AGOR AXIAL INJECTION, USING A POSITIVE LIGHT ION MULTICUSP SOURCE

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ABSTRACT

One of the injection lines of the AGOR superconducting compact cyclotron will be equiped with an ion source delivering hydrogen and helium beams. The first part of this injection line (the source, an Einzel lens, two sets of moveable horizontal and vertical slits, a 90 degree double focusing analysing magnet and an emittancemeter) has been built and fully tested. The ion source is derived from the multicusp negative ion source operating at TRIUMF and CYCLONE2. The measured characteristics (intensity, emittance, stability and lifetime) will be reported. The beam emittance can be finely controlled by the two sets of slits, in order to achieve a small emittance at the entrance of the cyclotron (essential for single turn extraction).

INTRODUCTION

One of the original features of the Orsay Groningen project AGOR of a superconducting cyclotron[1)] is the possibility of accelerating light ions besides the usual heavy ions produced in an ECR type source. The first part of the injection line, based on the use of a multicusp type ion source, has been built and fully tested. It includes all the elements from the source to the 90 deg. analysing magnet and will be followed by a matching section, an achromatic electrostatic deflector, a set of solenoids (located in the vertical direction before the cyclotron entrance), and a buncher placed at 50cm from the median plane inside the pole plug[2)]. The present paper deals with the various components of the first part of the injection line and with the measured properties of the source itself.

THE FIRST PART OF THE INJECTION LINE

The first part of the AGOR axial injection line, to be installed horizontally underneath the cyclotron, is shown in fig.1.

The Light Ion Source and the Einzel Lens

Multicusp ion sources are developped in several laboratories, in particular for H^- cyclotrons (see ref.3 and references there in)

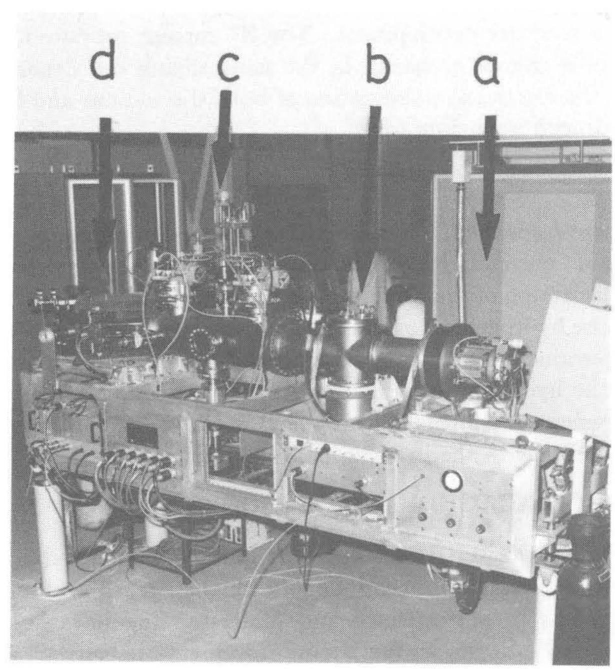


Fig. 1 : First part of the AGOR injection line :
(a) ion source;
(b) Einzel Lenz;
(c) moveable slits;
(d) 90° analysing magnet.

and are known to have very attractive features. With the cusp structure of the magnetic field, high intensity beams can be produced with small emittance and very little angular momentum. The principle of operation is very simple because of the use of only one plasma chamber, an easy and permanent gas flow adjustment and the absence of any magnetic coil. Moreover a simple tungsten filament, without any special coating (as is the case for the duoplasmatron ion source), can be used without frequent replacement, making maintenance operations fairly easy.

TABLE 1: Power Supplies

Polarization	40 kV	10 mA	10^{-4}
Arc	200 V	10 A	10^{-3}
Filament	10 V	100 A	few 10^{-3}
Extraction	-5 kV	5 mA	10^{-3}
Einzel Lens	30 kV	1 mA	10^{-3}
90 deg. magnet	35 V	80 A	10^{-4}

Furthermore, the source structure can be simplified if one aims at producing positive light ions, because there is no need to remove the electrons by magnetic filters, as in the case of H^- operation. The environment of a multicusp ion source delivering positive ions is simpler than in the case of negative ions (power, vacuum, gas flow, neutral emission).

Such an ion source* (fig.2), in a simplified version for positive hydrogen and helium ions, operates satisfactorely since December 1988. Confinement is obtained by 10 permanent Sm-Co magnets positioned around the plasma chamber in which a twisted tungsten wire of 0.75 mm diameter and 140 mm long is heated up to 2800 deg.K. The ions are extracted by a moveable extractor and focused trough a standard Einzel lens of a diameter of 80 mm. In order to match the cyclotron characteristics for light ions[4)], the source voltage is 40 kV at its maximum. The Einzel lens is set approximately to half the source voltage. A turbo-molecular pump of 1000 l/s maintains a vacuum of the order of 10^{-5} mbar in the line, in the presence of gas flow.

The Moveable Slits

One of the goal of the cyclotron is to achieve single turn extraction for light ions. This implies that the injected beam is bunched to reach a RF phase width in the order of 6 degrees. This is possible in principle at two conditions: - one has to use a buncher located very near to the median plane(50 cm), so that the velocity modulation given to the beam becomes much greater than the source noise; in that case space charge effects are also less important; - the emittance has to be reduced so that any debunching effects caused by the axial magnetic field and the inflector can be considered as negligible.

For this last purpose, a set of two pairs of motorized tungsten jaws** in each transverse plane has been installed after the Einzel lens. The maximum aperture of each slit is 35 mm and its position reproducibility is within 0.1 mm. The jaws are electrically isolated by BeO plates and water cooled, as to tolerate beam power up to 500 Watts and to allow intensity measurements. Two pairs, corresponding to each transverse plane, are separated by 500 mm and are therefore able to control the size and the divergence of the beam. The required emittance, down to a value of the order of 5π mm.mrad, can be produced in this way.

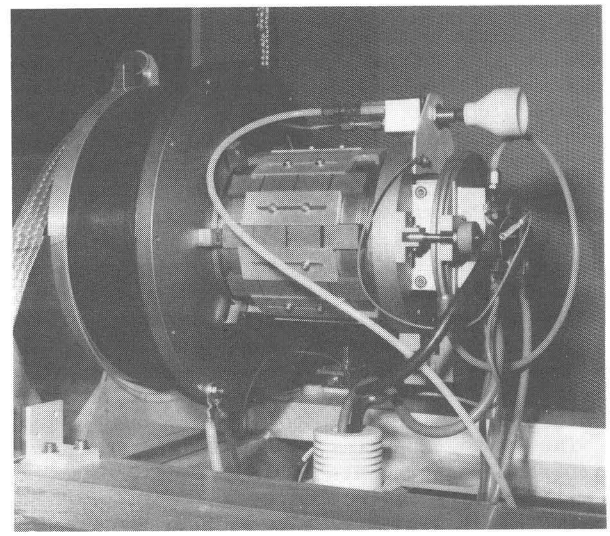


Fig. 2 : The light ion multicusp source.

The Analysing Magnet

A 90 deg. magnet (radius= 200 mm, maximum field= 3350 Gauss) provides the q/m selection of the beam. This magnet has a homogeneous field and its entrance and exit angles are both equal to 32 degrees. The symetrical beam, coming from the source, is focused through the Einzel lens at a point situated at 230 mm from the magnet entrance. Beyond this optical element, the beam is then refocused at the entrance slit of the emittancemeter.

* purchased from Ion Beam Application, Louvain-la-Neuve, Belgium.

** water cooled slit 563, purchased from Danfysik, Jyllinge, Denmark.

The General Set-up

All these elements are located on a rigid aluminium alloy frame, which can be taken away from the vault underneath the cyclotron, in case the pole plug has to be removed. After a first general alignement at 0.1 mm, using a Rank-Taylor telescope, the overall rigidity of the line insures that no further alignement of the elements and of the frame are necessary.

The beam line is made of a succession of vacuum chambers. In order to minimize steering effects on the beam due to stray magnetic field from the cyclotron (100 Gauss at maximum), these chambers are all made in mild steel. In this condition, beam handling becomes easy due to a residual field less than 1 Gauss. The chambers are nickel plated inside, to diminish outgassing.

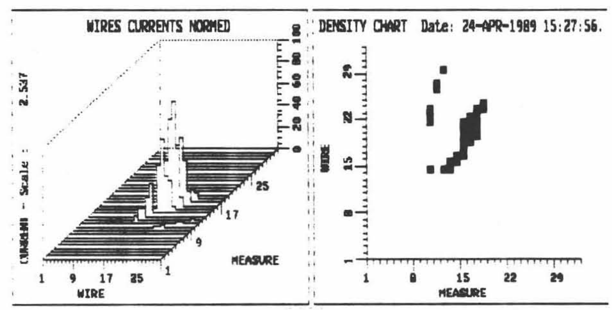
The power supplies, the motorizations and the current measurements (Faraday cup and slits) are all remotely controlled by a RT-Vax computer through the interface system BITBUS. Vacuum and valve system as well as pneumatic systems for in and out movements are controlled through the BBC's Programmable Logical Controller.

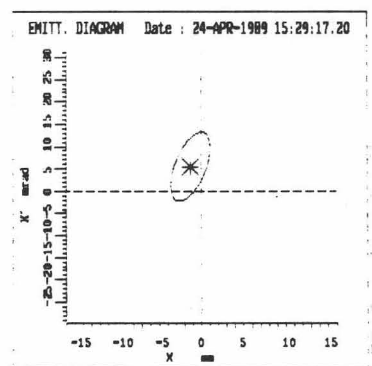
SOURCE PERFORMANCES

Emittance Measurements

The emittancemeter is made of a slit 0.2 mm wide, 20 mm long, and a set of 32 thin stainless steel plates located at a distance 162 mm ahead. The whole system is mounted on a moveable frame. The 32 thin plates are isolated from each other by a mica sheet 0.2 mm thick so that the distance between two adjacent plates is 0.3 mm, covering a total divergence of 60 mrad . The total beam size which can be analysed is 32 mm in one transverse plane at the time. The moveable slit of the emittancemeter is located at the image given by the 90 deg. analysing magnet to be near the beam waist. For each of the 32 slit positions explored by step of 1 mm, beam currents falling on each of the 32 plates are recorded. This yield a 32 by 32 matrix which is subsequently analysed. One deduces first the distribution of beam densities in the phase space coordinates (x,x') , after substraction of a certain percentage of the total beam intensity analysed. A bi-dimensional representation of the emittance is obtained which reveals the usual aberrations, if any. Secondly, the deviation of the position and the direction of the beam with respect to the beam line axis is directly related to the first moment of the beam distribution given by this matrix. Finally, centred second order moments of the same distribution yields the coefficients of the 2 by 2 matrix of the equivalent ellipse of emittance, supposing that the beam is uniformely distributed.

The result of the measurements, made only in the vertical transverse plane, is given in fig. 3. It confirms a very good emittance of such a source, even with fairly large currents, namely $\varepsilon_n = 0.07\ \pi$ mm.mrad, where ε_n is the normalized emittance ($\varepsilon = \varepsilon_n/\beta\gamma$).





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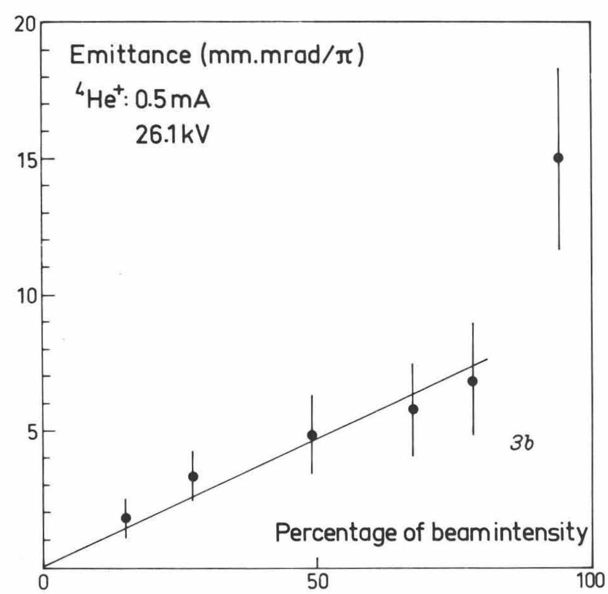

Fig. 3 : Measured emittance on a 0.5 mA He^+ beam at 26.1 kV :
3a - Emittancemeter data analysis at 90 % of beam intensity.
3b - Emittance dependence on beam intensity percentage.

Lifetime Test

A 500 hours test (fig. 4) at an intensity of 0.8 mA of He^+ shows a continuous degradation of the filament, whose resistance increases gradually. After the test, its thickness was reduced to approximately 0.5 mm; it could be dismounted without breaking, suggesting that the lifetime of the system was not limited by the filament itself but merely by the filament power supply limited to 10 V (tab.1).

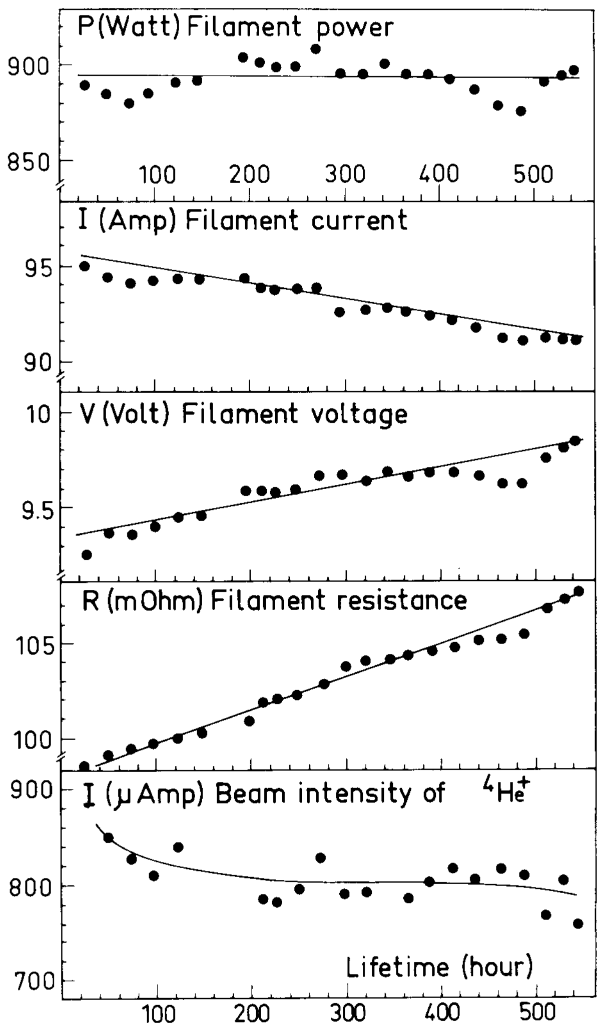

Fig. 4 : 500 hours lifetime tests : variation of the source parameters during this test.

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REFERENCES

1) H. Schreuder, "The AGOR cyclotron past the half-way mark", invited paper at this conference.
2) J.P. Schapira, S. Brandenburg and P. Mandrillon, "Axial injection in the Orsay project of a superconducting cyclotron and in the medical cyclotron MEDICYC", in Proc. 10 th Int. Conf. on Cyclotrons and their Applications (East Lansing, 1984), p. 332.
3) R. Baartman et al., "An intense ion source for H^- cyclotrons", in Proc. 11 th Conf. on Cyclotrons and their Applications, (Tokyo, 1987), p. 717.
4) J.P. Schapira et al., "AGOR central region design", paper presented at this conference.