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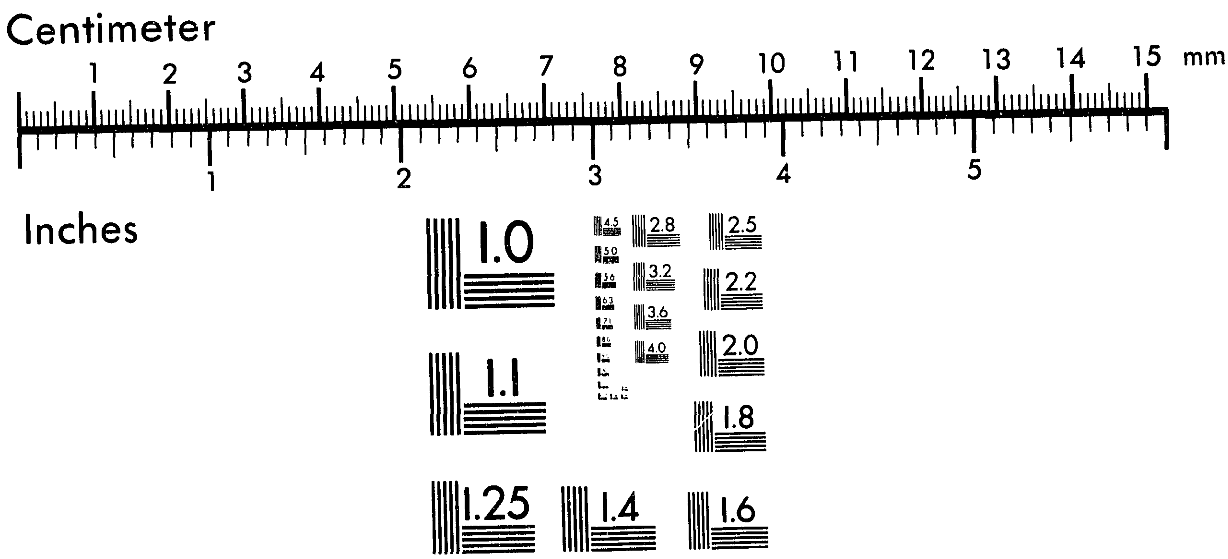

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6th Int'l. Symp. on the Production and Neutralization of Negative Ions and Beams, BNL, 11/9-13/92.

Conf-921145--8

BNL-49073

BNL VOLUME H^- SOURCES*

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ABSTRACT

An H^- current of up 30 mA has been extracted from a 1 cm^2 aperture in a 20 cm diameter volume source with a conical filter field. From a 9.7 cm diameter version of this source, an H^- current of up to 35 mA was extracted from a 0.5 cm^2 aperture. In both sources, the electron-to-H^- ratio is typically < 10, and often < 5.

INTRODUCTION

At BNL, we are continuing to study a type of volume H^- source of novel design. This source has a toroidal plasma generation region, and a conical filter field. Since the previous Symposium in 1989, we have performed further studies of the 20 cm diameter version of this source, and have also now tested a 9.7 cm diameter model of the source. Parametric studies of the two sources show that their performance is very similar. Both sources typically operate with an electron-to-H^- ratio of under 10, an advantage of the unique geometry. Higher H^- current densities can be extracted in the smaller source. Some results of parametric studies of the two sources will be presented in the following sections.

SOURCE GEOMETRIES

The original toroidal volume H^- source[1] has a cylindrical copper source chamber 20 cm ID and 6 cm long. Rings of SmCo magnets line the walls in an arrangement forming circular cusps, with 5 rings of magnets on both the front and back plates, and 3 rings around the sides. A SmCo magnet opposite the extraction aperture (inside the source chamber) produces the conical filter field, since the field lines from this magnet terminate at the innermost ring of magnets around the extraction aperture. The cathode of the source is a single loop of 1 mm diameter W or Ta wire, placed outside the filter region. There is a stainless steel plasma electrode on the front of the source which can be biased.

A scaled down version of this source has been tested more recently. This source has a 9.7 cm ID, and was 2.5 cm long. This was a reduction in the discharge chamber volume by a factor of 10 over the original source. A schematic of this source is shown in Figure 1. Later, the small source chamber was modified to be 4.1 cm long. The filter field magnet was placed outside the discharge chamber in this source.

*Work performed under the auspices of the U.S. Department of Energy.

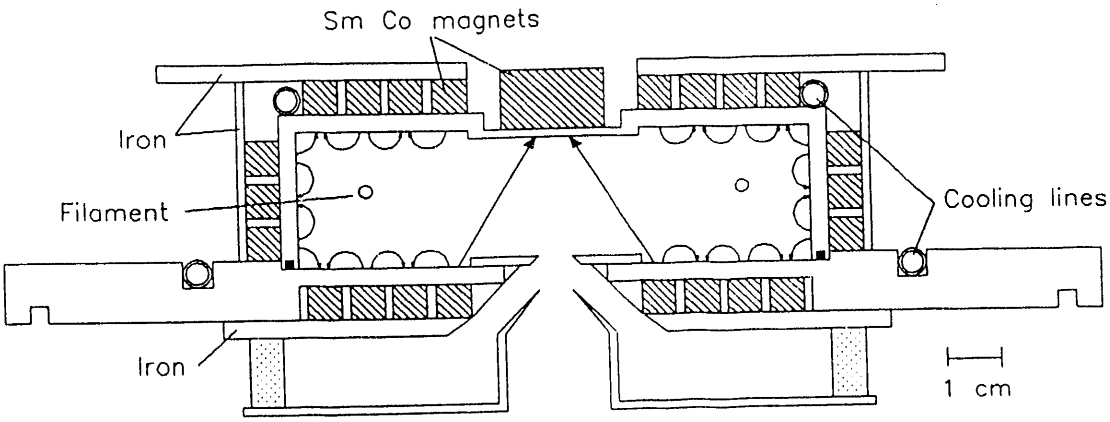

Figure 1. Cross-section of the small ("10 cm") toroidal source. The magnetic cusps and conical filter field are shown schematically.

Both sources were typically operated with a 1.2 ms discharge pulse width, and with the gas pulsed. The extraction voltage was typically 20 kV. The H^- current was measured on a Faraday cup 10 cm from the source, with a dipole magnetic field between the extractor and the Faraday cup to prevent electrons from reaching the cup. (This was checked by operating the discharge in Argon, extracting electrons, and verifying that no negative current was detected on the Faraday cup). The total power supply load was read with a current transformer, and the difference between this current and the Faraday cup current is assumed to be electrons. A slit and collector type emittance head could also be moved in at the Faraday cup location.

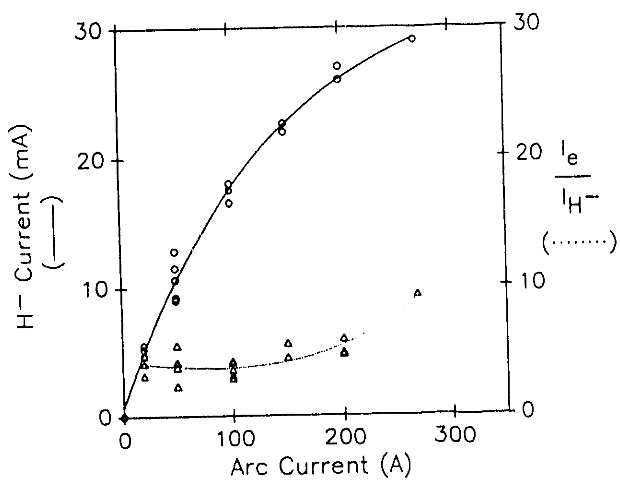

Figure 2. H^- current and e/H^- ratio from the 20 cm source with a 1 cm^2 extraction aperture.

RESULTS

Figure 2 shows the output of the large ("20 cm") source as a function of discharge current, for a 1 cm^2 extraction aperture. From a 1.87 cm^2 aperture, an H^- current of up to 50 mA was extracted. Figure 3 is a plot of the electron-to-H^- ratio vs. H^- current for a variety of source operating conditions, aperture sizes, etc. All results are without any cesium added to the source. In Figure 4, the output of the small ("10 cm") source is shown, for a 0.5 cm^2 aperture. Since we had previously seen that the output of the large source scaled with aperture in going from 0.5 cm^2 to 1 cm^2, one sees that the smaller source gives more than twice the H^- current density at a given discharge current. The electron-to-H^- ratio was similar for the two sources.

Depth of the Discharge Chamber

The small source was tested with a 4.1 cm long discharge chamber, with 5 rows of magnets around the chamber, as well as the 2.5 cm long version having 3 rows of magnets. The H^- current and electron current vs. discharge was the same in both cases, although the discharge volume was increased by 60%.

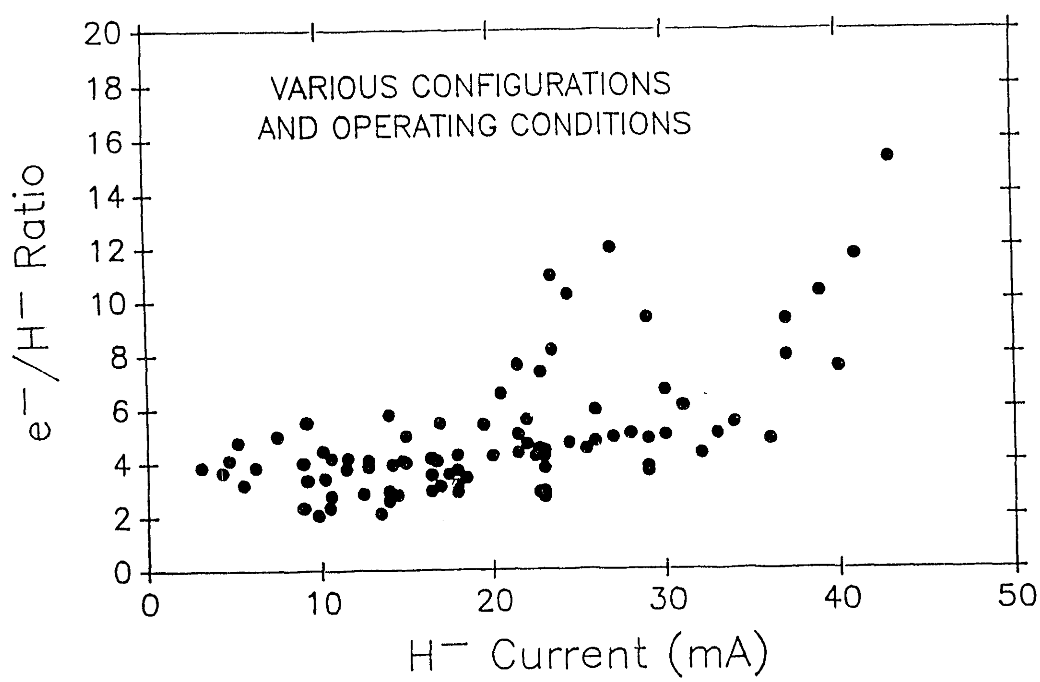

Figure 3. The electron-to-H^- ratio vs. H^- current for a variety of conditions in the 20 cm source.

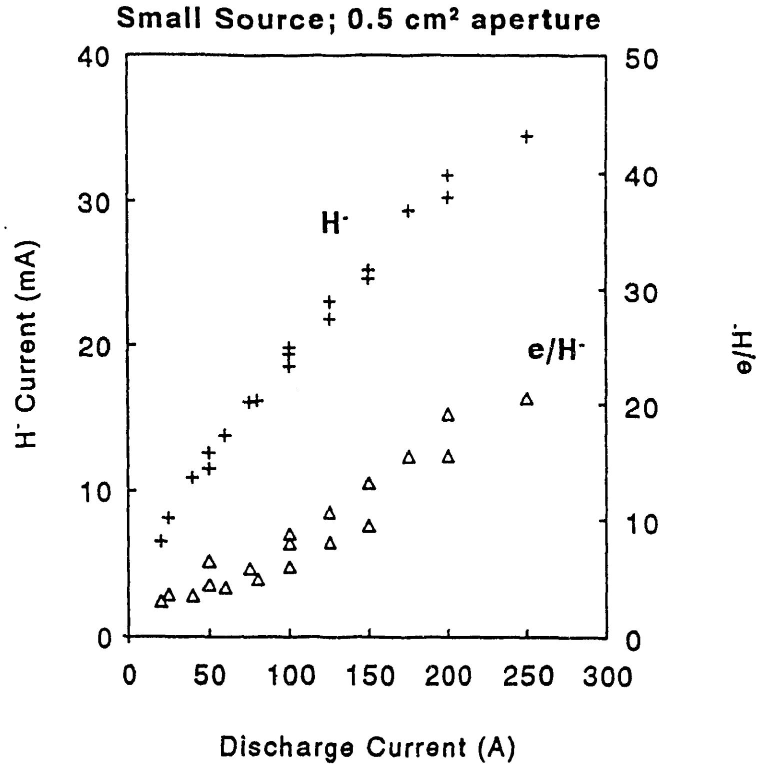

Figure 4. H^- current and e/H^- ratio from the 10 cm source with a 0.5 cm^2 extraction aperture.

Conical vs. Dipole Filter Field

By removing the magnet in the center of the back flange, and rearranging the inner ring of magnets on the front flange, we were able to produce a conventional dipole filter field near the extraction aperture in this source. Figure 5 compares the source operation with the dipole vs. conical filter field. The H^- current is approximately 50% higher, and the e^-/H^- ratio is decreased by more than a factor of 5 with the conical filter field. Similar results were obtained with the 20 cm source.[1]

Conical Filter Field Strength

In the 20 cm source, the strength of the filter field was varied by adding additional magnets outside the back of the source. In the 10 cm source, the filter field was varied by changing the configuration of this magnet in the center of the back plate (position from the back plate, number of magnets, adding an iron return for the magnets, etc.). The effect of these changes on the filter field strength was determined by actual measurements on the source when removed. In both sources, it was important to be at the optimum filter strength. Figure 6 shows, for the small

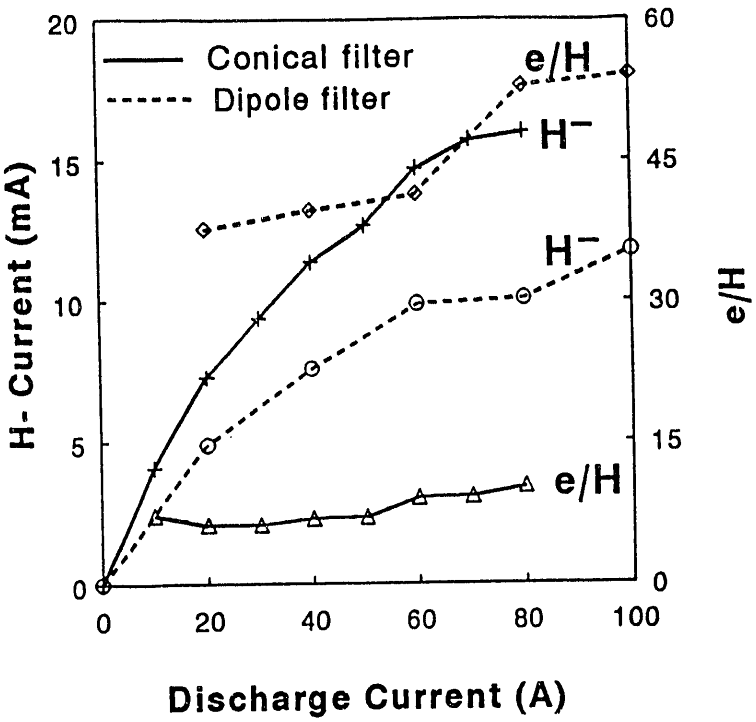

Figure 5. Comparison of the H^- current and e/H^- ratio in the 10 cm source when operated with the conical filter, and a conventional dipole filter field.

source, that the e/H^- ratio drops rapidly with filter strength, while there is an optimum for H^- output. This optimum filter field increases with discharge current. The same dependence on filter field strength was observed in the large source.[1]

Magnetic Cusp Geometry

The geometry of the magnetic cusps in the 20 cm source was changed from the normal circular cusps to radial cusps. The source had 32 lines of magnets of alternating polarity, each going radially out from the front and back flanges, and connected by lines down the side. The conical filter field was formed between the disk magnet in the back of the source, and an 8 cm diameter ring of magnets of opposite polarity around the extraction aperture. The H^- current with the radial cusps was less than half of that measured with the circular cusps, for the same discharge current. The electron-to-H^- ratio was approximately the same for the two geometries, however.

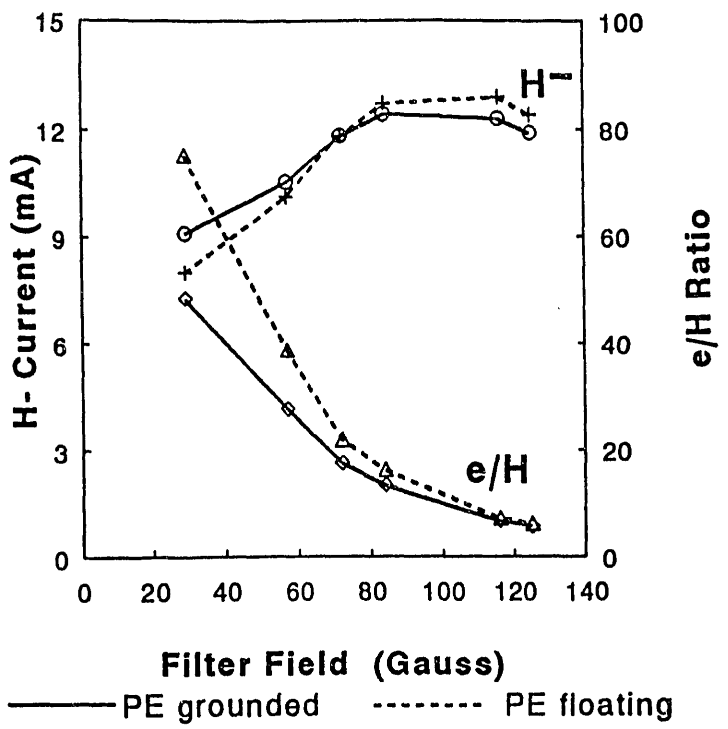

Figure 6. H^- current and e/H^- as a funtion of the strength of the conical filter field in the 10 cm source, at a 50 A discharge current. Dotted line: plasma electrode floating; solid line: plasma electrode grounded. The field shown is that measured at one point in the filter region, and is meant only to indicate the relative change in the field.

Isotope Effect

Both the 10 cm and 20 cm sources were tested with deuterium as well as hydrogen. In both sources, the extracted D^- current was about 60% of the H^- current at the same discharge current. In addition, the e^-/D^- ratio was approximately 4 times the e^-/H^- ratio.

Tungsten vs. Tantalum Filaments

Figure 7 compares the operation of the 10 cm source with W vs. Ta filaments, of the same diameter and shape. It can be seen that with tantalum, the electron-to-H^- ratio was improved. A similar, but less pronounced effect was observed in the 20 cm source.

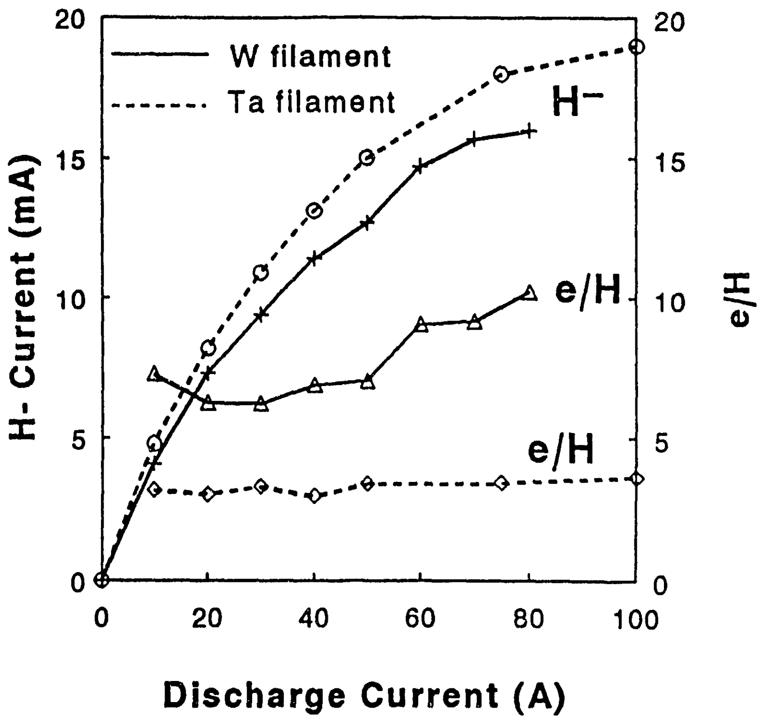

Figure 7. H^- current and e/H^- when operating the 10 cm source with tungsten and tantalum filaments.

Scaling of the Output Current with Aperture

The extracted H^- current vs. discharge current for five different aperture areas in the 10 cm source are shown in Figure 8a, and the H^- current density is shown in 8b. For comparison, the output of the 20 cm source scaled with aperture in going from 0.5 cm^2 to 1 cm^2, but there was a falloff in H^- density at 1.87 cm^2.[1]

Emittance Measurements

Emittance measurements on the 20 cm source with a 1 cm^2 aperture were reported in 1989.[2] The normalized, 90% emittance of a 13 mA beam was found to be $\epsilon_{n,90\%}=0.32$ π mm-mrad. For a 19 mA beam, we measured $\epsilon_{n,90\%}=0.44$ π mm-mrad. For the 10 cm source, with a 0.5 cm^2 aperture, we have now measured for a 23 mA and 35 mA H^- beam, $\epsilon_{n,90\%}=0.4$ and 0.65 π mm-mrad, respectively. In general, the rms emittances for both sources under various conditions correspond to ion temperatures between 0.6 and 3.0 eV.

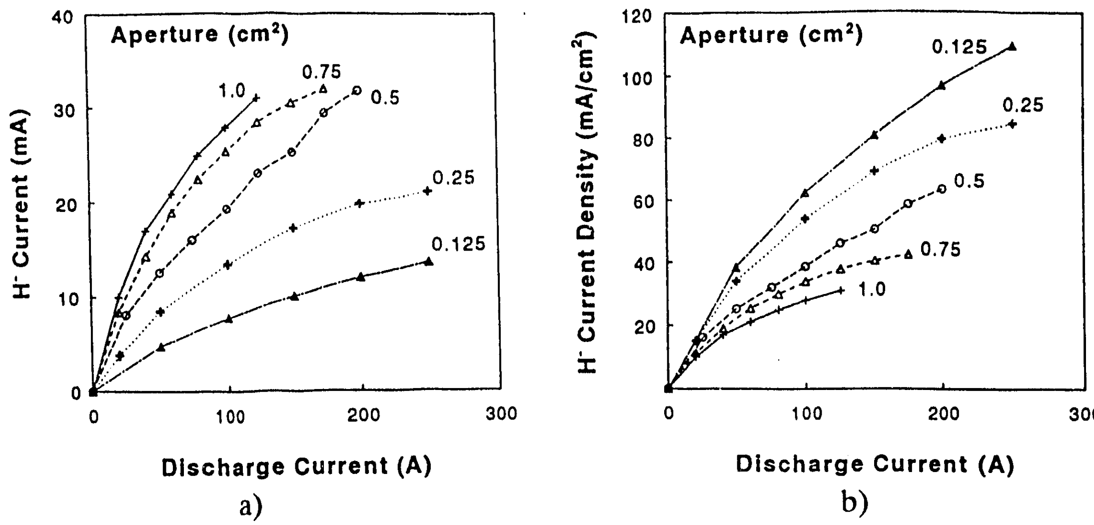

Figure 8. a) H^- current vs. discharge current for five different extraction apertures, for the 10 cm source.
b) H^- current density vs. discharge current for five different extraction apertures.

Effect of Cesium

A small cesium dispenser was placed in the discharge chamber of the 20 cm source.[3] We found that the addition of Cs approximately doubled the H^- current, while reducing the e/H^- ratio to less than 1. The operating pressure of the source could be reduced by approximately a factor of two.

Steady State Operation

Although neither source was designed for steady state operation, both have been operated dc at low discharge currents. In the 20 cm source, an H^- current of 6 mA was extracted from a 1 cm^2 aperture, with a 20 A, 150 V discharge.[4] With the 10 cm source, a D^- current of 0.91 mA was extracted at a 5 A, 90 V discharge. In both cases, the electron-to-H^-(D^-) current was 2-3 times higher than what one measured in pulsed operation.

CONCLUSIONS

Two size toroidal volume H^- sources, with discharge volumes differing by an order of magnitude, have now been tested. The performance of both sources was found to be very similar, with the same dependence on filter field, gas pressure, filament material, etc. A higher H^- current densities could be extracted from the smaller source. Both source have electron-to-H^- ratio which are typically < 10, and often 2-5. This feature seems to be the result of the conical filter field, as demonstrated by the much larger e/H^- ratios measured when both sources were modified to have a dipole filter field.

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