A MINIATURE H- ION SOURCE FOR THE C-30 COMPACT CYCLOTRON AT SWIERK

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Abstract

A direct current, low power rated multicusp H- source for the C-30 SINS isochronous cyclotron was constructed and tested. In order to lower the costs the dimensions of its arc chamber were reduced to 3.35 cm in diameter and 6 cm in length. The H- beam current in the injection line reached about 500 μA.

1 INTRODUCTION

So far the C-30 compact, isochronous cyclotron at SINS was run with small, PIG-type, internal H- sources [1]. The H- ions of final energy were converted to protons by stripping on an aluminium foil. The external proton beam current was limited by the operating parameters of the sources. The high H- density requires high hydrogen pressure in the source discharge, which leads in turn to the stripping during acceleration. The good extraction efficiency of ions from thermal plasma calls for the very high RF dee voltage. This, due to the RF break-downs, limits the RF pulse duty ratio and the mean beam intensity.

To overcome these restrictions, H- ions are to be injected from an external source. Filter equipped multicusp sources can deliver high quality H- beams to be used for both neutral beam heating of fusion plasmas and accelerators [2,3].

A source of this type was manufactured at SINS. The recent financial restrictions led to the limitations of the available discharge power. The arc current did not exceed 12 A. In order to decrease the costs and reach a relatively high plasma density in the source discharge region the source dimensions were strongly reduced. A simple, two-electrodes extraction system was designed with the aid of a computer code, which was used to optimize the distribution of the magnetic field in the extraction region.

2 ION SOURCE AND EXTRACTION SYSTEM

The ion source has a small cylindrical plasma chamber from copper. Its inner diameter is 33.5 mm and length 60 mm. For fast electrons and plasma confinement it is surrounded by 12 rows of 0.3 T samarium-cobalt permanent magnets arranged in a line-cusp configuration. A supporting structure of the magnets is water cooled. The cooling water can absorb up to 2.5 kW of a heat flux from the plasma chamber while the average temperature of the chamber inner wall is kept below 600 K. A single samarium-cobalt magnet is inserted into the back wall of the source.

In cusp sources a permanent magnet filter divides the plasma chamber into a discharge and an extraction region. Ionization and excitation of gas molecules by energetic (>100 eV) primary electrons is performed in the discharge region. In the extraction region negative hydrogen ions are formed by dissociative attachment of thermal electrons to highly vibrationally excited hydrogen molecules and extracted.

In our case a magnetic filter is a limited region of magnetic field normal to the extraction direction, created by two additional ferrite magnets placed outside the chamber, close to its front wall. It is used to prevent the primary electrons from entering the region close to the emission aperture and to reach the optimal plasma parameters for H- generation. The strength of the magnetic filter can be easily modified by changing the number and position of the magnets. The magnetic field-free discharge volume in the discharge region is very small (about 17 mm in diameter and 40 mm long). A single cathode filament of tungsten wire is mounted on the back wall. It extends approximately 35 mm inside the chamber.

The front end of the source is enclosed by a plasma electrode which is insulated from the plasma chamber. It has an emission aperture in the centre. Plasma electrons are extracted along with negative ions. In order to reduce the electron space charge in the extraction region one should minimize the electron drain current. It is usually done by biasing a plasma electrode at a potential more positive than an arc chamber and creating an additional transverse magnetic field close to an emission aperture. In our source a pair of small samarium-cobalt magnets in a dipole configuration were placed in the plasma electrode. Electrons trapped on the field lines are collected by a copper cylinder inserted into the electrode.

The ion beam injection energy is 18 keV. The ion source is kept at a potential of 18 kV below the potential of the ground. The extraction system consists of the plasma electrode and a grounded extractor. Electrons are not fully suppressed by the transverse magnetic field in the emission aperture and a fraction of them are accelerated to full energy and intercepted by the extractor. In order to absorb the electron beam power, cooling water is flowing very close to the extractor tip.

3 BEAM EXTRACTION MEASUREMENTS

The H^- beam extraction tests were done using the entrance part of the injection system. The ion source was followed by the extractor, an einzel lens and a doubly focusing 90° bending magnet. The source was operated in a dc mode. The beam intensity was measured using a Faraday cup placed 2.5 m downstream of the source.

To determine the optimum conditions for H^- generation the transverse magnetic field in the plasma electrode region was optimized. The optimal magnetic field intensity in the plane of the emission aperture was 16 mT.

The available power supply units allowed to reach an arc power of no more than 1.5 kW. Typical discharge voltage was within the limits 90 V - 150 V. Changing the voltage between these two values hardly influenced the beam intensity.

The source was tested with emission hole diameters equal 4, 5, 6 and 7 mm. The 6 mm diameter was optimal. Further increasing of the hole dimension lowered the H^- current due to an excessive gas leak into the extraction region, which led to hydrogen pressure drop in the arc chamber and beam losses because of stripping in the extraction region. The optimum hydrogen flow rate depended on the arc current. For arc currents of 6 A and 10 A the optimal flow rates were close to 5.5 ccm/min and 9 ccm/min, respectively. The latter is equivalent to a source pressure of about 0.9 Pa.

When the plasma electrode is biased at 5 V positive in comparison with discharge chamber the extracted electron current is typically reduced by an order of magnitude [3]. In our case the electron drain current dropped from 20 to 3 mA. The dependence of the H^- beam current on the plasma electrode bias voltage was typical. When increasing the bias voltage to 4 V the beam intensity did not change significantly at the optimal gas flow rate. Further increase to 7 V resulted in the H^- current drop by a factor of 2. The beam intensity obtained so far and the corresponding ion source working parameters are listed below:

- operation mode	dc
- arc voltage	90 - 150 V
- arc current	10 A
- plasma electrode bias voltage	4 V
- extraction voltage	18.5 kV
- gas flow rate (hydrogen)	9 ccm/min STP
- emission aperture diameter	6 mm
- H^- current in the injection line	500 μA.

The work upon the source optimization and completion of the injection system is continued.

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4 REFERENCES

[1] J. Lorkiewicz et al., "Upgrading Programme of the C-30 Cyclotron at Swierk and its Use for Experimental Physics", in Proceedings of the Fourth European Particle Accelerator Conference, London, UK, June-July 1994, Vol. 1, pp 542-544

[2] C.W.O. Ehlers et al., "Characteristics of a Small Multicusp H^- Source", in AIP Conference Proceedings No. 158 (1987), pp 282-288

[3] D.H. Yuan et al., "Extraction of H^- Ions from a DC Cusp Source", in AIP Conference Proceedings No. 158 (1987), pp 346-355.