BNL VOLUME H^- SOURCE RESEARCH*

J.G. Alessi, D. McCafferty, K. Prelec
AGS Department
Brookhaven National Laboratory
Upton, NY 11973 USA

Abstract

At BNL, work is in progress on the development of a volume production H^- ion source having a toroidally shaped plasma generation region and a conical filter field. With the original, 20 cm diameter source,[1] up to 50 mA of H^- was measured at a current density of 25 mA/cm^2 in pulsed operation. In first results with a version of this source scaled down to 9.7 cm diameter, up to 25 mA of H^- at a current density of 50 mA/cm^2 has been obtained. In both sources the extracted electron current is typically 3-10 times the H^- current.

Introduction

A magnetron surface-plasma source has been used for H^- injection on the BNL 200 MeV linac for the past 10 years. This source delivers 70-100 mA of H^- in 500 μs pulses, and is capable of operating continuously for 4-6 month running periods. In spite of this good performance, we have been doing development on volume H^- ion sources at BNL as a possible future replacement for the magnetron. The volume source has the advantage of being easier to operate and maintain, since it does not require the use of cesium for H^- production. It may also produce a lower emittance beam, since the H^- ion temperature is lower in this source than in surface-plasma sources.

The BNL volume H^- ion source is unique in that it has a conical filter magnetic field, rather than a dipole filter field as is used in other volume H^- sources. This difference has resulted in a lower than normal ratio of extracted electron - to - H^- current, which is usually quite large in other volume sources. The performance of the initial 20 cm diameter version of this source was presented at the previous Linac Conference.[1] By subsequently increasing the strength of the filter field, the extracted electron current was reduced to the point where H^- currents in excess of 30 mA could be obtained with an electron-to-H^- current ratio of less than 5.[2] In this paper, the results of studies of a version of the source scaled down by approximately a factor of two in all dimensions (i.e., one eighth of the discharge volume) will be presented. Some comparisons will be made between the two sources.

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Source Geometry

A cross section of the source is shown in Figure 1. Magnetic field lines are indicated schematically in order to illustrate the formation of the conical filter field. The copper discharge chamber is cylindrical, 9.7 cm inner diameter, and 2.5 cm deep. As will be described later, tests were also made with the chamber modified to be 4.1 cm deep. The front wall of the source is aluminum, and the stainless steel plasma electrode, through which ions are extracted, can be biased. Rings of SmCo magnets of alternating polarity, on the outside of the source, form the magnetic cusp fields for plasma confinement. The strength of the magnetic field at the inner wall of the source is approximately 1 kG. A magnet in the center of the back flange of the source produces the filter field. The filament, 1.0 mm diameter W or Ta wire is a single loop of approximately 6 cm diameter, placed outside of the filter field region. The cathode voltage is applied to the filament. The source anode aperture is 8 mm diameter, and the extraction gap is 10 mm. Operation of the source was primarily in the pulsed mode, with a 1.2 ms discharge width. The extraction voltage was dc, and typically 20 kV. The measurement setup was the same as described in Ref. 1.

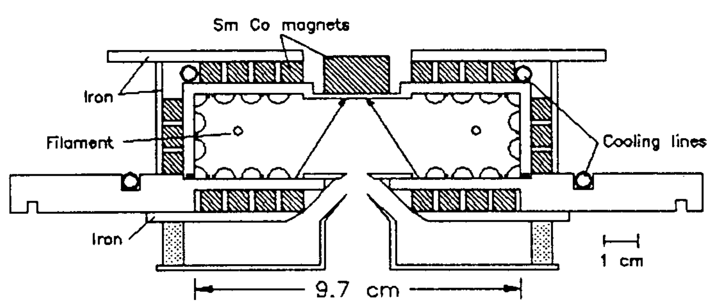

Fig. 1 - Cross section of the small BNL volume source. Magnetic field lines are shown schematically.

Results

Figure 2 shows the H^- current and e/H^- ratio as a function of discharge current for the small ("10 cm") BNL volume source with a 0.5 cm^2 extraction aperture. Also shown for comparison is a result with the large ("20 cm") BNL volume source, with a 1 cm^2 extraction aperture. In both cases, a Ta filament was used. Previous studies on the 20 cm source had shown that the H^- current scaled with aperture area in going from 0.5 cm^2 to 1 cm^2.[1] Therefore, from these results, one sees that the two sources have similar e/H^- ratios, but that the small source gives more than twice the extracted current density at a given discharge current.

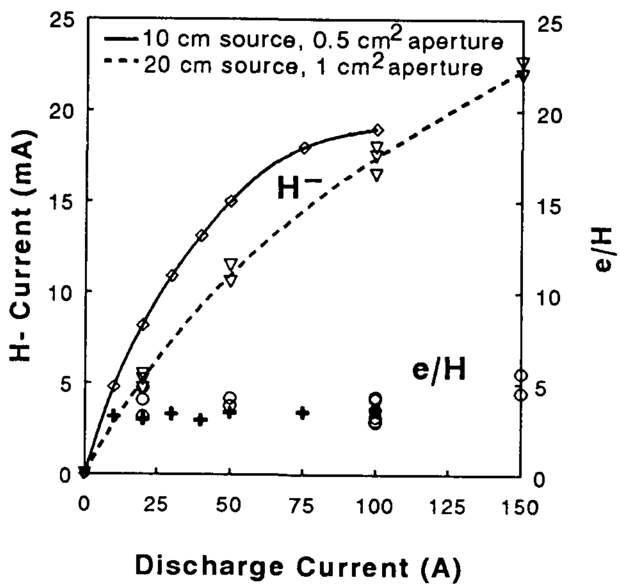

Fig. 2 - Comparison of the H^- current and electron-to-H^- ratio vs. discharge current for the 10 cm and 20 cm diameter BNL sources.

Depth of the Discharge Chamber

The discharge chamber of the small source was modified from the initial configure shown in Figure 1, in which the chamber depth was 2.5 cm with 3 rows of magnets around the chamber, to one in which the chamber was 4.1 cm deep, with 5 rows of magnets. Although this increased the discharge volume by approximately 60%, the performance (H^- and electron currents vs. discharge) was the same in both cases.

W vs. Ta Filaments

Figure 3 compares the source performance with tungsten and tantalum filaments. This improved performance with Ta was similar to what was observed in the 20 cm source.

Filter Field Strength

The performance of the 10 cm source as a function of the strength of the conical filter field is shown in Figure 4. These data were taken with a 50 A discharge current. The effect of the field strength is shown both for operation with the plasma electrode floating and grounded. The filter field strength was varied by changing the magnet in the center of the back flange. 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.

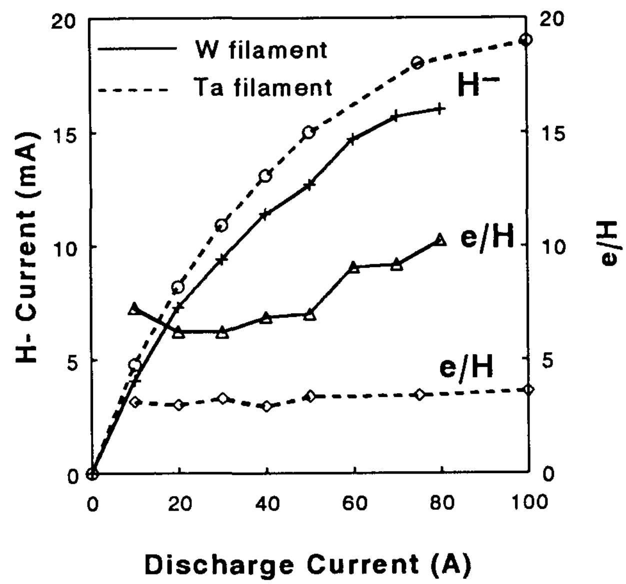

Fig. 3 - H^- current and electron-to-H^- ratio vs. discharge current when operating the source with tungsten and tantalum filaments.

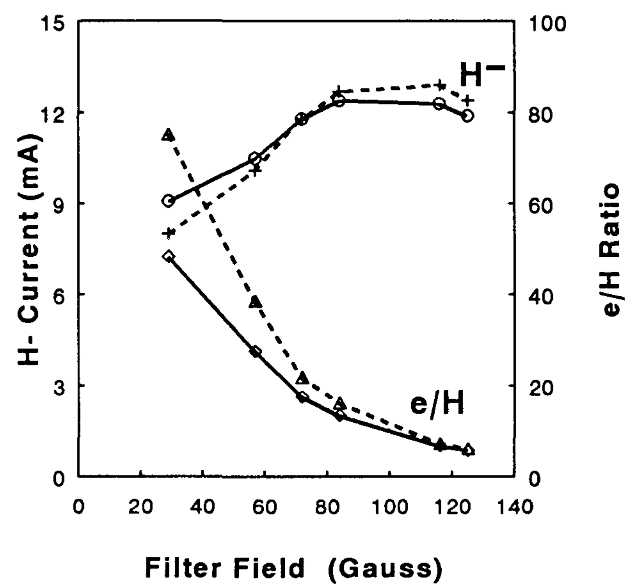

Fig. 4 - H^- current and electron-to-H^- ratio as a function of the strength of the conical filter field. Dotted line: plasma electrode floating; solid line: plasma electrode grounded. Discharge current = 50 A.

Comparison with a Conventional Dipole Filter

The center magnet in the back flange was removed, and the ring of magnets closest to the extraction aperture was modified in order to produce a dipole field near the extraction aperture, to act as the filter. Figure 5 shows the H⁻ current and e/H⁻ ratio for both the dipole filter and the conical filter geometries (both with a W filament). One sees the dramatic decrease in electrons when the conical filter is used, as well as an approximately 50% increase in H⁻ current. Similar results had been obtained previously with the 20 cm source.

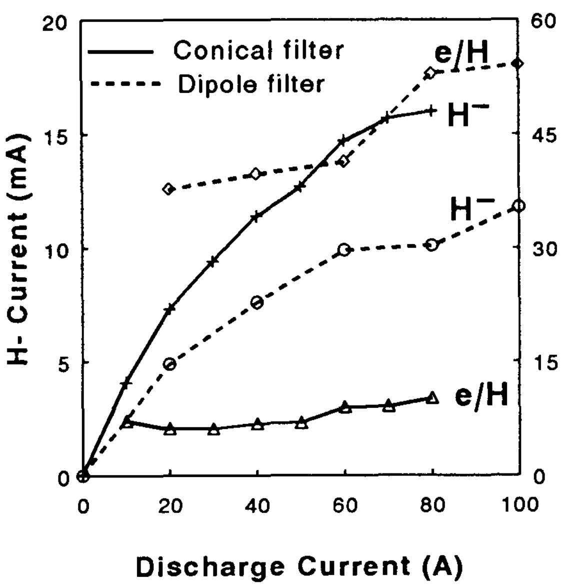

Fig. 5 - H⁻ current and electron-to-H⁻ ratio vs. discharge current for the conical and dipole filter field geometries.

Conclusions

To date, studies of the smaller volume source have shown that a higher H⁻ current density can be extracted than that obtained with the larger source, while maintaining the low e/H⁻ current ratio. The addition of a small amount of xenon gas to the discharge increases the H⁻ current by approximately 20%, while the e/H⁻ ratio is increased by a similar ratio. In this way, up to 25 mA has been measured from this small source to date. Further studies of this source are planned, including tests of the scaling of the output with extraction aperture size, and emittance measurements of the extracted H⁻ beam.

References

[1] J.G. Alessi and K. Prelec, Proc. 1990 Linear Accel. Conf., Los Alamos Report LA-12004-C (1991) 671.

[2] J.G. Alessi and K. Prelec, 1991 IEEE Part. Accel. Conf., 91CH3038-7 (1991) 1913.