Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

Accelerator & Fusion Research Division

Presented at the Third European Workshop on the Production and Application of Light Negative Ions, Amersfoort, The Netherlands, February 17–19, 1988, and to be published in the Proceedings

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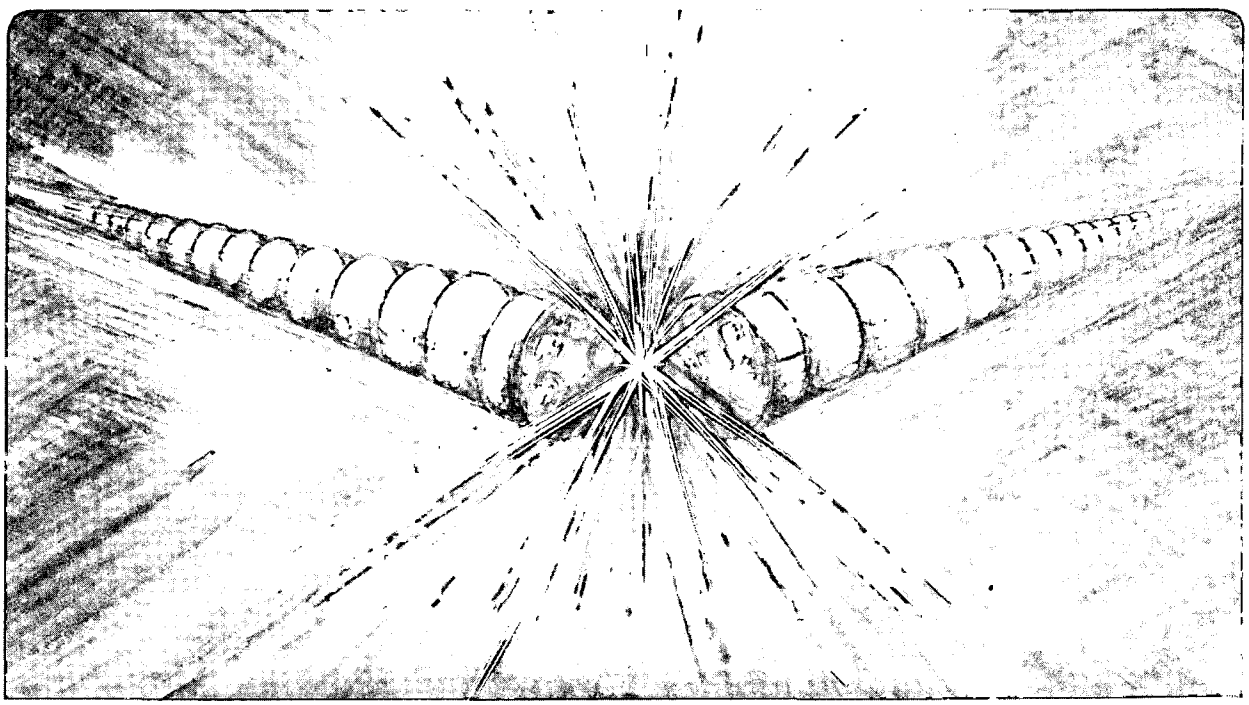
February 1988



Prepared for the U.S. Department of Energy under Contract Number DE-AC03-76SF00098.

DISCLAIMER

Enhancement of Volume H^- Production by Vibrationally Pre-exciting the Hydrogen Molecules*

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H^- and D^- ions have useful applications in high-energy accelerators and in neutral beam heating, or for current drive of fusion plasmas. Among the different techniques for producing H^- ions, direct extraction from a hydrogen discharge is the most attractive. This method requires no cesium and the H^- ions generated by volume processes have lower average energy than those formed by surface conversion or by charge exchange processes. For this reason, intensive research and development of volume H^- sources are now being conducted at various accelerator and fusion laboratories.

High quality volume-produced H^- beams have been generated from a multicusp source equipped with a permanent magnet filter.[1] It has also been demonstrated that a large improvement in H^- yield can be achieved by employing a small multicusp source, fabricated with the proper wall material and extraction chamber length.[2] From this small source, H^- current densities in excess of 250 mA/cm^2 have been extracted from a 1-mm-diam aperture for a discharge voltage of 150 V and a discharge current of 450 A. In order to improve the discharge and gas efficiencies, a new source configuration in which the hydrogen molecules are vibrationally excited before entering into the main source chamber has been examined. This article describes the experiment and its preliminary results.

In the past, several theoretical models have been developed in an effort to explain the H^- yield in the tandem discharge geometry.[3] It is generally assumed that the H^- ions are formed by the two-step dissociative attachment process.[4] By use of a mixture of xenon and hydrogen gas, it is found that the

* Work is supported by AFOSR, USASDC and U. S. DOE under Contract No. DE-AC03-7600098

Paper will be included in the proceedings of the Third European Workshop on the Production and Application of Light Negative Ions, Amersfoort, The Netherlands, February 17-19, 1988.

production of H^- ions in the tandem discharge geometry is indeed consistent with a model of dissociative attachment of low-energy electrons to vibrationally excited hydrogen molecules.[5]

Recently, two research groups in Europe observed vibrationally excited molecules that are produced in a gas chamber operated with a hot tungsten filament.[6] The interpretation is that neutral hydrogen atoms are first made by H_2 gas dissociating on the hot filament. These atoms in turn form vibrationally excited molecules $H_2(v")$ by recombinative desorption with other atoms on the chamber wall. In order to study the importance of this newly discovered process in volume H^- sources, an experimental investigation was first performed in a small multicusp source as shown schematically in Fig. 1.

The multicusp ion source is fabricated from a cylindrical water-cooled copper chamber (2.5 cm diam by 5 cm long) with the open end enclosed by a two grid ion extraction system. The source chamber is surrounded externally by 16 columns of small ceramic magnets to form a longitudinal line-cusp configuration for primary electron and plasma confinement. The use of 16 columns of magnets, as opposed to a smaller number, allows a larger "field-free" region where the filament is placed and primary electrons are emitted. The magnet columns on the cylindrical wall are connected at the end flange by two rows of samarium cobalt magnets that are also in a line-cusp configuration.

A samarium-cobalt magnetic filter near the plane of extraction divides the chamber into an arc discharge and an extraction region. The filter magnets provide a transverse magnetic field (~ 250 G at center) which serves to prevent energetic primary electrons from reaching the extraction region. However, positive ions and low energy electrons can diffuse across the filter into the extraction region.

A two-electrode acceleration system is attached to the open end of the source chamber. Hydrogen gas is first indroduced into a smaller "dissociator" chamber before entering into the source discharge chamber. The dissociator chamber is water cooled and it contains a 3.1-mm-wide tungsten strip filament. Hydrogen gas molecules enter the dissociator and some are

dissociated by the hot tungsten strip. The copper walls of the dissociator and the connecting pipe are water-cooled. The dissociated atoms can recombine on these cold surfaces to form vibrationally excited molecules and subsequently enter the ion source.

A plasma is produced by electrons emitted from a 0.5-mm-diam hairpin tungsten filament. The chamber wall serves as the anode for the discharge. The plasma electrode can be biased independently of the anode to optimize H^- ion extraction. Located downstream from the second electrode of the extractor is a compact magnetic deflection spectrometer for measurement of the ion species in the extracted beam.

To test the effect of the dissociator, the ion source was first operated with a discharge power of 80 V, 1 A and with the dissociator filament switched off. Figure 2(a) shows the H^- output signal as measured by the mass spectrometer. With the same arc parameters and gas flow, the heating current of the tungsten strip was then turned on. Although the H^- output signal increased initially, the signal returned to approximately the value obtained without heating the filament strip, as illustrated in Fig. 2(b). The same measurement was repeated for a wide range of dissociator filament temperatures (from 0 to 2800 C) and similar results were observed. The initial increase in H^- ion output is presumably due to an increase in the source pressure when out-gasing occurs from the dissociator walls.

There are several possible reasons why there is no significant improvement in H^- output when the dissociator filament strip is heated. The dissociator may indeed provide vibrationally-excited molecules through the recombinative desorption process. But this excitation can be lost due to wall collisions in the connecting tube. Another possibility is that the vibrational excitation provided by the source discharge is large enough to mask the effect of additional vibrationally-excited molecules entering the ion source from the dissociator chamber.

In order to resolve the first problem, a double chamber system with no connecting tube has been designed and fabricated (Fig. 3). In this configuration, the dissociator and the ion source chamber (both 7.5-cm-diam) are connected through a large 3-cm-diam aperture. In addition, a pair of ceramic-magnet

filter rods (B ~ 100G) was installed at the separation plane. A hydrogen plasma (80V, 2A discharge) was first generated in the source chamber and the H^- signal was recorded by the mass spectrometer (Fig. 4(a)). When the tungsten ribbon filament (5-mm-wide) in the dissociator was turned on, a slight increase (<10%) of the H^- output signal (Fig. 4(b)) was observed when the ribbon filament temperature reached about 2000^o C.

A hydrogen discharge was then generated in the dissociator chamber with about the same discharge power as in the front source chamber. The H^- signal (Fig. 4(c)) is observed to increase by approximately 20%. In this case, the two chambers are electrically connected and therefore no flow of plasma is expected. The increase in H^- output can arise from an increase in vibrationally-excited molecules coming from the dissociator chamber. This result seems to indicate that it is more effective to produce vibrationally excited H_2 by electronic collisions than by the recombinative desorption process. However, if a positive potential is now applied on the rear dissociative chamber with respect to the front source chamber, the H^- output signal increases by a factor of two as illustrated by Fig. 4 (d). By biasing the dissociator chamber more positive than the source chamber, positive ions and also electrons are "pouring" from the rear to the front chamber. As a result, both the plasma density and the number of vibrationally excited molecules in the front source chamber and therefore the H^- yield is enhanced.

With this new configuration, we expect the source can be operated with lower pressure and perhaps in a long pulse or cw mode to generate high H^- current density. Work is now in preparation for higher discharge power testing and the results will be reported.

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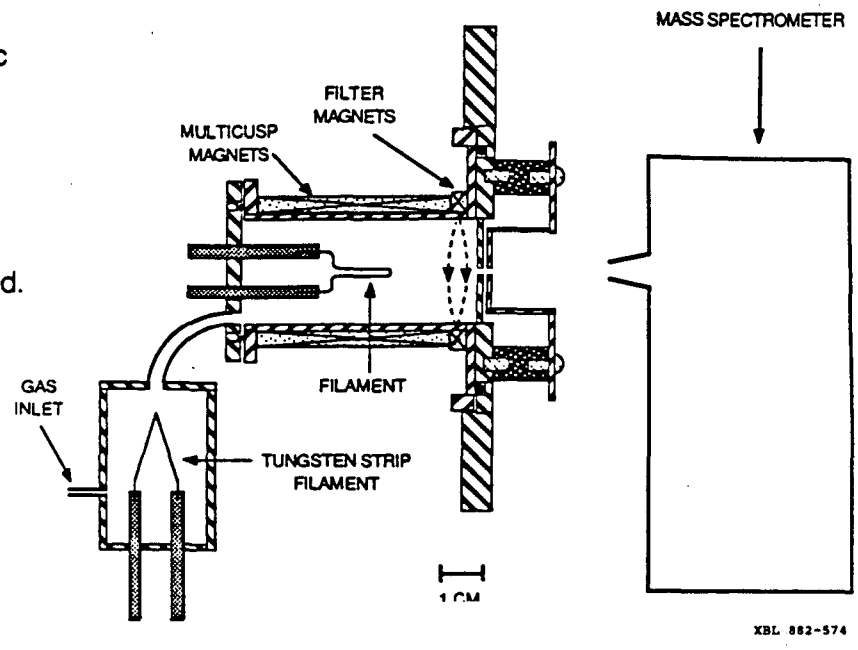
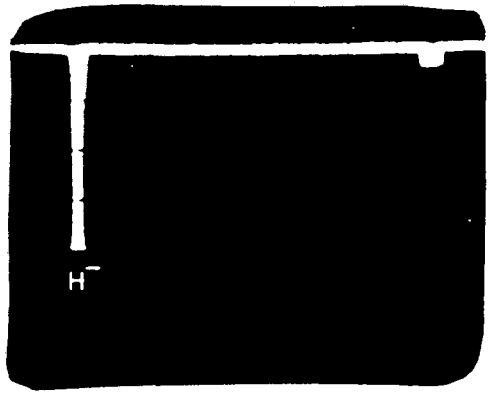
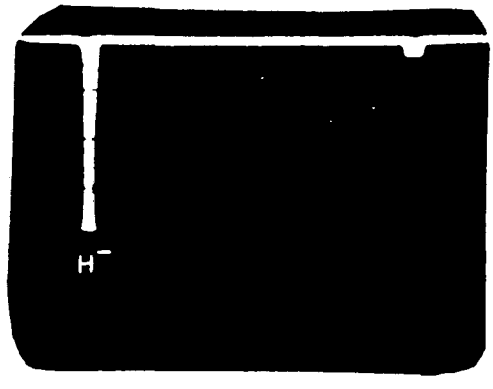
Fig. 1 A schematic drawing of the filtered multicusp ion source with a dissociator attached.





(a)



(b)

Fig. 2 Mass spectrometer output signal showing (a) the H^- ion output for operation without the dissociator, and (b) the H^- ion output for operation with the dissociator filament heated.

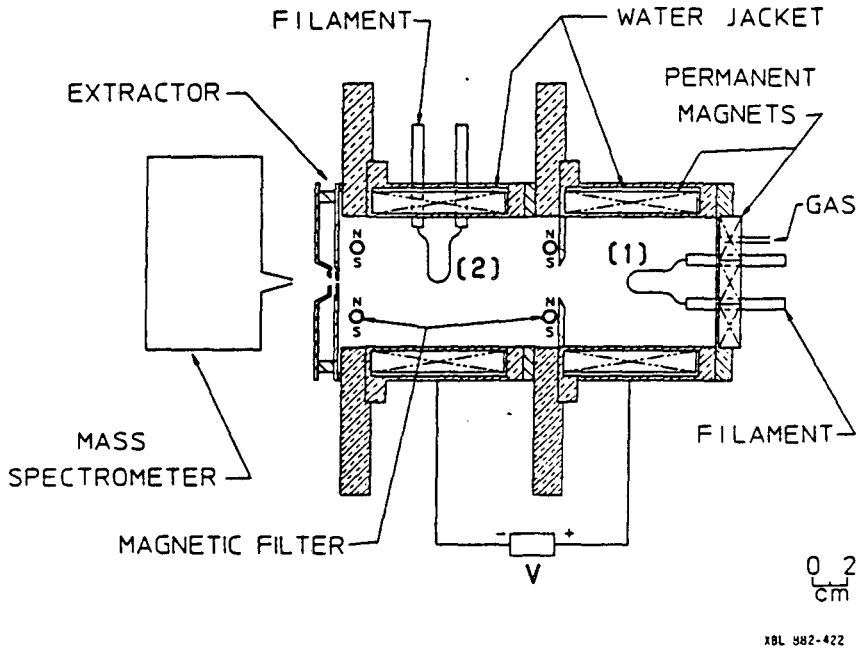


Fig. 3 Schematic diagram of the double chamber system.

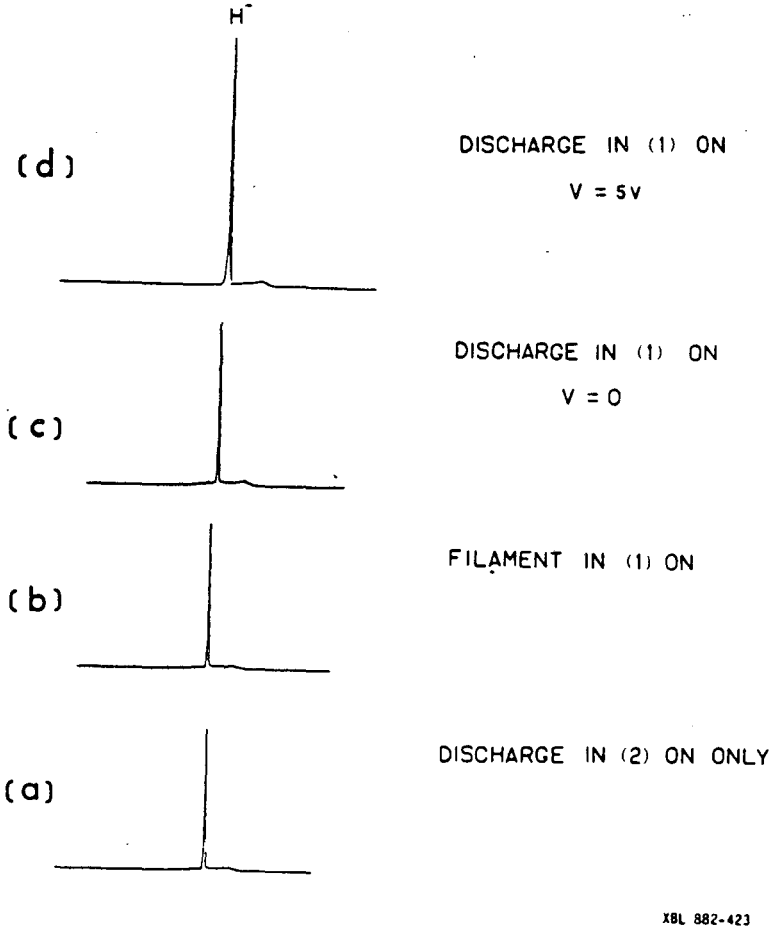


Fig. 4 Spectrometer signals showing the H^- output under different source operating conditions.

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