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January 1985

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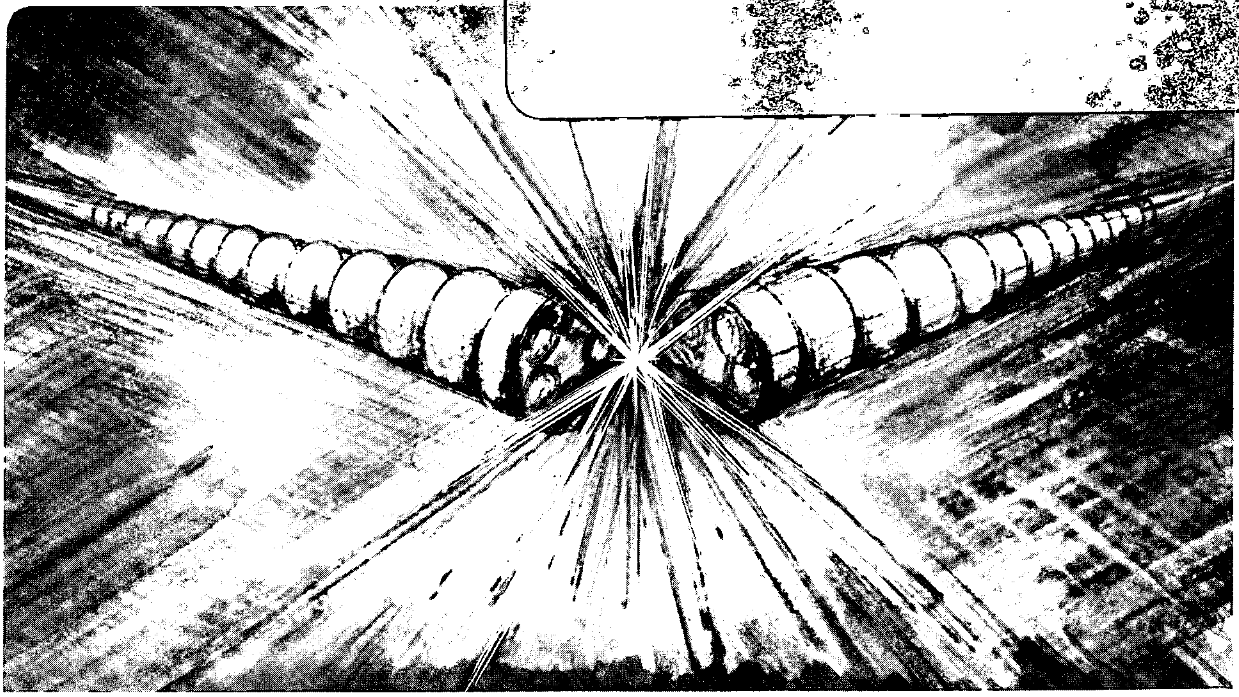

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A Small Mass-Spectrometer Probe for Analyzing Hydrogen-Ion Species*

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Abstract

The characteristics of a small, water-cooled, 90° magnetic deflection mass-spectrometer suitable for analyzing positive and negative hydrogen ion species is described.

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A hydrogen plasma contains electrons and ion species such as H^-, H^+, H_2^+, and H_3^+. In order to investigate the characteristics of such plasmas, knowledge of the distribution of these ions is always desired. The simplest technique to measure the ion species distribution is to use a magnetic deflection mass-spectrometer.[1] The magnetic field B for deflecting an ion of mass M_i and energy E to a gyroradius R is given by

$$B(\text{gauss}) = 144\ [\mu E(\text{eV})]^{1/2}/R(\text{cm}),$$

where $\mu = M_i/M_p$ and M_p is the proton mass. Different hydrogen-ion species can be identified from the known energy E and the measured B field.

In this paper, the design and operation of a miniature mass-spectrometer is presented. This spectrometer is well water-cooled and therefore can be placed inside a high density hydrogen discharge. Since the size of this device is relatively small (5 x 5 x 5 cm^3), it will not produce a large perturbation of the plasma being studied.

Figure 1 is a schematic diagram of the spectrometer. A stainless-steel pill box is installed in the gap between the two solenoidal coils (each magnet coil has 550 turns of 0.28-mm-diam copper wire), which can generate a B field as high as 2 kG. The coils are mounted inside an open end mild-steel box. The walls of the box form a return yoke to confine the magnetic flux. Thus, very little flux leakage occurs outside the spectrometer. The mild-steel box, in turn, is housed inside a copper case which is adequately cooled by water circulating around the small channels. The whole assembly is mounted on a 1.27-cm-diam stainless-steel shaft through which water and electrical connections are made (Fig. 2).

To extract positive ions, the copper and the mild-steel boxes are either left floating electrically or biased at the discharge anode potential. Since the stainless-steel pill box is isolated from the magnet and the mild-steel box by thin mica-foils, it can be biased at a higher negative potential of approximately 100 V. Charged particles, after passing through the entrance aperture (0.8 mm-diam) enter the pill box. The beam is first collimated and then deflected 90° by the magnetic field before being collected by a small Faraday cup. The cup is normally maintained at +1.5 V with respect to the pill box to suppress emission of secondary electrons.

A plot of the collected cup current versus the magnet coil current can be displayed on a storage oscilloscope. Figure 3(a) shows a scan obtained when the spectrometer is placed inside the neutralizer of a high power neutral beam system.[2] Since the beam is deflected by 90° (instead of 180°), one would not expect good geometrical focusing. Nevertheless, three distinctly resolved peaks representing the three positive-hydrogen ion species (H^+, H_2^+, and H_3^+) can be obtained. In this measurement, the current of the magnet coils is varied in a time period less than 10 ms. As a result, no significant heating will be generated in the coils.

When a negative beam is extracted from the hydrogen plasma of the neutralizer, and with the direction of the B-field reversed, a signal (in addition to that of the electrons) showing the presence of H^- ions is recorded (Fig. 3(b)). In this measurement, a positive potential of a few volts relative to the plasma potential is applied to the copper and mild-steel boxes to optimize the H^- signal. In order to reduce the current drawn by the biasing supply and to minimize the perturbation produced, the whole spectrometer, except for a small area around the extraction aperture, is covered by a floating anodized aluminum shield as shown in Fig. 2.

This spectrometer probe also has been used successfully to analyze the spatial ion species distribution inside an ion source. Similarly, the ion species composition of a low energy (~ 150 eV) hydrogen beam also has been measured with this small spectrometer.

We would like to thank D. Moussa, D. Kippenkan and S. Walther for all the technical assistance.

References

(1) K. W. Ehlers, K. N. Leung and M. D. Williams, Rev. Sci. Instrum. 50, 1031 (1979).

(2) W. B. Kunkel, G. Guethlein, K. N. Leung and S. Walther, Bull. Am. Phys. Soc. 29, 1368 (1984).

Figure Caption

Fig. 1	Cross-sectional view of the water-cooled mass spectrometer.
Fig. 2	A picture of the magnetic-deflection mass spectrometer probe.
Fig. 3	The Faraday cup signal versus the magnet coil current showing the presence of (a) the three positive hydrogen ions, and (b) the negative hydrogen ions.

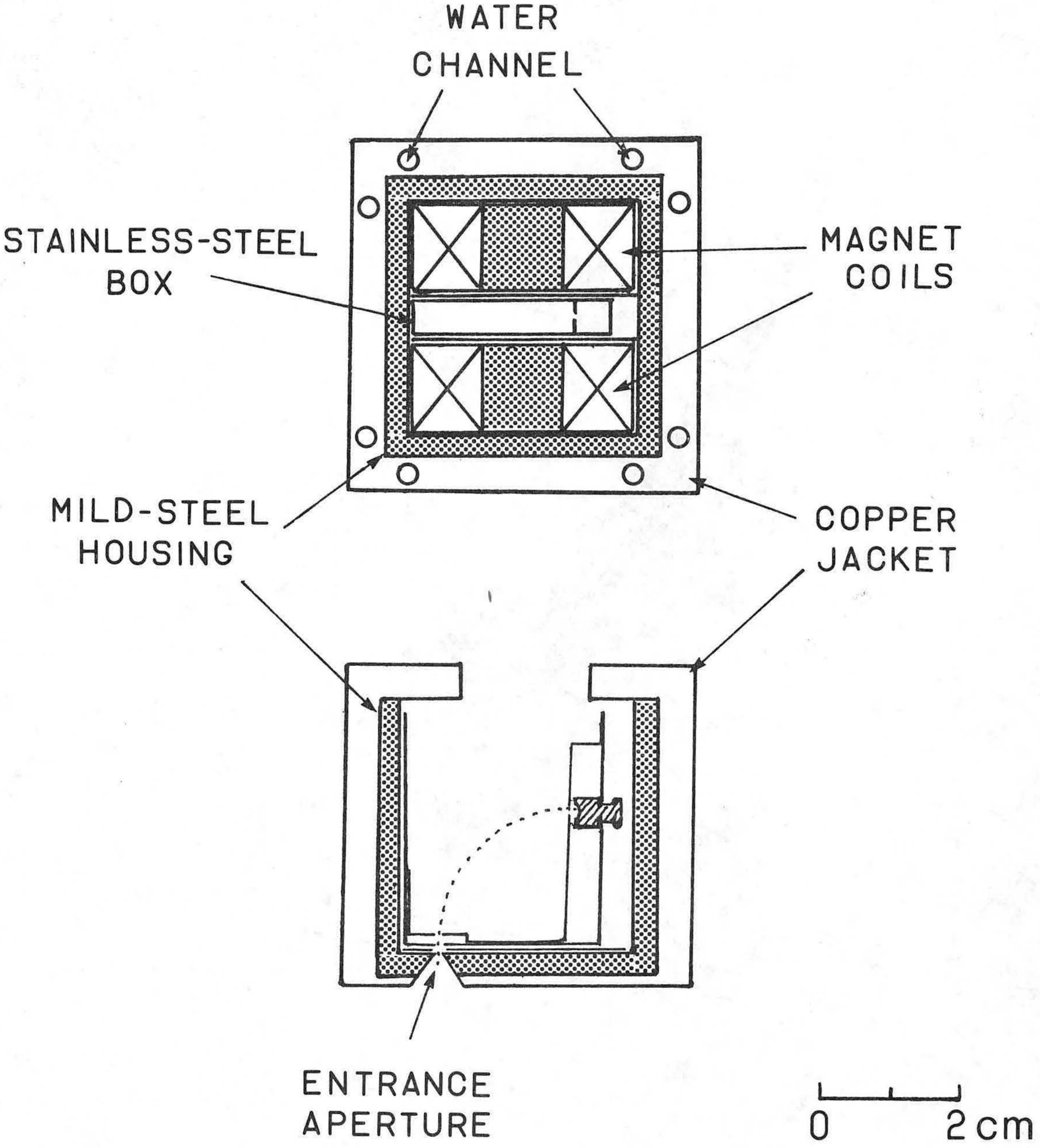

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Figure 1

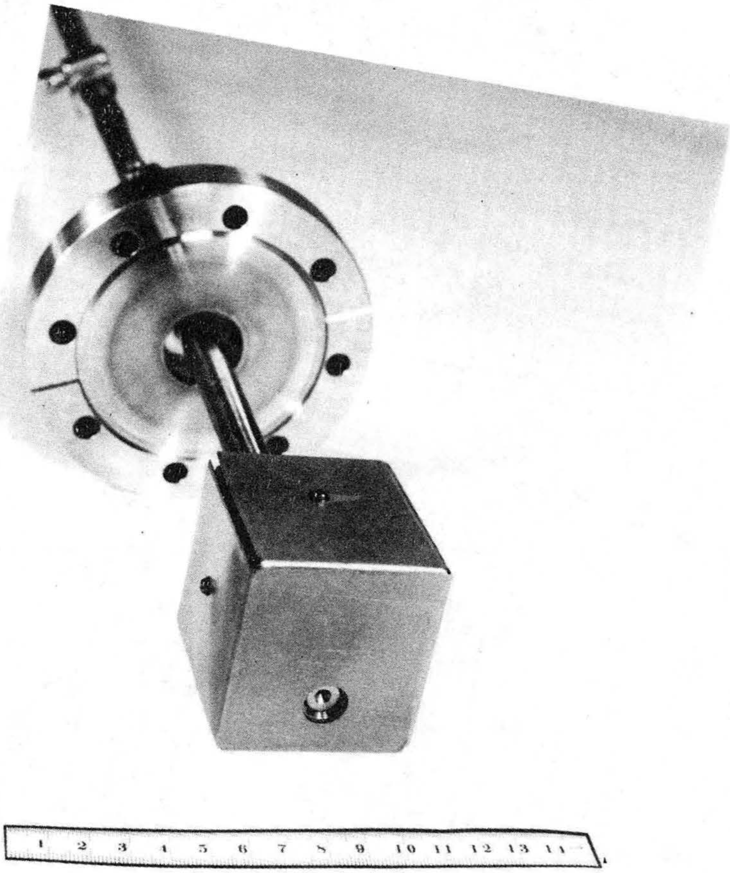

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Figure 2

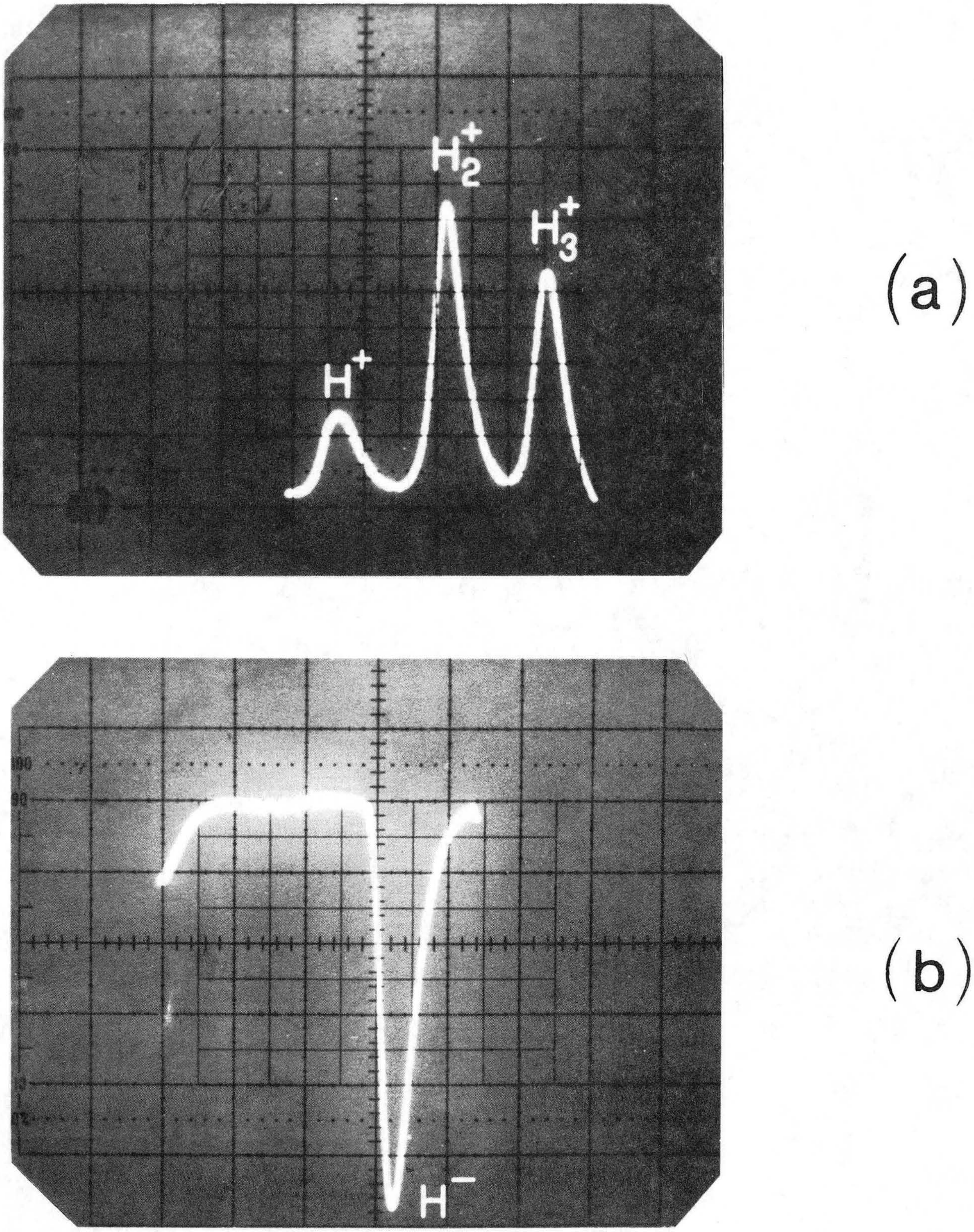

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Figure 3

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