Installation of the Legnaro ECR Ion Source

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Abstract

The mechanical parts of the 14.4 Ghz Legnaro Electron Cyclotron Ion Source "Alice" were built, in particular the 24 bars NdFeB Halbach hexapole. A newly designed extractor was implemented, with a tapered focus electrode and a reentrant puller. Several delays forced us to postpone the first tests to late June. The source is expected to inject a superconductive linac, which is being completed, via an RFQ.

I. INTRODUCTION

Electron Cyclotron Resonance (ECR) ion sources now routinely used as first elements to inject cyclotron [1] or heavy ion linacs [2] as an interesting alternative to tandem accelerators, require an intense magnetic field of a prescribed topology to confine the ions. In order to limit the dissipated power in the coil to about 30 kW (total power 60 kW), with a confining magnetic field of $B_w = 7300\,G$, the design of our source "Alice" (see Fig. 1), envisions a small main plasma chamber (radius= 3 cm, length= 19 cm), and a compact packing of the coils, their yoke and the hexapole, the whole occupying the region $r > 3.6cm$ and $|z| < 16.8cm$; here the origin of the cylindrical coordinates r, ϑ, z is the middle of the main plasma. In this context, the implementation of a first stage, a differential pumping on one side of the main plasma ($z < -9.5cm$) and the construction of a good beam quality extractor system are subjected to severe constraints [3], and few significant but overcome difficulties will be discussed here.

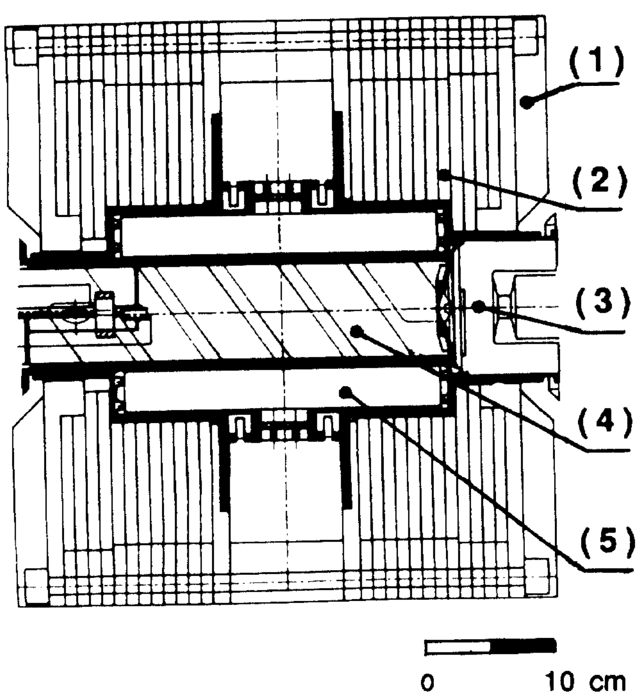

Figure 1 . Section of Alice source. The main components of the source are indicated: (1) iron (2) solenoid panacakes (3) extraction system (4) plasma chamber (5) NdFeB hexapole.

The optimal performances of the superconductive linac Alpi [4] and the superconductive RFQ (under development in our laboratory [5] in collaboration with State Univ. New York) are obtainable with a mass to charge ratio $A/Q \cong 7.3$, which implies a rather demanding charge state for uranium (32+): no stripping is then needed downstream to provide $6MeV/u$. This motivated us to an earlier installation of Alice, with the purpose of a long tuning up period.

II. MAGNETIC CONFIGURATION

The disposition of the hexapole and the coils is given in Fig. 1 ; it is well known that the hexapole bars exert forces up to 200 Kg one onto the other [6]; each bar is glued to its steel cage. From Fig. 1 we see that central rings, needed to keep the bars together, can be bolted by screws, since enough space is available there; yet lateral binding rings are necessary too, and it is possible to lock them in position by pressure. The assembling is done thanks to a 24 arm manual machine, so that the hexapole is demountable in its 24 constituent bars, whenever this may prove necessary. A stronger vice has been constructed to precisely place the bars.

Another practical difficulty arising from our magnets is the limited space ($< 4\,mm$) available for insulation, which must be cut in two parts for assembling; again the solution was an insulation built in two layers, the outer layer cut being rotated by 90 degrees with respect to the inner cut, so that discharge paths are at least 5 cm long.

Coils are standard double pancakes.

III. VACUUM

A classical differentially pumped two stage plasma was implemented for the configuration of the Alice first tests with gases, leaving further options open. There are two turbopumps (using Fomblin oil) for the two stages; a significative contribution to the main stage plasma pumping comes from holes (which can be closed) towards the extractor region, pumped by a third turbopump.

The vacuum chambers are made out of steel, the seals are metallic (except for the Pirani ones), so that good control of the plasma composition and clean current spectra are expected. The three insulation breaks (two 90 mm inner diameter and one 138 mm inner diameter) are made of brazed alumina, while the einzel lens is sustained by "stesalite" bars.

A removable and water cooled subassembly, called the "plasma chamber", is inserted inside the vacuum chamber. The plasma chamber houses the main plasma chamber, an iron ring so as to create the magnetic field depression of the first stage and a backbone which separates the two pumping manifolds and holds two waveguides and two gas-feed capillary tubes.

The purpose of the plasma chamber was to make tailoring to several metallic elements possible; for example, by building a new plasma chamber without the iron ring and with the backbone replaced by a suitable oven, the source may be optimized for fairly intense Bismuth beams. During the construction, the opportunity of not welding the backbone to the plasma chamber was evident.

Gate valves have not been purchased yet.

IV. BEAM EXTRACTION AND TRANSPORT

It can be argued that not only will a good extraction optics be of direct benefit to the extracted beam, but it will also allow for a better understanding of the source working regime. The Alice optics indeed envisioned the extraction of a slightly divergent beam, entering — after a 70 cm path — into a 50 cm-bending radius, 8 cm-gap analysis magnet, which is astigmatic and symmetric: an einzel lens of limited focal power $1/f_e < 1.m^{-1}$ matches the ion beam to the object point of the magnet, 115 cm far from the magnet entrance border. Beam diameter at magnet entrance is about $4 \div 5\ cm$.

This configuration minimizes the space charge effects, since the full extracted current is never focused to a waist, but a compact assembling is then required; between the source and the dipole magnet, we have: the mounting of the extractor, with a bended arm, and the suspended einzel lens (see Fig. 2), the $x - y$ steerers where the beam pipe diameter shrinks in order to enter into the magnet, a tentative concept of a x slit (see Fig. 2), and the field clamps of the magnet, closing a slanted CF100 flange.

The (removable) x-slit is determined by a prolate ellipsoidal surface, which is rotatable by 90 degrees around its axis. Since two opposite 90 degree sectors of this surface are removed, an elliptic slit is projected, with the minor axis $0 < a < 5.0\ cm$ and the major axis $b = 5.0\ cm$.

Due to the limited space available, interaction of the fringe fields of the beam transport elements — namely the einzel lens, the steerers and the magnet

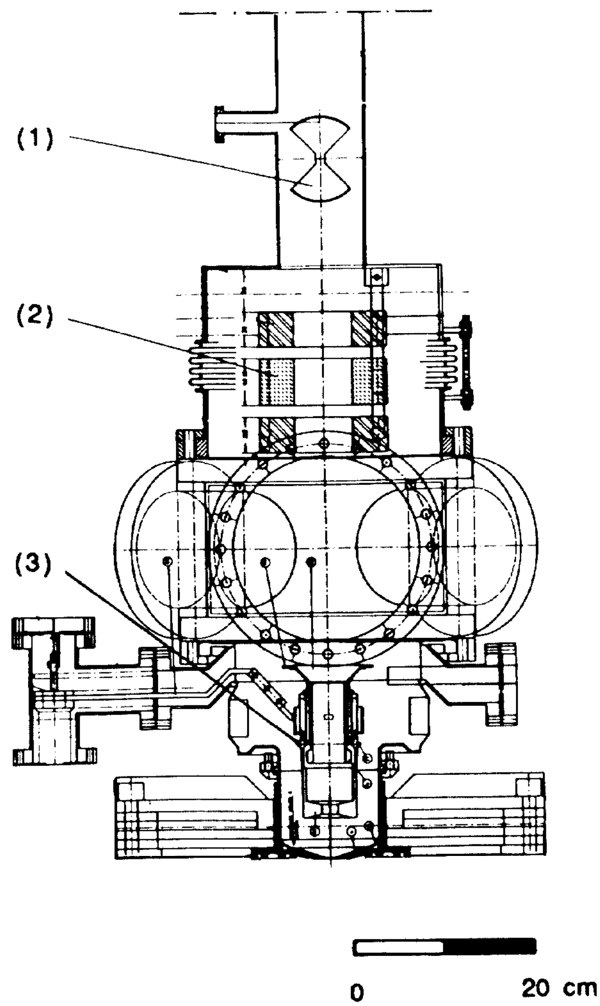

Figure 2 . Transport line to the magnet: the movable extractor (3), the einzel lens (2) and the x-slit (1) are shown.

— can not be ruled out. Studies of the magnet section showed that the C-shape solution was still possible.

The newly designed extractor is treated elsewhere [6]; we implemented a tapered focusing electrode [7] and a reentrant puller. The former, going from a 67.5^0 angle (with the z-axis) near the beam to a 74.16^0 angle when $r \rightarrow \infty$ is precisely given by analytic formulas and extensive computer simulations show its convenience with respect to the simple 67.5^0 semiangle cone [7] . The reentrant puller is proposed as a correction of the perturbing effect of the vacuum pipe.

We avoided to braze insulating and metal pieces in the puller assembly, the whole package being secured by screws.

V. SETTING THE TEST STAND

1. *Electronic control*

The ECR source requires some control at three different potentials, namely the plasma potential, the platform potential and the whole linac potential (clearly connect to the ground); fiber optics link them.

The basic control of the source is at platform potential, setting and reading the klystron amplifier, the power supplies, and several safety interlocks (e.g. boiling water). For its inherent simplicity and the wealth of boards available from several suppliers, the G-64 bus with the 6809 CPU results to be attractively unexpensive and was chosen. Equipment interfaces are RS-232C.

The plasma potential control consists of a gauge reading unit in this phase, so that only a 50 kV insulation transformer and a RS-232 fiber optic links are needed (negligible manpower, about 1500 ECU worth of components; usually it is $1\ \$ = 0.9 \pm 0.1 ECU$).

The final supervision and software development of Alice is performed by a workstation, not yet purchased.

B. Logistic

The test stand is being installed in a 8.5 times 23 meters room, shared with other users and surrounded by offices along two sides. A careful planning of our section (7.5 meter long) and of the ECR shielding, see Fig. 3 , was then necessary.

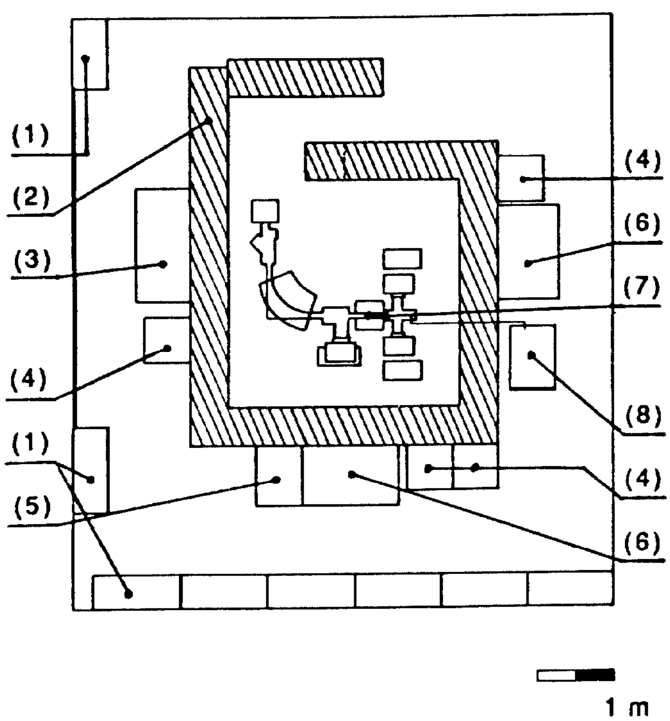

Figure 3 . Test stand of Alice. We see (1) shelves (2) concrete walls (3) table (4) racks (5) dipole magnet power supply (6) solenoid power supplies (7) the source itself (8) klystron amplifier

C. Major costs

The costs were generally kept at the lower expectation value, while several delays occurred. Mechanical construction was performed by an external contractor. In table 1, we quote the construction costs and manpower (not the installation work) of only what we have at the moment, excluding therefore any necessary equipment for metallic material, any plasma diagnostics and flow control equipment (a significant part of the whole).

Table 1: Construction costs

Item	Cost (no taxes)	Manpower (our workshop)
Basic mechanical parts	110000 ECU	none
Klystron & waveguides	80000 ECU	36 h.
Power supplies	70000 ECU	
Pumps	60000 ECU	
Analisys magnet	26000 ECU	
NdFeB magnet	16000 ECU	
Gauges, gas, etc.	15000 ECU	36 h.
Electronics	8000 ECU	72 h.
Magnetometry	6000 ECU	
Flanges, coil spares, etc.	15000 ECU	

Next year budget must include also the HV platform construction; the major technical problems to be addressed are the insulation transformer and its voltage compensation at a variable load.

VI. ACKNOWLEDGMENTS

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VII. REFERENCES

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