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Summary

During the 2nd Symposium on Ion Sources and Formation of Ion Beams, we reported on the development of our Mk II pulsed double slit magnetron source for the production of negative hydrogen ions.[1] The source was capable of yielding beam currents up to 125 milliamperes, corresponding to current densities of 1.25 A/cm^2. In order to increase negative hydrogen beam intensities by an order of magnitude (this would be quite useful for initial high energy neutral injector systems on Tokamaks), a larger, Mk III magnetron has been constructed, with the number of slits increased up to six. The idea was to utilize in a more efficient way the plasma width. In addition, such a source geometry will be more adaptable for beam formation and acceleration than single slit structures. With three extraction slits, we obtained a negative hydrogen yield of 300 mA with current densities of 1.2 A/cm^2; preliminary results with six extraction slits showed beam currents in excess of half an ampere with averaged current densities in excess of 0.75 A/cm^2.

The basic design and operation of the magnetron has been extensively described in previous papers.[2,3] The source consists of two electrodes, cathode and anode with the discharge chamber in between them in the form of a racetrack (see Fig. 1). In the main part of this racetrack the electric and magnetic fields are mutually perpendicular. The thickness of the ribbon-shaped discharge is determined by the height of the discharge chamber (0.7 - 1 mm); in the direction of the magnetic field the discharge is limited by the cathode end shields (distance 10 mm), while the useful length of the discharge is determined by the length of the cathode (23 mm).

Although some negative ions are formed in the discharge itself, most of them appear to be created by surface conversion of energetic positive ions and neutrals from the discharge, bombarding the cathode.[3] The negative ion emission is enhanced by the injection of cesium into the source, with the effect of lowering the working function of the cathode. Negative ions are accelerated toward the anode and a part of them survives

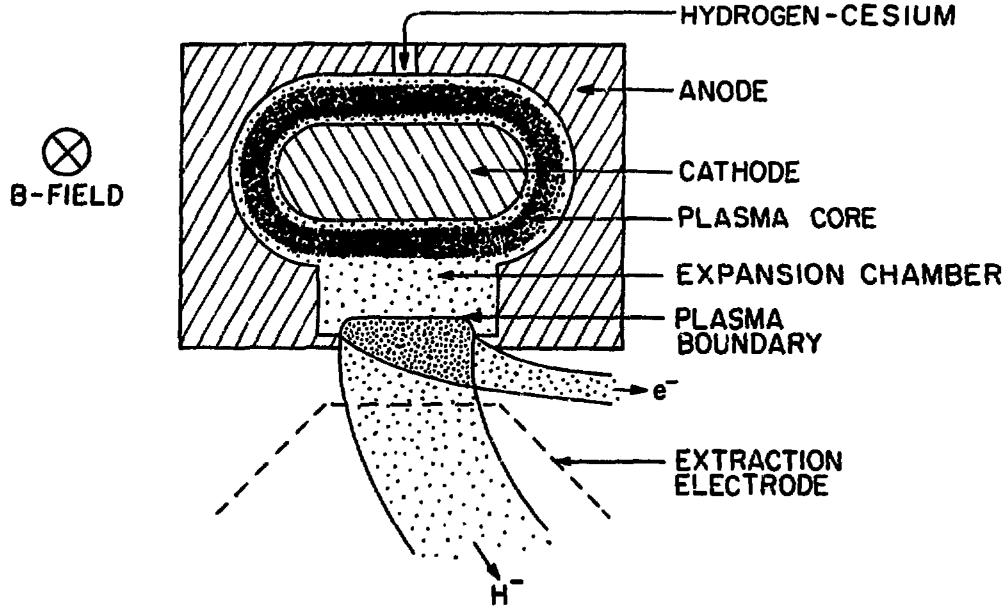

ILLUSTRATION OF NEGATIVE ION MAGNETRON

Fig. 1

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*Work performed under the auspices of the U.S. Energy Research and Development Administration.

while passing through the thin discharge plasma. Some of these escape through the extraction slits in the anode expansion chamber with high initial energy and some exchange charge in collisions with slow atoms creating in this way slow negative hydrogen ions which are then extracted with low initial energy.

Figure 2 shows a cross section of the three slit Mk III magnetron with the simple titanium extractor mounted on the grounded pole pieces. The extraction slits are 0.5 x 16 mm^2 with a pitch of 1 mm, while the extraction gap is 2 mm. Anode parts are made from stainless steel, while the cathode and its side shields are machined out of molybdenum. Titanium shields cover the magnetic poles to secure voltage hold-off. Hydrogen gas and cesium vapors are injected through a common tube. Negative ion beam currents (and densities) are measured with Faraday cups and a beam current transformer. Arc voltage, arc current are monitored together with the temperatures of the cathode, anode and cesium cell.

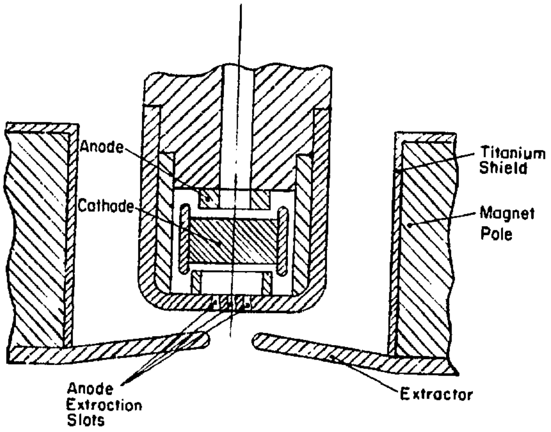

Fig. 2. Cross section of the three slit Mk III magnetron.

The arc power is supplied by a 1.2 Ω, 2.5 ms delay line.

With a relatively low repetition rate, one pulse every 10 sec, a new source has to be conditioned during several hours of operation in a hydrogen discharge made with typical arc voltages around 600 V and arc currents around 50 A. During this period the average temperature of the cathode reaches 300°C and the anode about 150°C. With the source operating in the hydrogen mode, no attempt was made to optimize the H$^-$ yield.

After loading the source with cesium, the arc voltage drops to about 150-200 V. Figure 3 shows typical arc voltage and arc current waveforms as well as the corresponding negative ion output (measured with the beam current transformer) for an extraction voltage of about 15 kV. Negative beam currents of 350 mA were reached with an arc current of 120 A and an extraction voltage of 16 kV. The ion density corresponds to an average density of 1.4 A/cm^2 at the extraction slits. In a distance of about 3 cm from the extraction slit the density distribution of the beam has been measured in a direction perpendicular to the slits. Figure 4 shows such a distribution for a 55 mA beam at an extraction voltage of 11 kV. The three peaks correspond to the three rectangular beams emerging from the source. A similar distribution has been observed for 300 mA beam currents. Such a beam structure suggests a partial neutralization of the dense negative ion beam in the relatively high back pressure in the vacuum chamber during the pulse (> 10^{-4} torr). This phenomenon will be further investigated theoretically as well as experimentally.

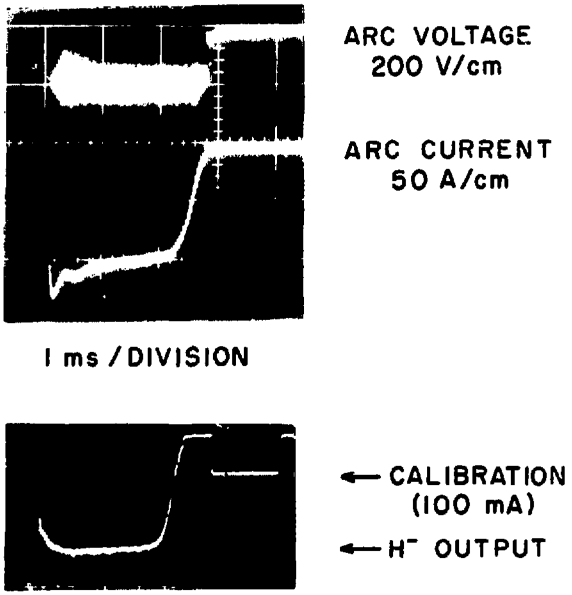

Fig. 3. Arc voltage, arc current and corresponding negative ion output during a 2.5 ms pulse at 15 kV.

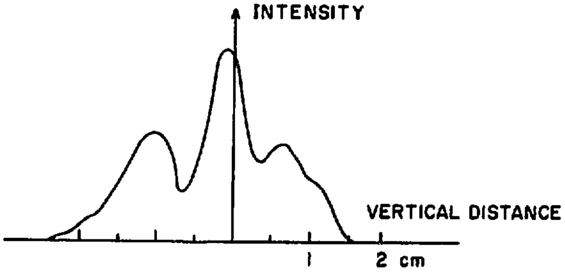

Fig. 4. Density distribution of the negative ion beam from a three slit magnetron.

In an effort to increase the beam current up to the one ampere range, the three-slit anode cover has been replaced by a six-slit cover. The slit dimensions were 0.5 x 22 mm^2 with a pitch of 1 mm. The cathode is now 12 mm wide and 27 mm long. The stainless steel extractor has two slits separated by a 0.5 mm tungsten wire in order to obtain a more uniform extraction field. The width of each extractor slit is 3 mm. Figure 5 is a picture of the source, during a 120 A hydrogen discharge, photographed through the window at the end of the vacuum box.

Preliminary results with the six slit Mk III source show beam currents in excess of 0.6 ampere. Figure 6 is the arc current and corresponding H^- current during a 2.5 ms pulse length at an extraction voltage of 13 kV. Density distribution measurements across the beam at these high currents do not show the fine structure, corresponding to six slits. The heavy negative ion content appears to be smaller than 5%. It is interesting to note that the negative hydrogen production per ampere discharge current in this multi slit magnetron source is about three times larger than for similar currents in single slit structures.

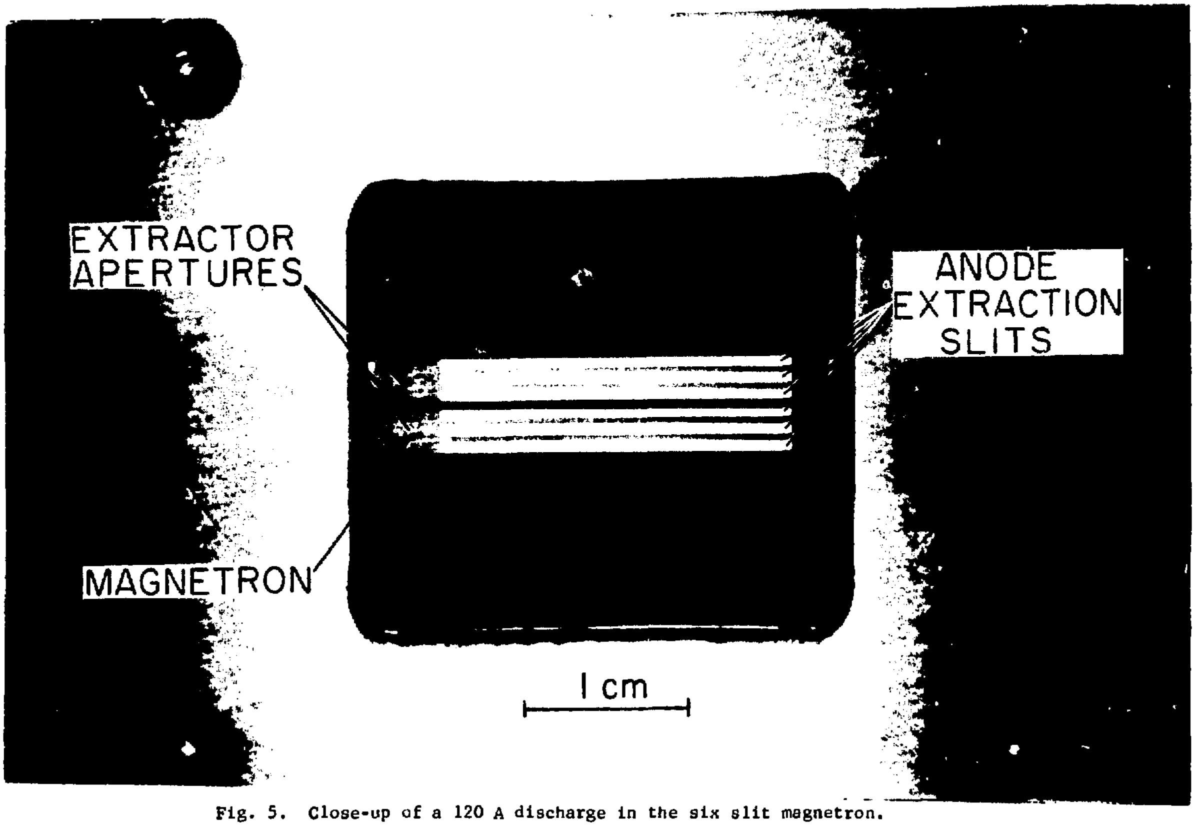

Fig. 5. Close-up of a 120 A discharge in the six slit magnetron.

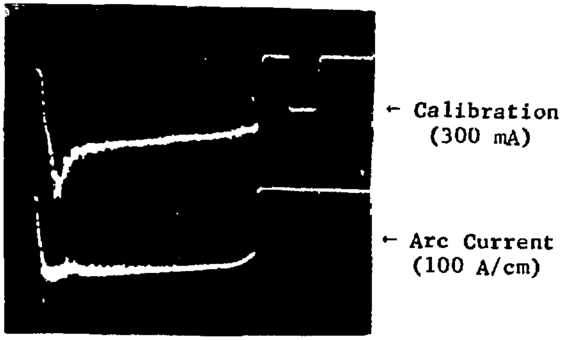

Fig. 6. Arc current and corresponding H^- current during a 2.5 ms beam pulse at 13 kV.

Acknowledgments

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