IMPROVEMENTS ON H^- SOURCES FOR SPALLATION NEUTRON SOURCE APPLICATION[*]

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Abstract

Lawrence Berkeley National Laboratory is engaged in the development of the ion source and transport system for the upgrade of the Los Alamos Neutron Science Center (LANSCE) facility. For the upgrade of the LANSCE facility, the H^- ion generator has to deliver an output current of 40 mA. The repetition rate is 120 Hz at a pulse length of 1 ms. Furthermore, the normalized RMS emittance has to be less then 0.1 π mm mrad. During the last years, the Ion Beam Technology Group has improved the so-called surface conversion source for the generation of higher H^- currents. The present effort is aimed at meeting the emittance requirements, focusing on improvement in the extraction region. A new repeller geometry has been proposed, incorporating a magnetic dipole field instead of a magnetic cusp field. The purpose of the repeller is to efficiently repel electrons from the beam with a minimal emittance increase. The displacement of the H^- beam by the magnetic dipole field is compensated by an electrostatic dipole field. Results on the self-extracted H^- beam will be presented.

1 INTRODUCTION

One of the main difficulties when extracting negatively charged ions from an ion source is the accompanying current of electrons. When not prevented from exiting the ion source, this electron current can easily be 2 orders of magnitude larger then the H^- current. Different schemes have been tested to solve this problem. The LANSCE H^- source has used a linear cusp magnet in the extraction aperture, strong enough to bend the electrons back but only weakly effecting the H^- beam. In the upgrade LANSCE H^- source we have modified and improved the existing repeller design.

2 EXPERIMENTAL SETUP

The LANSCE H^- source is a so-called surface conversion source [1,2]. A schematic drawing of the ion source is shown in figure 1. The H^- is mostly formed at a cesium-covered converter surface. The converter material is molybdenum. The cesium is evaporated into the source by an oven, which typically heats the cesium reservoir to 250 °C. The plasma is generated by 6 tungsten filaments, which are typically operated at 110 A. A discharge voltage of 70 V is applied to the filaments in a pulsed mode. A typical arc current is 150 A. The pulse length is 1 ms at a repetition frequency of 120 Hz. An H^- current of 40 mA is routinely extracted.

The H^- beam is 'self-extracted': the converter surface is set at a voltage of typically –300 V. Any negative hydrogen created on the surface of the converter is accelerated across the plasma sheath towards the exit of the ion source. Because the converter is slightly curved this will result in a focused ion beam.

The exit of the source is conical in shape. Permanent magnets can be mounted at this exit, in order to create a magnetic field that repels the electrons. In our test-stand the H^- current after the repeller can be measured by a faraday-cup which has an extra set of dipole magnets and a collector in order to measure the electron current as well. If the repeller is functioning well we expect this electron current to be very small. Instead of the faraday cup other diagnosing equipment can be mounted here as well.

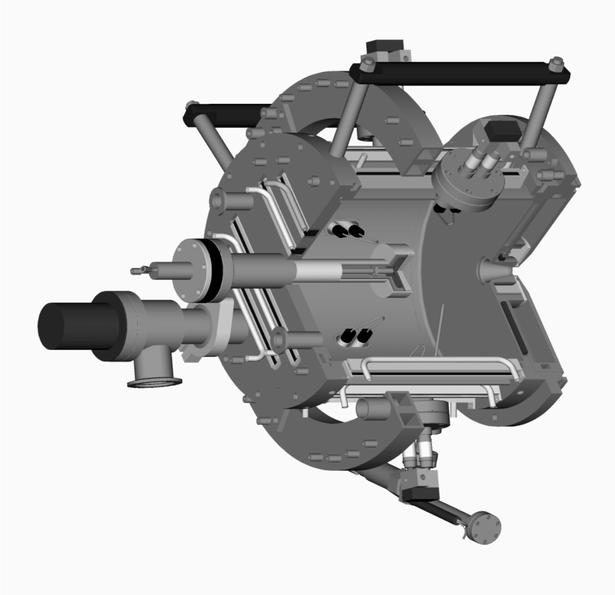

Figure 1: The plasma chamber of the LANSCE H^- ion source.

3 ELECTRON SUPPRESSION MEASUREMENTS

We have compared three repeller setups: no magnetic field, cusp magnetic field and dipole magnetic field. In figure 2 these different geometries are shown. In order to measure the electron and H^- currents without a magnetic repeller field the magnets were simply removed. On the left side of these pictures the orientation of the bar magnets with respect to the conical shaped repeller is shown in a cut-through. The ions are formed at left side of this repeller. The bar magnets are orientated perpendicular

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to the direction of movement of the ions. They are permanent Samarium Cobalt magnets. The strength of the dipole field is 280 gauss in the center between the magnets in the transverse direction. The same magnets are used for the cusp field, the field strength in the center in beam direction in that case is 150 gauss.

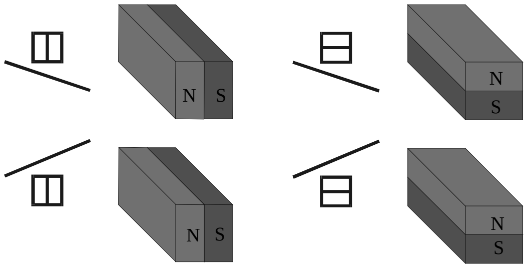

Figure 2: The configuration of the permanent bar magnets for the cusp field (left) and the dipole field.

In the following figures, the electron current is compared with the H^- current as a function of arc power. The arc power is the current delivered from the filaments multiplied by the discharge voltage. Fluctuations in the H^- current for a given arc power are due to different source conditions like pressure and the amount of cesium in the source. In each graph, data from a series of measurements is shown.

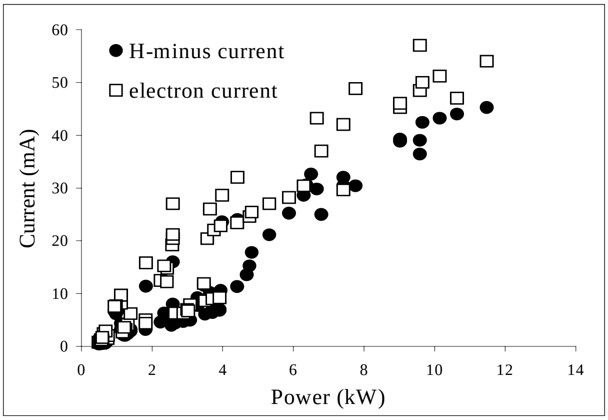

Figure 3: H^- current compared to electron current for the case without repeller magnets

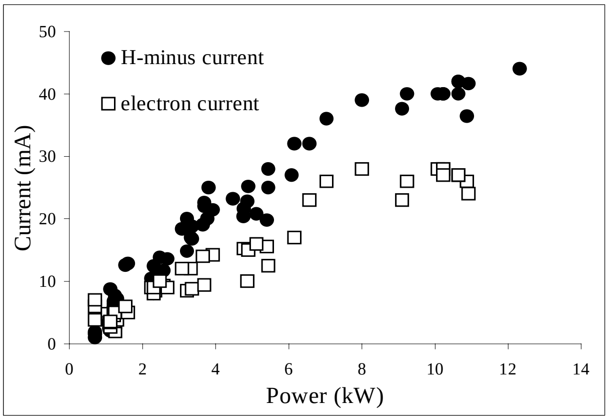

Figure 4: H^- current compared to electron current with a cusp magnetic repeller field.

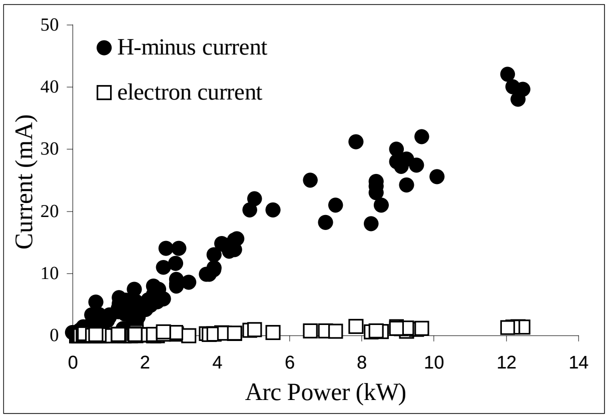

Figure 5: H^- current compared to electron current with the dipole magnetic repeller field.

We see that the measured H^- current in the faraday cup does not change by changing the magnet geometry. The electron current however is a strongly influenced by it. In all these cases the conical repeller body itself is isolated from the rest of the source and at ground potential. In the case of the dipole magnet arrangement the electron to H^- ratio is very low, for an H^- current of 40 mA the electron current is still only a few mA. Clearly this is much better then the cusp magnetic field where the electron to H^- ratio is around 1.

We have also measured the current on the conical repeller itself, and in the case without repeller magnets we measured currents up to 6 A for an arc power of 10 kW. In the case of either the cusp magnetic field or the dipole magnetic field, this current would only go up to 3 A for the same conditions.

Another main reason for using a dipole field instead of a cusp field for this particular ion source is that the ion beam is converging from the converter to the exit. The principle of the cusp field is that the magnetic force on the ions in the first half of the cusp field is cancelled by the second half, where the field is directed in the other direction. For a converging beam however these forces do not cancel out, and this could be a major source of emittance increase. For the dipole field this would not be the case. However we introduce a bending of the ion beam and we have to find a way to cancel the magnetic force on the H^- ions, without increasing the emittance.

4 COMPENSATING THE MAGNETIC BENDING OF THE IONS

When using the dipole magnets to repel the electrons, we also inevitably bend the H^- ions when they are passing through the repeller. This can be compensated by tilting the ion source with respect to the accelerating axis as was recently done in the volume H^- ion source developed for the Spallation Neutron Source (SNS) project [3]. But one can also try to cancel the effect of the magnetic field on the ions by an electrostatic field applied perpendicular to the magnetic field. We have started experiments with a split repeller body. The repeller is split into two halves and a voltage can be applied between them, which should cancel out the magnetic force on the moving ions.

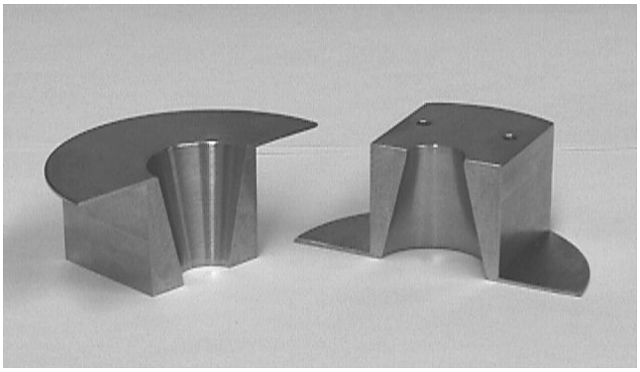

Figure 6: The two halves of the repeller.

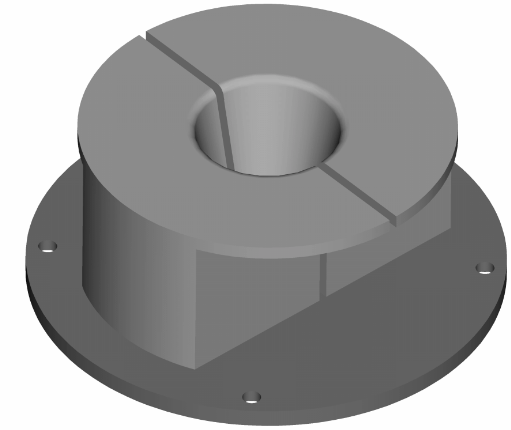

Figure 7: A computer rendering of the split repeller design. The two halves are kept together and electrically isolated by a ceramic plate.

We can easily calculate the bending of a 300 eV electron in a field of 280 Gauss. This gives us a 0.7 mm radius for the electron. For the negative hydrogen ion in the same magnetic field the radius is 26 cm. For a magnetic field that only extends in the area of the repeller, which has a length of 27 mm, this would give us a displacement from the central axis of roughly 1.5 mm at the exit of the repeller. The angle with the central axis would then be roughly 3 degrees.

The electric field strength needed to compensate this magnetic bending can easily be calculated. Assuming that the electric and magnetic fields extend over the same length, and that both fields are perfectly homogeneous a field strength of 7.5 V/mm is found. The average diameter of the repeller is 19 mm, which gives us a required voltage difference between the two halves of 143 V as a first order approximation. The voltage difference in the experiment is expected to be somewhat higher due to the inhomogeneity of the electric field between the two repeller halves.

The experimental approach we have taken to test this concept is the following: 4 segments that separately measure the current in 4 segments of the beam have replaced the Faraday-cup. By now adjusting the voltages on the repeller halves we should be able to detect a shift of the beam by a change in the current on the segments. This setup is shown in figure 8.

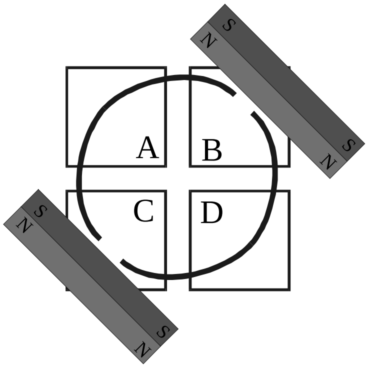

Figure 8: The layout of the 4 segments, the two repellerhalves and the bar magnets, as seen from the inside of the source.

Measurements are in progress with this setup. Preliminary results show that it is indeed possible to center the beam on the 4 segments. With both halves of the repeller at zero voltage, it is found that the beam is deflected as expected by the magnetic field. For the four segments, the following percentages of the total beam were measured:

13%	27%
21%	39%

When applying a positive voltage of 300 V to one of the repeller halves while keeping the other at ground, the following percentages are found:

21%	25%
25%	29%

The total amount of H^- beam that was measured on the segments decreased from 23.5 to 10.3 mA when applying this voltage. One has to keep in mind that the current measured on the segments is the total current, which is the difference between the H^- current going towards the segments and an electron current of secondary electrons leaving the segments.

A possibility with this kind of repeller that will be investigated in the future is to chop the ion beam. A strong voltage pulse can easily be supplied to one of the repeller halves to deflect all the H^- ions

5 CONCLUSION

Initial experiments on a new repeller design for the LANSCE H^- source have been presented. It is shown that the magnetic dipole field is very effective in repelling the electrons. Furthermore, it has been demonstrated that an electrostatic dipole field can compensate the bending of the H- ions by the magnetic field.

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