STUDIES OF PULSED VOLUME SOURCES OF H^- IONS*

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Abstract

As part of the improvement program at the BNL Alternating Gradient Synchrotron (AGS), a new RFQ preinjector and its beam line are being assembled. While the modified H^- magnetron source of the plasma-surface type is the first choice to be used in the new preinjector, work is in progress to develop a 50 mA, low emittance volume-type H^- ion source that would not require a continuous injection of cesium vapors into the source chamber. Studies of the effect of different cusp configurations were done on a source model with a diameter of 12.5 cm and a length of 20 cm. Highest yields were obtained with linear and circular cusps, while the performance of checkerboard cusps was inferior. More than 20 mA of H^- beam current was recorded on a Faraday cup, corresponding to a current density in the extraction aperture of more than 25 mA/cm^2. A second model was then designed, constructed, and initial tests performed. It features a very low length-to-radius ratio of 0.6, cusps covering the whole discharge chamber, and the possibility to use a conical dipole field separating the outside, toroidal discharge chamber and the central extraction chamber. So far, an H^- beam current of close to 10 mA was obtained, at an arc current of 200 A. Further tests, with the objective of optimizing the magnetic field configuration, will be performed this year.

Introduction

Studies of volume H^- ion sources at BNL started in late 1986 with the objective to reach eventually an H^- beam current of 50 mA in pulses of 1 ms duration, at a rate of 5 Hz; the normalized beam emittance should be less than π mm mrad. Both sources studied so far are of the tandem type, with a dipole field separating the discharge and extraction regions of the source. Of the three cathodes tried in the sources, the LaB_6 cathode proved to be the most reliable, capable of maintaining arc currents up to 500 A; a tungsten wire (1.25 mm diameter) showed signs of recrystalization after a relatively short run, resulting in breaking, while an oxide coated cathode was the least satisfactory. Results quoted in this paper were obtained by using either an LaB_6 cathode (long source) or a tungsten cathode (short source).

Several cusp configurations were studied; in all cases either bar or small disc samarium-cobalt magnets were arranged on the inside surface of a mild steel shell serving as a flux returning path. In this way, there was no need for a special magnet mounting fixture and it was easy to change magnet configurations. Disc magnets also served to create a dipole field across the extraction aperture.

Experimental Arrangement

Test Stand

An existing test stand was used for ion source studies. High voltage for single-gap extraction, up to 10 kV, was applied to the extractor and target assembly, while the source chamber was grounded. The extracted beam has a large electron component, and a strong dipole field (10^{-3} Tm) in front of the Faraday cup served to remove this component from the beam. The H^- ion beam current was measured via the voltage drop across a 1 kΩ resistor in series with the cup, while the total high voltage power supply load was monitored by using a standard beam transformer. A tungsten mesh electrode (90% transparency) served to prevent the exchange of secondary electrons. Most of the measurements were done with a pulsed gas injection; the performance was not much different when a steady gas flow was used. Both d.c. and a.c. filament heating were used. In the former case, the source operation depended on where the arc power supply was connected to the filament; in the latter case, the source operation could be optimized by varying the phase between the arc pulse and filament current.

Long Source

This source is of a standard cylindrical design, 20 cm long and 12.5 cm in diameter. Line cusps (8 and 16 lines), circular cusps (8 rings, 3 different spacings between individual disc magnets) and checkerboard cusps were studied on this model. The plasma electrode could be biased, but most of the time it was left floating. Two different dipole field strengths were used, by arranging a certain number of disc magnets on the plasma electrode.

Short Source

Figure 1 shows a cross section of the short source. There are four concentric rings, assembled by using 1.25 cm long disc magnets on each of the two base plates, and three rings on the short, cylindrical side wall, creating a continuous cusp field around the discharge (Figure 2). The chamber is made out of copper, with the side wall water cooled (Figure 3). Two cathodes were tried on this model, a single tungsten wire loop (1.25 mm diameter) and two LaB_6 cathodes placed 180° apart facing the center of the chamber. The idea behind the design of this source has been to produce a dense discharge of a toroidal shape that would be separated from the region adjacent to the extraction aperture by a properly shaped conical dipole field. Such a field can be created either by removing the inner-most ring of magnets on the base plate or by adding a fifth ring with a small diameter on the top plate. A simple dipole field across the extraction aperture can also be used, either alone or in conjunction with the conical field. Either of the two small center plates can be biased to optimize the electron energy distribution for H^- production; it will also be possible to inject low energy electrons into the extraction region from a filament mounted on the top center plate. Gas is injected through four apertures near the periphery of the top plate.

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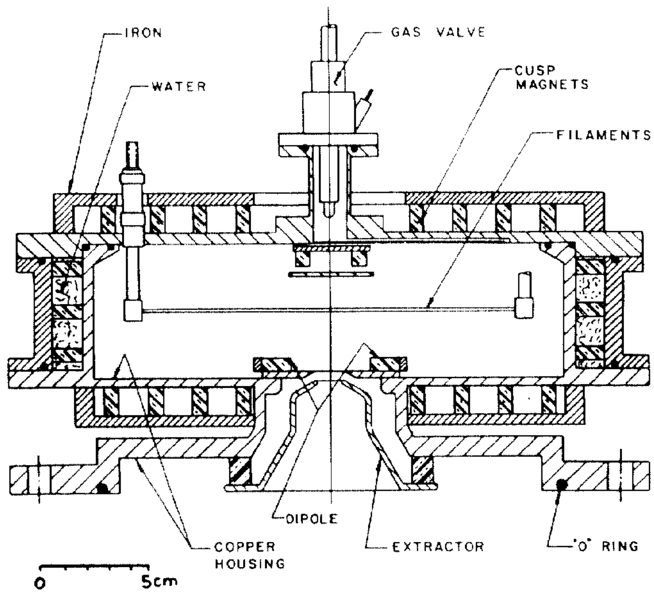

Figure 1. Short source, cross-section.

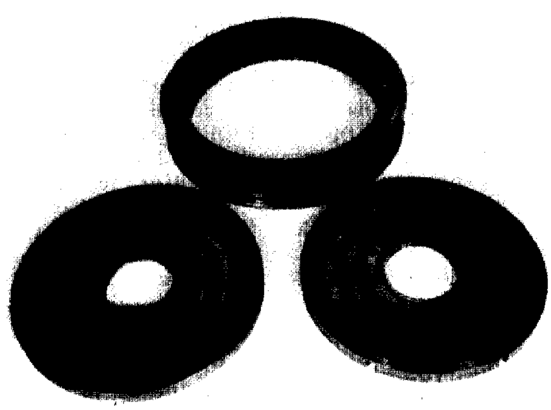

Figure 2. Cusp field magnets.

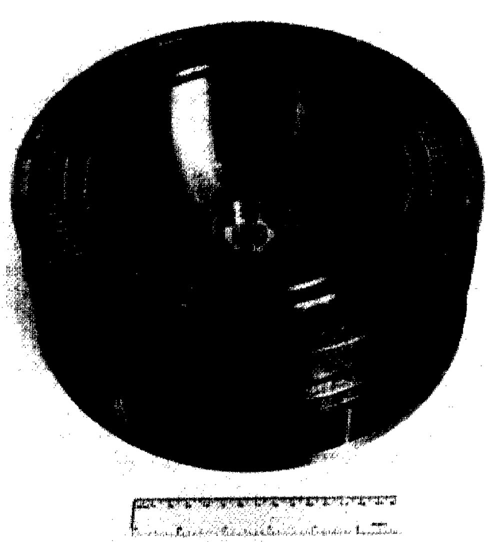

Figure 3. Source chamber.

Results

Long Source

Figure 4 shows the H^- yield as a function of the arc current for a constant source pressure and arc voltage optimized for the highest yield. While the difference between line and circular cusps is not large, the performance of checkerboard cusps was inferior, possibly due to a poorer plasma confinement. Figure 5 shows the ratio of the total H.V. power supply load vs. the H^- yield for the same conditions; again, line cusps were somewhat better than circular. In this experiment a pulsed gas supply was used and the pressure (not measured) was close to the optimum. Figure 6 shows the dependence of the H^- yield on arc current for three different values of source pressure, the cusp geometry was linear. Table I shows the best yields for the three cusp configurations, with neutral gas pressure and arc voltage optimized. All the measurements were done with the plasma electrode floating; grounding of this electrode or applying a positive bias resulted in a reduction of both H^- yield and electron component. The extraction voltage was 6 kV, which was the test stand limit at that time.

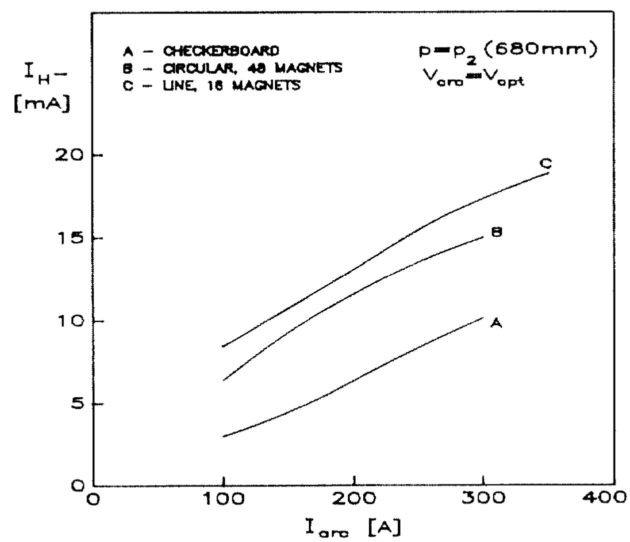

Figure 4. Long source; H^- yield vs. arc current.

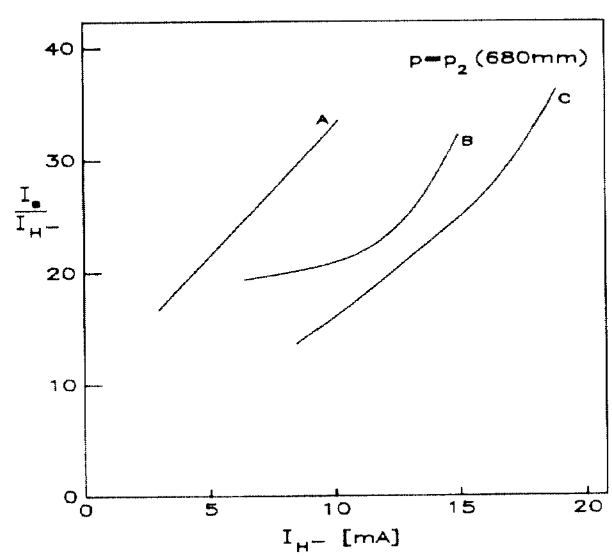

Figure 5. Long source; ratio I_e/I_{H^-} vs. H^- yield.

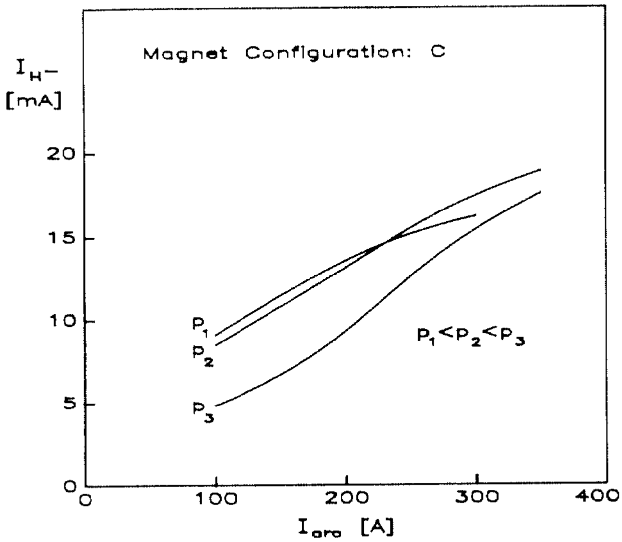

Figure 6. Long source; H^- yield vs. arc current, with source pressure as parameter.

Table I
Long Source Performance (Optimized)

Geometry	Arc Current (A)	Arc Voltage (V)	I_{H^-} (mA)	I_e (mA)	I_e/I_{H^-}
Checkerboard	390	220	14	700	50
Circular	400	220	23	900	39
Line	410	220	20	700	35

Short Source

The source was assembled and ready for initial tests in early May, 1988. Magnetic field distribution measurements have shown that the maximum cusp field strength on the inside chamber wall is more than 0.1 T. By either adding the fifth ring on the top plate or removing the innermost ring on the base plate, an asymmetry is created in the cusp configuration resulting in a roughly conical dipole field around the source axis, with a strength of a few hundred Gauss. It is planned to test all the dipole configurations for the best H^- ion yield.

Most of the discharge and H^- extraction tests were done with a tungsten filament serving as cathode. The arc current was limited to about 200 A; higher currents will be possible after a small modification of the source has been done. A new LaB_6 cathode will be made, better adapted to the short source geometry, consisting of four segments arranged in place of the W filament.

Initial tests, performed only very recently, have shown that it is possible to extract close to 10 mA of an H^- beam current with a performance similar to the best performance of the long source, at comparable power levels. This result is very encouraging because it has been obtained a few days after turning the source on for the first time. Optimization of magnetic field configuration, both dipole and cusps, and of electrode potentials should lead to a substantial increase in the H^- yield.