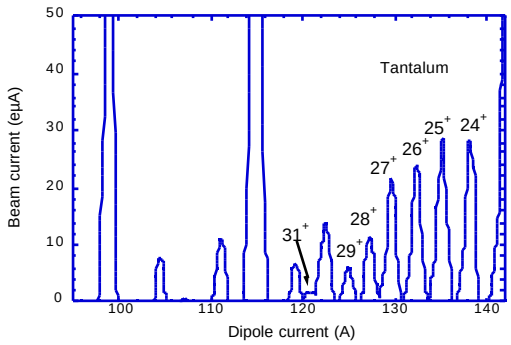

Fig. 5 – A charge state distribution optimized for Ta^{31+}.

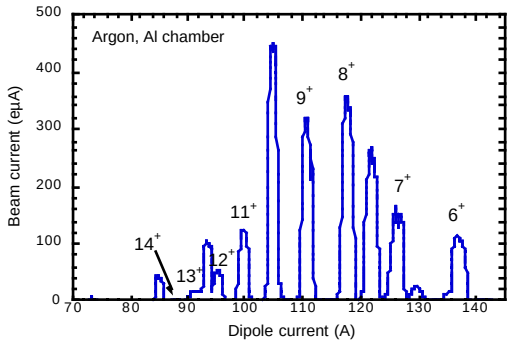

Fig. 6 – A charge state distribution, optimized for Ar^{11+}.

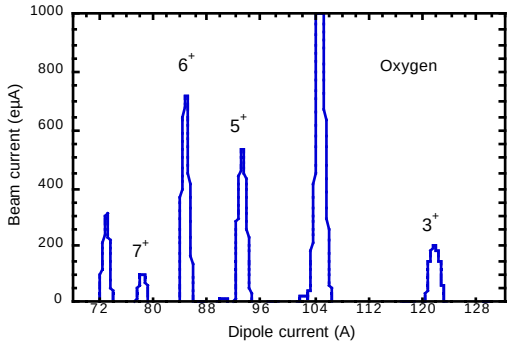

Fig. 7 – A charge state distribution, optimized for O^{6+}.

2.2 - The tests with the Aluminum chamber

The stainless steel chamber was dismounted and replaced by an Aluminum chamber, with the same shape and dimensions, according to the experience reported in [4,5]. The tests were carried out with a maximum power of 600 W for the whole duration of tests, except a short period, when the power was increased to 750 W (this chamber was never tested with plasma and we had some concerns about its robustness, but it is to be remarked that after the end of tests, the inspection of the chamber gave positive results and no evidence of overheating was found out). The tuning with the Aluminum chamber was even easier because the aluminum wall is a source of "cold" electrons, which decrease the plasma potential [4].

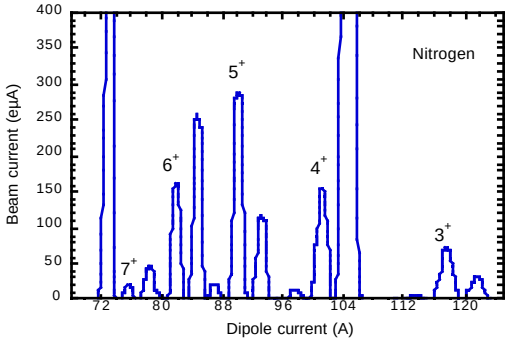

Fig. 8 – A charge state distribution, optimized for N^{7+}.

Ion	GANIL-ECR4M	LNS-ECR2
N^{5+}	500	515
N^{6+}	120	160
$^{15}N^{7+}$	-	25
O^{6+}	700	720
O^{7+}	100	105
Ne^{7+}	-	230
Ne^{8+}	-	170
Ne^{9+}	-	14
Ar^{11+}	200	120
Ar^{14+}	15	10
Ar^{16+}	1	2
Ca^{12+}	60	52
Ca^{14+}	12	6
Ni^{17+}	10	18
Kr^{22+}	10	10
Kr^{28+}	0.1	1
Ta^{26+}	5	10
Ta^{27+}	4	10

Tab. 2 – Typical currents produced ECR4M and ECR2

The same performances are obtained with lower power, because of the smaller electron losses, and the average charge state increased as effect of the higher ion lifetime.
Fig. 6 shows a charge state distribution, optimized for Ar^{11+}, which peak is above 120 eμA, 30% higher than the currents obtained with stainless steel chamber. For Ar^{14+} more than 10 eμA were obtained with a power below 0.75 kW, whereas more than 1.1 kW were necessary for the same current with the stainless steel chamber. Fig. 7 shows a charge state distribution optimized for O^{6+} (more than 700 eμA, and more than 100 eμA for O^{7+}). It is reasonable to expect that higher currents be obtained with higher power.
Two tests were carried out explicitly for the EXCYT project [10]. The first consisted of the optimization of Ne^{9+} for which a quite high value (14 eμA), close to the goal of EXCYT, was obtained. When the current was optimized for Ne^{8+}, it exceeded 170 eμA, with 230 eμA of Ne^{7+} and 400 eμA of Ne^{6+}.

The second test was about $^{15}N^{7+}$, for which the higher was the RF power, the higher was the current of $^{15}N^{7+}$, above 20 eμA for a power of 700 W (fig. 8). More than 160 eμA of $^{15}N^{6+}$, were measured with the same tuning. With a typical tuning for medium charge states (lower magnetic field and higher pressure), the currents were above 500 eμA for the charge state 5^+ and 400 eμA for the 4^+. In tab. 2 the results hereabove described are compared with the best ones measured on ECR4M during years of operations. It comes out that the insertion of the Aluminum chamber has considerably increased the capability of the source to produce high current of high charge states, which is the primary goal of ECR2 design. It is to be pointed out that the duration of all tests with Al chamber was about one day, so that there is still room for large improvements.

3 THE INSTALLATION AT LNS

The source was installed at LNS in March 1999 and on March 19th the first beam was obtained. We started with the three-electrode system and a rather rough alignment of the solenoid and of the 90° analyzing magnet, because part of the vacuum beam pipes was not timely delivered (the alignment procedure is now under way). Once that the conditioning of the source was completed, typical currents were a factor two below the current measured on the testbench. We expect to settle all these problems, once that the beamline will be completed, and the optimum vacuum and alignment will be obtained.
The analysis beamline after the source is a copy of the one of SERSE [6], consisting of a solenoid, focusing the beam to the object point of the 90° analyzing magnet, after which the axial injection beamline to the K-800 Superconducting Cyclotron [11] begins. Fig. 9 shows the area where ECR2 is installed. The 14 GHz generator is located close to the source and put aside the main coil supply. The 18 GHz generator is available nearby. The installation of ECR2 at LNS have obliged us to plan carefully every positioning, because in the same area it is present SERSE with its cryogenic equipment. In addition, the accomplishment of some particular requests, concerning the high pressure cooling water for the coils and large power from mains, have been crucial for the success of the installation of the source.

4 CONCLUSIONS

It can be concluded that the preliminary source tests have been satisfactory and that already the source performs reasonably well, in comparison with the other CAPRICE-type sources, in spite of the short duration of the tests. Moreover the other options described in the abstract will certainly allow significant improvements, and even if we cannot expect that this source achieve the results of SERSE, anyway its flexibility will certainly be advantageous for routine cyclotron operations, because of the short time needed for the opening of the source and for any maintenance. Once that alignment will be completed, final tests will be accomplished, with a particular emphasis on the production of metallic ions, which will be the main task of ECR2. While SERSE will be used for the highest charge states and the highest currents, ECR2 will be devoted to the frequent changes of metallic ions, because of its flexibility and short time for dismounting/mounting that will be helpful in order to satisfy a strict Cyclotron schedule.
The source will be connected to the K-800 Superconducting Cyclotron by the end of summer 1999.

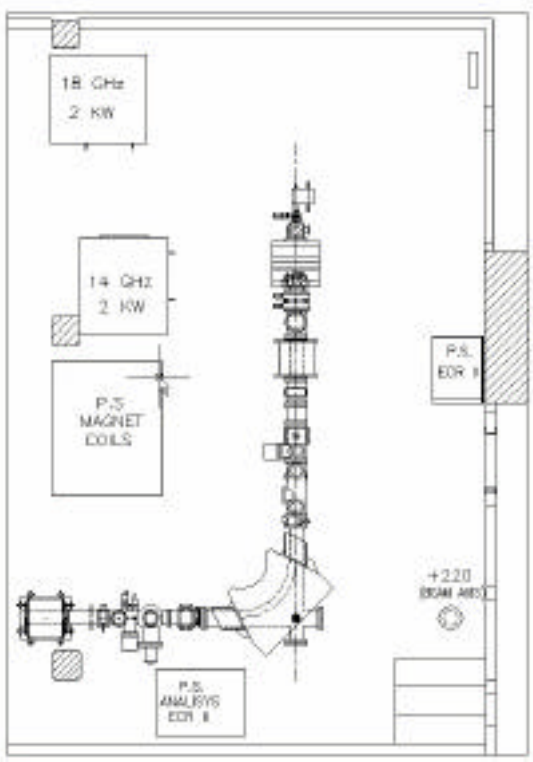

Fig. 9 – ECR2 beamline.

5 ACKNOWLEDGEMENTS

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