Characteristics of the H^-/D^- Beam Extracted from an RF-Driven Volume Source

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Abstract

The tungsten filament cathode normally used in negative-ion volume sources is the component responsible for most periodic maintenance of the source. In addition, contamination due to filament sputtering during source operation eventually degrades performance when plasma additives are used. These problems are greatly alleviated by replacing the filament with an RF antenna. Previous experiments[1,2] have shown that an RF antenna produces higher H^- current density at the same source power, and that the emittance and divergence of RF-driven sources and filament-based sources are comparable. In this paper, the characteristics of the D^- beam produced in an RF-driven multi-cusp volume source are reported as a function of source power and equivalent current. These characteristics are compared to those of H^- beams from RF-driven sources, and to H^- and D^- beams from filament-based sources.

I. INTRODUCTION

Lawrence Berkeley Laboratory (LBL) and Grumman recently completed a collaborative effort to compare the effect on H^-/D^- beam characteristics of replacing the filaments in a negative ion volume source with an RF antenna. The configuration was almost identical to that shown in Fig.'s 1 and 2 of reference [1], except that the extractor geometry was modified to the Pierce-like geometry shown in Fig. 1. LBL provided a glass-coated copper antenna, the matching network, and the associated 50 kW, 2 MHz power supply. Grumman provided the test stand and diagnostic station. First, H^- and D^- beam characteristics from Grumman's existing 10 cm diameter multi-cusp volume source were measured, using filaments, over a range of input arc power. Emittance and divergence were mapped out with an electrostatic LANL-type scanning pod[3] located 13.7 cm from the extractor. Then, the filament backplate was replaced by the new antenna backplate in the same discharge chamber, and the measurements were repeated over a similar range of input RF power. The optimum filter field strength for maximum H^- output current was ≈200G, somewhat higher than that with filaments (120G). The same fields were used for the D^- data (i.e. 120G for the filament case and ≈200G for the RF case). Thus, the comparisons discussed in this paper are for optimum filter field strength for H^- rather than the same filter field strength.

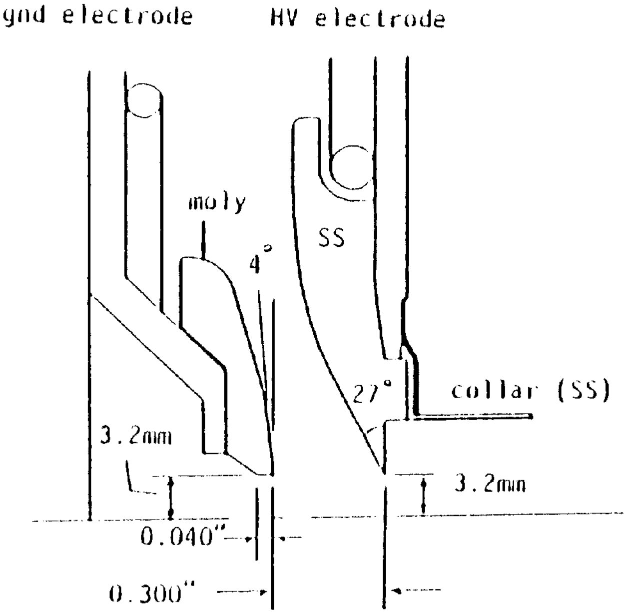

Fig. 1 Pierce-like extraction geometry.

For all measurements, argon at a partial pressure of 4×10^{-5} torr or xenon at a partial pressure of 1.4×10^{-5} torr was introduced into the vacuum tank for space charge neutralization.

II. RF/FILAMENT COMPARISONS

A. D^- Current and Electron-to-D^- Current Ratio

Fig. 2a compares the dependence of D^- current vs input power for RF vs filaments. As observed with H^-[1,2], RF is more efficient than filaments at producing the negative ions. The peak efficiency using RF or filaments is about 3x lower for D^- than for H^-. Electron/D^- current ratios are compared in Fig. 2b. The ratio is lower using RF since the filter field is higher. At a given input power, the ratio using

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RF or filaments is about 4x higher for D$^-$ than for H$^-$. At low power, the current in the RF cases is reduced because the antenna match was not optimized for low power operation. If the match was retuned for low power operation, those current levels would have increased.

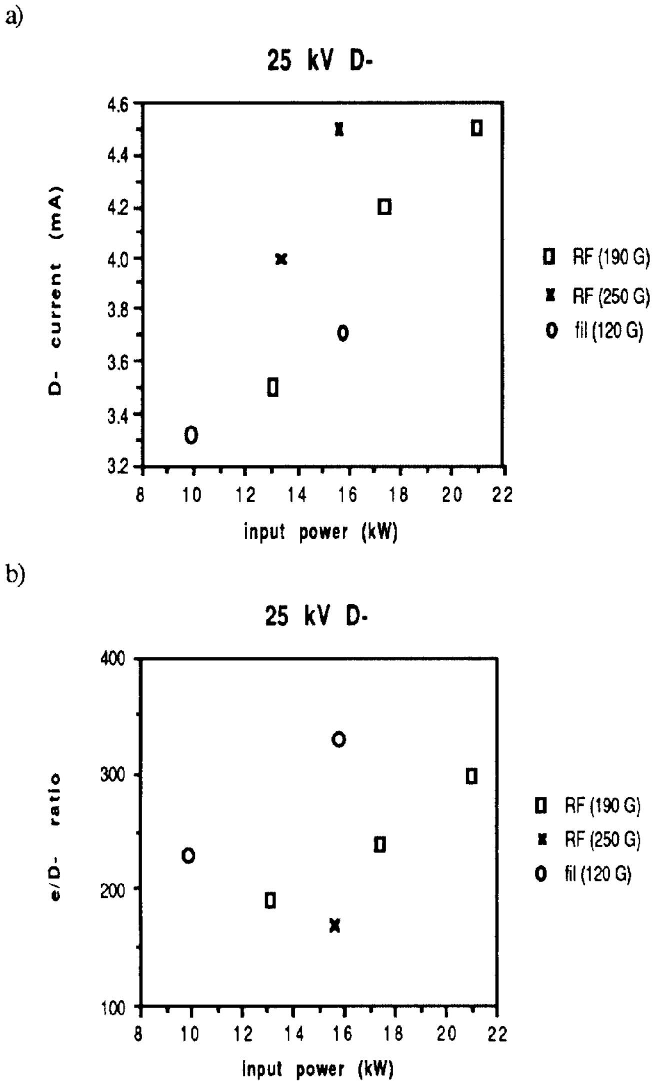

Fig. 2 a) D$^-$ current vs input power for RF and filaments and b) electron-to-D$^-$ current ratio vs input power for RF and filaments.

B. Emittance

Since emittance is a function of beam perveance ($\propto I_{equiv}/V^{3/2}$), it is important to know this dependence when making comparisons. Fig. 3 compares beam divergence vs equivalent H$^-$ current, $I_{equiv,\,H^-}$, for various cases where:

$$I_{equiv,\,H^-} = I_{H^-} + I_e/42.8 \text{ for hydrogen}$$

$$= \sqrt{2}\, I_{D^-} + I_e/42.8 \text{ for deuterium}$$

and beam divergence is taken as twice the rms angular divergence.

The solid line shows a parabolic fit to H$^-$ results at 25 kV using RF. At ≈42mA, the beam divergence is minimum ("on perveance"). Divergence increases at lower currents ("underdense"), and would have increased if higher currents had been obtained ("overdense"). This conclusion is supported by some 20 kV results (not shown) where the data did extend to overdense operation and a minimum divergence was clearly identified at ≈31mA, which is approximately the value expected based on $V^{3/2}$ scaling. H$^-$ results using filaments and D$^-$ results using RF and filaments are superimposed on the plot. Clearly, all the data is for underdense to on perveance operation.

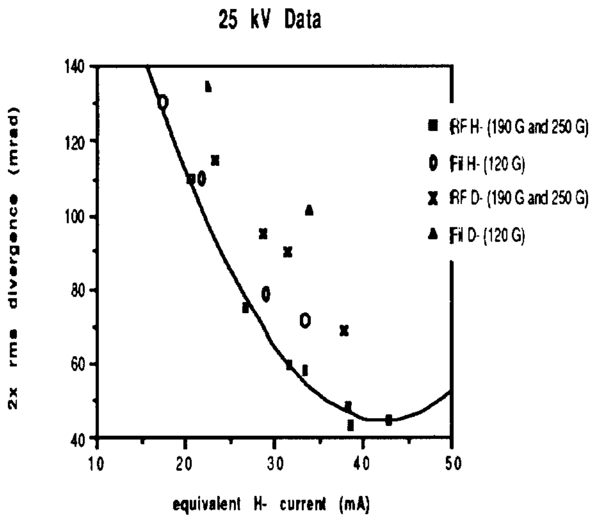

Fig. 3 Divergence vs equivalent H$^-$ current.

Fig. 4 compares the normalized rms emittance at 100% beam fraction vs equivalent H$^-$ current and actual D$^-$ current for these cases. The data for the filament and RF H$^-$ cases shows the typical variation of emittance with perveance ($\propto$ equivalent current). This data illustrates a couple of features always observed with this source: 1) the emittance is always high for underdense and overdense operation due to poor extraction optics for these cases, and reaches a broad minimum in between, and 2) this minimum always occurs at an equivalent current somewhat lower than that where divergence is minimum. The D$^-$ data for filaments and RF is superimposed. The source pressure during D$^-$ operation appears to have been a bit low because the D$^-$ current drooped significantly (up to 30%), and a large (up to 20%) noise level in the current was observed toward the end of the 1 ms pulse. These problems, especially the large noise level, result in a source of random error in the data analysis, so the D$^-$ points do not lie on as smooth a curve as the H$^-$ points. Nevertheless, it is clear that the D$^-$ data follows pretty much the same curve in Fig. 4a as the H$^-$ data. Fig. 4b shows that RF produces a brighter D$^-$ beam than filaments produce, just as it produces a brighter H$^-$ beam.

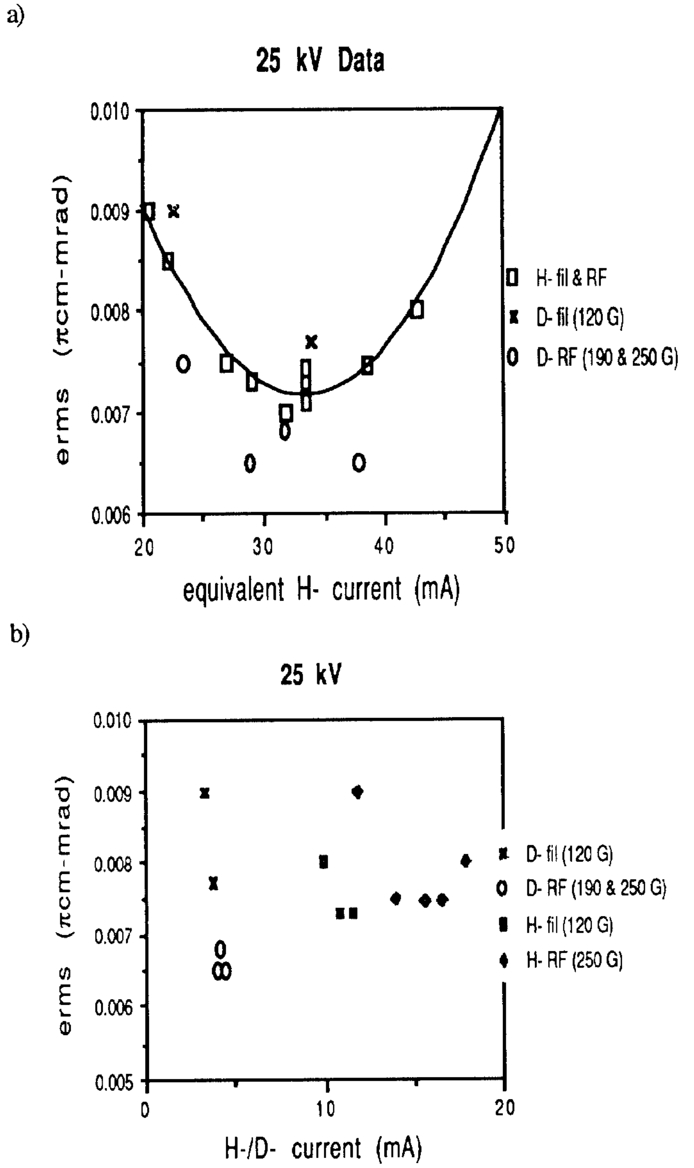

Fig. 4 a) 100% normalized rms emittance vs equivalent H^- current for RF and filaments and b) vs actual H^- or D^- current as indicated by the legend.

III. CONCLUSIONS

At the same equivalent H^- current, the normalized rms emittance using the RF antenna was about the same as that using filaments. At the optimum filter field strength, the D^- current was up to 20% higher at a given input power level, and the peak brightness was 20-30% higher. Since the optimum filter field strength was higher with RF, the electron-to-D^- current ratio was lower with RF. All these conclusions favor the use of RF to form a high brightness negative ion beam.

IV. REFERENCES

[1] K.N. Leung et. al., "RF Driven Multicusp H^- Ion Source", Rev. Sci. Instrum. 62, pp. 100- 104, (1991).

[2] G. Gammel et. al., "Emittance Measurements on an RF-Driven H^- Volume Source", in Proceedings of the Third NPB Technical Symposium, Boulder, Colorado, 16-19 April 1991 (in press).

[3] R. Heuer et. al., "A New Stand-Alone Beam Emittance Measurement System", Nucl. Instrum. and Meth., B42 pp. 135- 137, (1989).

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