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STATUS OF THE E.C.R. HEAVY ION SOURCE AND ITS INTERFACING WITH CYCLONE*

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Summary

The construction of an E.C.R. source at the Louvain-la-Neuve cyclotron is described. Design features of the first stage are explained. For the magnetic field in the second stage, two alternative solutions are compared, and vacuum problems mentioned. Finally the beam transport and axial injection systems are described and a schedule is given for the completion of the system.

1. Introduction

A heavy ion source, using the Electron Cyclotron Resonance, is under construction at the cyclotron laboratory of the Université de Louvain at Louvain-la-Neuve (Belgium). The device has been named ECREVIS (Electron Cyclotron REsonance Versatile Ion Source).

The beam design goals are summarized in Table I.

E.C.R. Source Design Goals Conditions: 20 KV, Ø Ext. 14 mm, Emittance: < 480 (π, mm, mrad) all Intensities in Electrical Microamperes.

Carbon	Nitrogen	Oxygen	Neon	Argon
4^+ 45	5^+ 45	5^+ 50	6^+ 50	7^+ 45
5^+ 12	6^+ 10	6^+ 25	7^+ 25	8^+ 45
6^+ 4	7^+ 2	7^+ 5	8^+ 6	9^+ 30
		8^+ 1	9^+ 0.5	10^+ 15
				11^+ 4

Extracted currents from Cyclone should be approx. 5% of those values.

In this type of source the ions are contained in a magnetic field consisting of two mirrors and a hexapole, during times of serval tens of milliseconds. The ions are stripped by a cloud of energetic electrons ($E \approx 40$ keV) accelerated at the electron cyclotron resonance in the gradient of magnetic field around the plasma.

To conserve the high charge states and to minimize losses by charge exchange with the residual gas, a low neutral pressure is required. Computations show that a vacuum of 10^{-7} Torr is required to bring the average charge changing time around 50 msec for the ions listed in Table I.

This implies that the plasma has to be generated in a separate first stage. The first stage operates also by E.C.R. but at a higher pressure (10^{-3} Torr) and the plasma diffuses into the main stage along a gradient of magnetic field through a succession of differential pumping holes.

The source was designed after the prototype developed at Grenoble by Geller et. al.[1,2,3].

Table II summarizes the basic technical data for the two stages of the source.

	Stage 1 Plasma Injector	Stage 2 Main Confinement
F_{RF}	14.3 GHZ	7.15 GHZ
P_{RF}	1.4 KW	5 KW
B_{RESON}	5.20 KG	2.50 KG
N^-	10^{12} CM^{-3}	$2\ 10^{11}$ CM^{-3}
$< E^- >$	50...100 EV	10...40 KEV
P	10^{-3} TORR	$2\ 10^{-7}$ TORR
$\frac{N^-}{N_O}$	0.03	30
$< \tau^+ > (\approx < \tau^- >)$	$...10^{-5}$ SEC...	$1...5\ 10^{-2}$ SEC

2. Injector Stage Design

The magnetic structure is made of water cooled solenoids . The coils are optimized for mimimum power consumption, at the expense of a higher copper volume. Basic data are: 500 A in 1500 turns, maximum axial field 7.8 kG, total power consumption 120 kW.

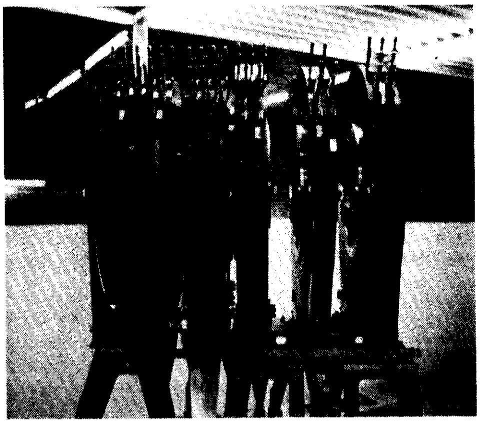

Fig. 1 Coil assembly for the injector stage.

The ionisation occurs in a small cylindrical chamber in which gas and microwaves are fed. This chamber is pumped through a 15 mm aperture from the next chamber, giving an operating pressure of $\approx 10^{-3}$ Torr. Microwaves are fed at 14.3 GHz with a maximum power of 1.5 kW. The E.C.R. occurs then at 5.2 kG.

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The ionisation chamber is followed by two transition chambers which are pumped by oil diffusion pumps, in order to reduce the neutral gas injection into the main stage to a very low value.

3. Main Stage Design

3.1. Magnetic Field

The prototype developed by Geller et. al.[1] uses holow copper watercooled coils requiring about 3 MW of power to create the main confinement magnetic field.

In order to reduce this power, two alternative solutions are considered:

1. The use of superconductivity: several manufacturers have proposed schemes meeting the specifications. The cost (approx. 0,3 M $) is lower than the cost of an equivalent classical system and it has the advantage that the field can be increased to twice the original value in a further step. This would allow a 4-fold increase in the electron density and, consequently an improvement of the $n^{-}\tau$ product (electron density times confinement time).

2. The use of permanent magnets: the hexapolar field is obtained from Sm-Co permanent magnets, as far as a reduction of the specifications is allowed: the internal bore is reduced from 35 to 25 cm and the hexapolar field at the tank wall is reduced from 4.6 to 4.3 kG. Here the axial field is still obtained from watercooled coils, and the power consumption is reduced to 130 kW by a careful design of the coils.

   To test the validity of this method of hexapole construction, a 1/4th scale model (25 cm long, 7 cm dia.) was built.

   Magnetic field measurements were carried out at the Karlsruhe Kernforschungs Anlage in collaboration with the Karlsruhe cyclotron team. No significant divergence from the theoretical predictions was observed.

3.2. Vacuum

The loss of plasma due to neutralisation at the surfaces in the second stage is an important source of neutral gas estimated from experimental data to be 10^{-3} Torr l/s.

To reach an operational pressure of 10^{-7} Torr a total pumping speed in the main stage of at least 10^{4} l/s is thus required.

The severe geometrical limitations and economical considerations led to the choice of two identical custom designed annular cryopumps located at both ends of the main stage. Each pump will use a 2W cryogenerator cooled panel at 20 K enclosed in a liquid nitrogen cooled shield. The cost of each pump is estimated to be approximately 32 K$. Roughing and helium pumping will be done by a turbomolecular pump.

3.3. Microwaves

Electron heating will be provided by a 5 kW transmitter operating at 8.15 GHz. In a first step, no circular polarizing device will be used.

4. Beam Line and Axial Injection Design

The beam line has been designed for maximum acceptance with a mimimum of optical elements of reasonable size. The location of the source in the cabin is determined by constraints such as good accessibility and maximum deflection of the beam between transport and extraction lines. This deflection is needed for sufficient charge state separation while changing physical parameters for high charge states production.

An achromatic system was chosen for the transport. Two 30° magnets separated by a triplet are located between the source lens and the transport line containing three doublets. This line goes through a 20 cm I.D. × 3 m long hole drilled in the cyclotron shielding wall. Its axis is 1.3 m above the cyclotron yoke, providing enough room for the 90° bending system towards the vertical axial injection line.

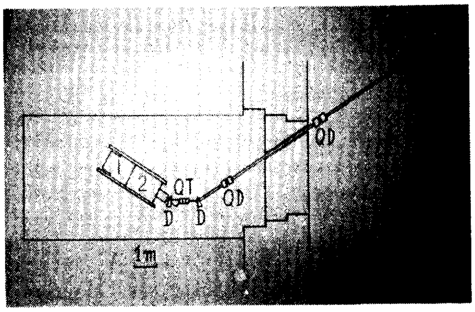

Fig. 2 Layout of source and beam transport line.
1 = injector stage
2 = main confinement stage
D = 30° bending magnet
QT = quadrupole triplet
QD = quadrupole doublet

The axial injection system is similar to the one at the Grenoble Cyclotron.[4] It is composed of four cylindrical magnetic lenses and an electrostatic helical inflector. Performance of the injection system will be evaluated in a test stand simulating the center region of the cyclotron.

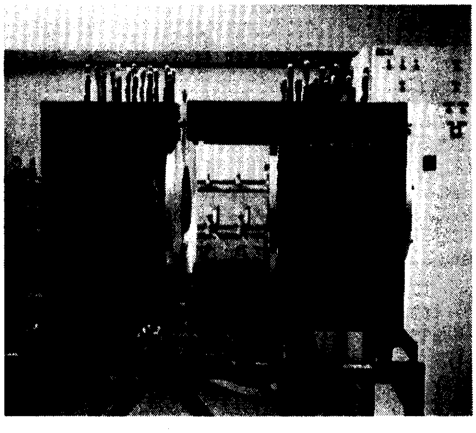

Fig. 3 Test stand for axial injection system.

5. Status and Schedule

By February 1979, all the necessary hardware is completed: mounting platform, power and cooling water distribution etc... The coils, assembly structure and power supplies of the first stage are connected and magnetic tests are underway. The microwave transmitter is expected by early March. The vacuum chambers and other mechanical elements are well under way. The first plasma in the injector stage is expected at the end of March 1979.

At the same time, the solution for the second stage will be decided and its mainparts as well as the elements of the beam transport line will be ordered.

Testing of the second stage is expected at the end of 1980 and beam through the cyclotron should be obtained in 1981.

6. Acknowledgements

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References

1. P. Briand, R. Geller, C. Jacquot, B. Jacquot, A. Meiss, C. R. Acad. Sci. (Paris) 280, B 11 (1975).
2. R. Geller, IEEE Trans. on Nucl. Science NS23, 2, 904 (1976).
3. P. Briand, R. Geller, B. Jacquot, C. Jacquot, Nucl. Inst. Methods 131, 407 (1975).
4. J. L. Belmont, Rapport Interne ISN 7506.