Submitted to Review of Scientific Instruments

A MASS SPECTROMETER FOR ANALYZING HYDROGEN ION SPECIES

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March 1979

Prepared for the U. S. Department of Energy
under Contract W-7405-ENG-48

A Mass Spectrometer for Analyzing Hydrogen Ion Species

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Abstract

The design of a compact, high resolution 180° magnetic deflection mass spectrometer for the study of positive and negative hydrogen ion species is described.

The design of a 180° magnetic deflection mass spectrometer for measuring the ion species composition of a hydrogen plasma or a low energy hydrogen ion beam is presented. This spectrometer is compact (6.4 cm high, 12.7 cm wide and 7.6 cm deep), and can be conveniently placed inside a vacuum system. It produces almost no fringe magnetic field so that a higher resolution is obtainable. 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.

A schematic diagram of the mass analyzer is shown in Fig. 1. Charge particles after passing through the entrance slit (0.75 mm wide, 5 mm high) will enter into a copper case. They are deflected 180° by the magnetic field and are collected at one of the four Faraday cups. These cups are made of graphite which has a relatively low secondary emission coefficient. In addition, the cup that is used for collection is normally biased at +1.5 V with respect to the copper case so that any secondary electron produced will be drawn back to the cup. Cup 1, which is closest to the entrance slit, is used mainly for detecting electrons. Cups 2, 3 and 4 are used for collecting positive or negative ions which have larger gyroradii. The copper case is located in the gap between two solenoidal coils (each has 260 turns of 0.5 mm diameter copper wire) which can generate a B field as high as 2 kG. This B field is uniform over the area of the copper case. All the side-walls of the spectrometer (except the back which is open for pumping) are made of mild-steel. They form a return yoke to confine the magnetic flux. As a result, very little flux leakage occurs outside the spectrometer. The B field decreases rapidly inside the slot where the two slits are located. A Hall probe is installed at one corner of the gap so that the magnitude of the B field can be determined accurately during the measurement.

A plot of the collected cup current versus the B field can be displayed on a x-y recorder by applying the cup signal to the y-input and the Hall probe signal to the x-input. Figure 2 shows some of the scans obtained when the spectrometer is used to detect a 300 eV hydrogen ion beam extracted from a multi-line-cusp source.[1] In this measurement, the entrance slit and the copper case are both connected to ground potential. Figure 2(a) shows the peaks of the three positive hydrogen ion species (H^+, H_2^+ and H_3^+) obtained at cup 3. The peaks are sharp indicating the spectrometer has a good resolution. When a negative beam of the same energy is extracted from the source and with the direction of the B field reversed, the signal of cup 3 shows the presence of H^- ions (Fig. 2(b)). However, a much higher electron peak is seen at cup 1 as shown in Fig. 2(c). Thus the ratio of H^- ion to electron density in the source plasma can also be estimated.

Apart from being used to analyze the species of hydrogen ion beams, this mass spectrometer can be mounted at the boundary of a hydrogen plasma to study the ion composition. In this case, the entrance slit is left floating or biased at the anode or cathode potential. The copper case and the Faraday cups (which can be electrically isolated from the magnet) are both biased at a voltage of approximately -300 V relative to the entrance slit to extract the positive ions. Peaks similar to those shown in Fig. 2(a) have been obtained.

We would like to acknowledge the skillful technical assistance of L. A. Biagi, H. H. Hughes, and members of their group. This work is supported by the U. S. Department of Energy, Office of Fusion Energy, under contract No. W-7405-Eng-48.

References

1. K. W. Ehlers and K. N. Leung, Bull. Am. Phys. Soc. 23, 805 (1978).

Figure Caption

Fig. 1 Cross-sectional view of the mass spectrometer.

Fig. 2 The Faraday cup signal versus the magnetic field showing the presence of (a) the positive hydrogen ions, (b) the negative hydrogen ions, and (c) the electrons in a 300 eV extracted beam.

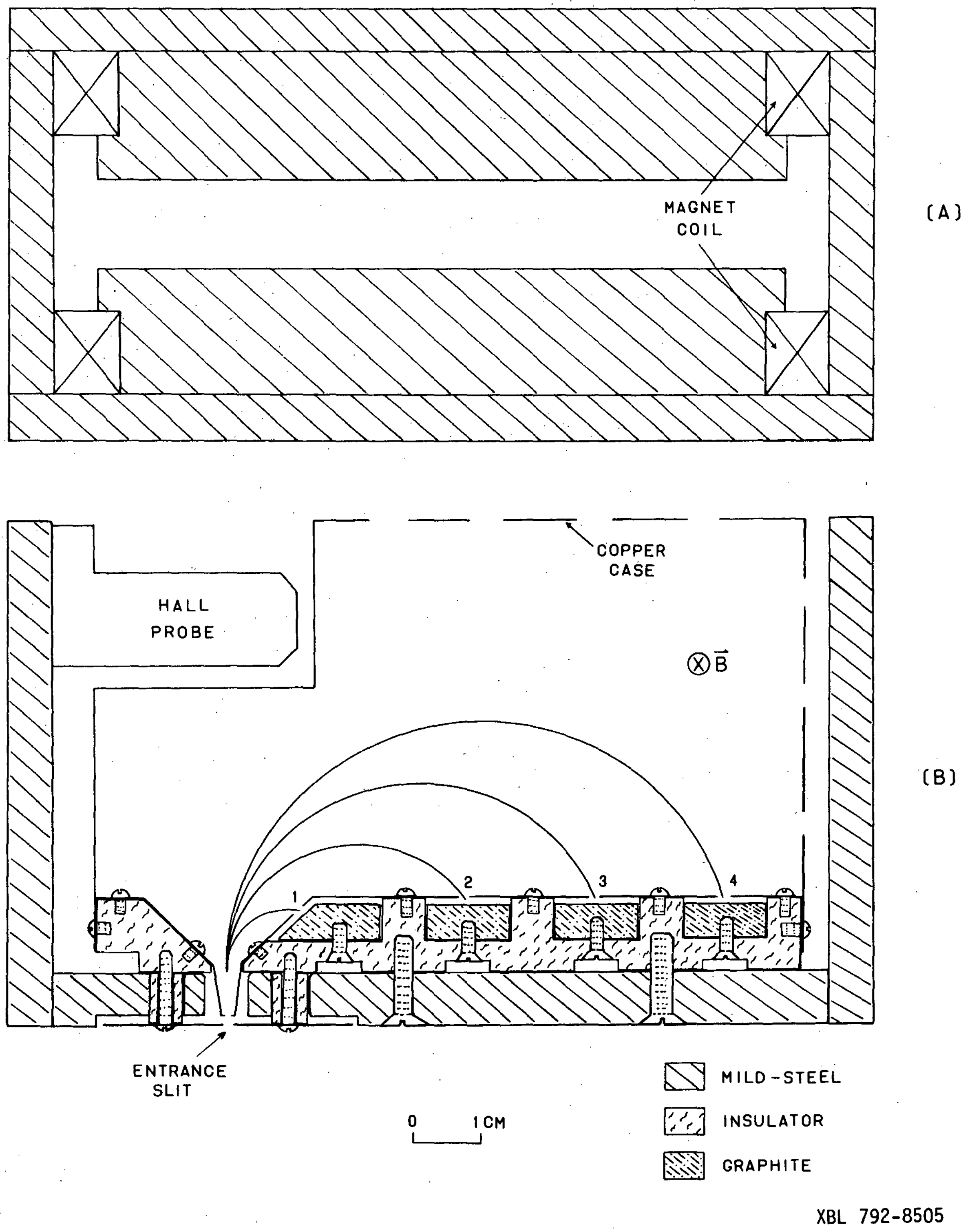
MAGNET
COIL
(A)
COPPER
CASE
HALL
PROBE
⊗B
(B)
1
2
3
4
ENTRANCE
SLIT
0
1 CM
MILD-STEEL
INSULATOR
GRAPHITE
XBL 792-8505

Fig. 1

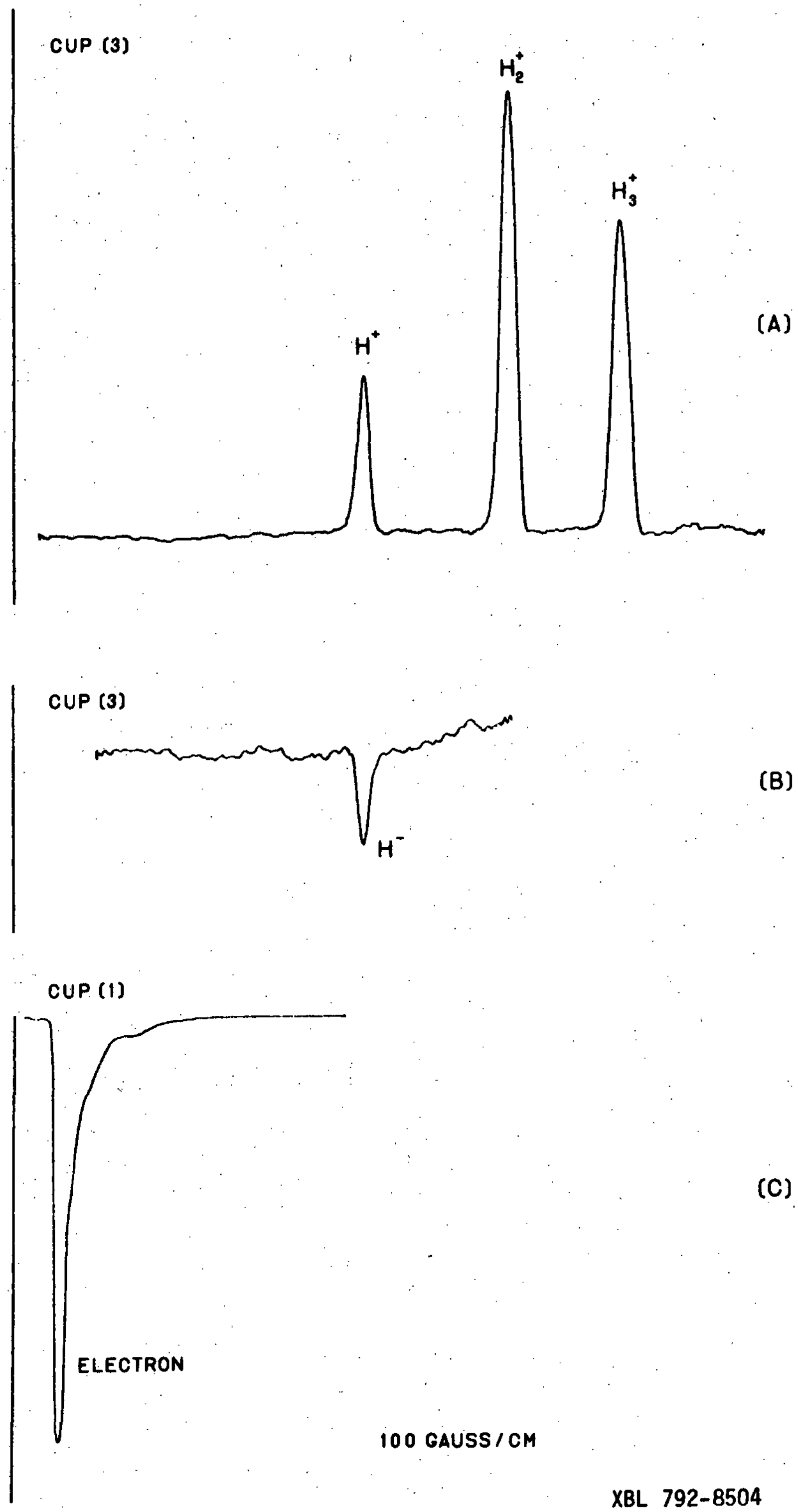

Fig. 2

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