Measurements on the LANSCE Upgrade H^--Source*

R. Thomae#, R. Gough, R. Keller, K. Leung, D. Meyer+, M. Williams, Lawrence Berkeley National Laboratory, O. Sanders, W. Ingalls, B. Prichard, R. Stevens, Los Alamos National Laboratory

Abstract

For the upgrade of the Los Alamos Neutron Science Center (LANSCE) Facility, the Lawrence Berkeley National Laboratory is developing an H^- ion generator that can deliver the required beam. The output current has to be 40 mA at a repetition rate of 120 Hz and a pulse length of 1 ms (12 % duty factor), and the normalized emittance must be less than 0.1 π mm mrad. During the last years, we improved the so-called surface–conversion source for the generation of higher H^- currents. Experiments with magnetic filter fields have shown that the output current increases linearly with the discharge power in contrast to saturation when operating without a filter. In the latest source configuration, the filter field is generated by the cusp magnets itself, resulting in a simple and reliable setup. In this paper we present measurements on the output current as a function of discharge power. We discuss operation conditions of the source at the required 40 mA output current. Furthermore, preliminary results using 2 MHz RF power with an antenna for plasma generation will be described.

1 INTRODUCTION

The requirement for higher intensity H^- ion beams for the upgrade of the Los Alamos Neutron Science Center (LANSCE) Facility necessitated the development of a new ion source. Lawrence Berkeley National Laboratory has been contracted by Los Alamos National Laboratory to develop an H^- ion source, which can deliver the required beam parameters, demanded by the LANSCE upgrade. In particular the output current has to be increased from 16 to 40 mA, whereby the beam emittance may not increase. Furthermore, the source must operated reliably at the prescribed 12 % duty factor (1 ms pulse length at 120Hz).

The Ion Beam Technology (IBT) Program at LBNL is developing the so-called surface converter source for the generation of negative ions for a number of years. This type of source was chosen as a candidate for the LANSCE upgrade because it is known as a very effective and reliable source. Although this principle was expected to have an intrinsic current limit, experimental studies at LBNL demonstrated that the output current can be increased linearly with discharge power when a magnetic filter field is applied, which prevents energetic electrons reaching the converter region [1]. Covering the converter surface with a thin layer of cesium can increase the efficiency of the source.

*This Work was supported by Los Alamos National Laboratory and the Department of Energy under Contract No. AC03-76SF00098.

Email: rwthomae@lbnl.gov

+Present Address: KVI, Atom Physics Group, Zernikelaan 25, 9747 AA Groningen, The Netherlands

2 EXPERIMENTAL SETUP

The multicusp surface conversion source is under investigation at LBNL for a long time [2,3]. It is primarily composed of a plasma chamber and a negatively biased converter. The ions present in the hydrogen plasma (H^+, H_2^+, H_3^+) are accelerated towards the converter surface. H^- can be formed either through a back scattering process or a sputtering process when the positive ions collide with the converter surface.

The LANSCE upgrade source consists of a cylindrical stainless steal plasma chamber, in which the converter is mounted along the axis. The diameter and length of the chamber are 250 mm and 230 mm, respectively. Outside the chamber 18 columns of magnets provide the cusp field. Fig. 1 shows a 3-D cutaway picture of the source.

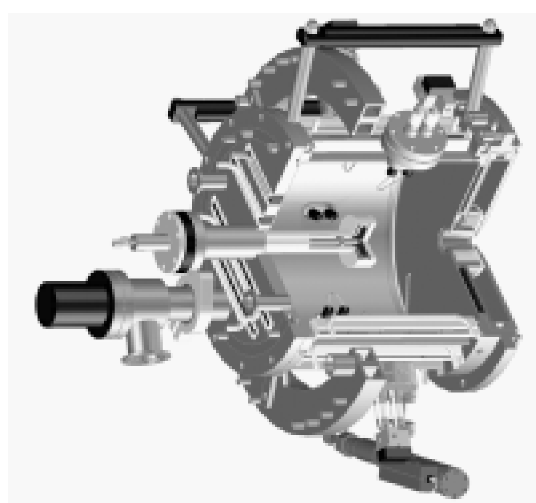

Figure 1: The LANSCE upgrade source. Shown here is the plasma chamber with the magnets and the filaments. The converter is mounted to the end plate. In the front

plate a collar with two magnets is used to deflect the electrons.

The position and length of the filaments are arranged in such a way that their tips are surrounded by a magnetic field of approximately 30 Gauss. This is sufficient to prevent energetic electrons to reach the converter and extraction regions. The filaments are biased at 70 V negative with respect to the source body. They are heated by 5 V and 100 A each. The potential of the converter is varied in between -200 to -400 V. Cesium is brought into the plasma chamber by heating the oven and the valve to 200^0 to 300^0 C. During operation, the converter current, the repeller current, and the Faraday cup current are monitored. More detailed information on the design and construction of the source can be found in reference [4]. Fig. 2 shows a photograph of the source in the test stand.

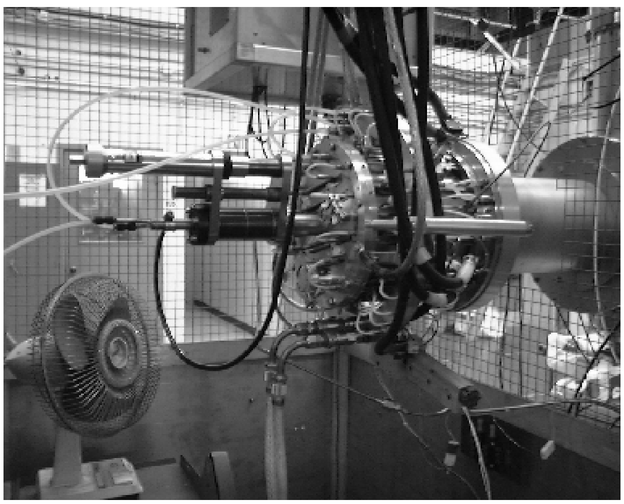

Figure 2: Photo of the source in the test stand.

3 EXPERIMENTAL RESULTS AND DISCUSSION

After assembling the source has to be conditioned for at least 10 hours. Conditioning is done by heating the source with filaments and plasma discharge. Then cesium is injected into the source chamber via a nozzle by means of heating the reservoir and oven valve. For an optimum oven temperature, the H^- output current is enhanced by more than a factor of 10. The cesium from the oven covers the surface of the plasma chamber and the converter surface. During the discharge pulses, the positive ions, which are present in the plasma, are accelerated across the plasma sheath formed in front of the converter surface. They can sputter a portion of the cesium coverage. The amount of cesium coverage on the converter surface is especially important for efficient H^- generation. It is therefore substantial to control this parameter. There are 3 different ways:

i) A Change of the duty factor, either pulse length or repetition rate, influenced the amount of sputtered cesium. Increasing the duty factor can reduce the thickness of the cesium layer.

ii) A change in converter voltage can modify the ion energy and therefore the sputter coefficient. A higher converter voltage reduces the thickness of the cesium layer.

iii) A change of the converter surface temperature can influence the cesium coverage. Increasing the converter surface temperature (e.g. by reducing the cooling water flow) can reduce the thickness of the cesium layer.

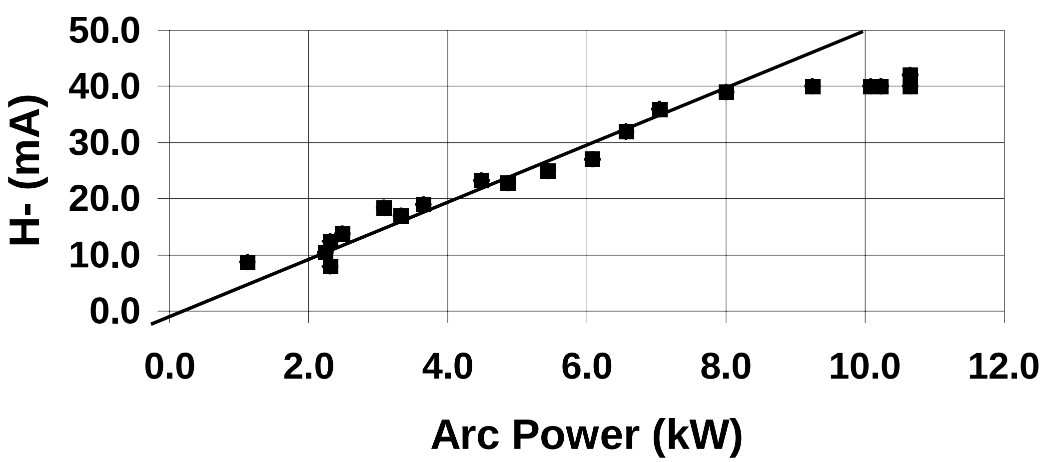

Figure 3: H^- current as a function of discharge power. The arc and converter voltages are 70 and 300 V, respectively. The pulse length and repetition rate are kept constant at 1.2 ms and 100 Hz (12% duty factor), respectively. The cesium coverage is optimized by adjusting the converter surface temperature.

For LANSCE operation the duty factor is fixed and only ii) and iii) can be applied. Because the converter voltage is limited by arcing towards the plasma, we believe that iii) is the best approach for adjustment of the converter surface cesium coverage.

In Fig. 3 the H^- current (measured in a Faraday cup, placed 3 cm behind the outlet electrode) is shown as a function of the discharge power. The arc and converter voltages are 70 and 300 V, respectively. The pulse length and repetition rate are kept constant at 1.2 ms and 100 Hz (12% duty factor), respectively. The cesium coverage is optimized by adjusting the converter surface temperature. It is clear from the figure that the current increases linearly with the discharge power from 10 mA at 2 kW to 40 ma at 8 kW. For larger values of discharge power the current saturates. We believe that this is due to the fact that at higher power levels more impurities are present, which has also been observed with a residual gas analyzer.

In Fig. 4 the pulse shape is plotted for an H^- current of 44 mA. The discharge power amounts to 8.6 kW. In this example the cesium coverage on the converter was optimized via the repetition rate, which is 190 Hz at a pulse length of 1.2 ms (duty factor 23%). The peak at the beginning of the pulse indicates a slightly overcesiated converter.

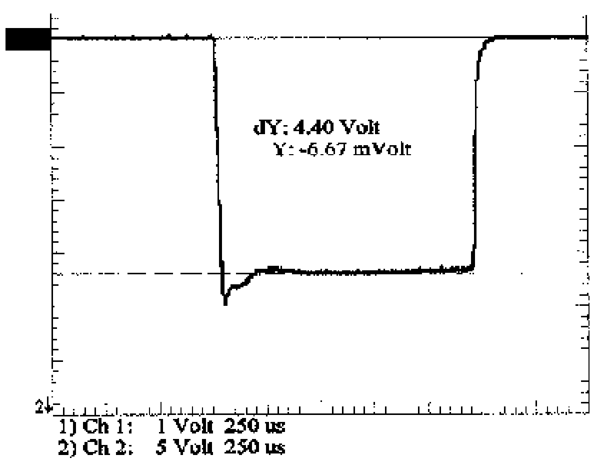

Figure 4: Pulse shape of a 44 mA H^- beam. The arc power amounts to 8.6 kW at a pulse length of 1.2 ms and a repetition rate of 190 Hz.

Recently we try to improve the overall efficiency of the source by using RF power to generate the plasma. Therefore, the filaments have been removed and are replaced by a quartz antenna as shown in fig. 5. The antenna is connected to a 2 MHz power supply via a matching network. In contrast to the operation with filaments the power load of the source for RF operation is reduced by at least a factor of two.

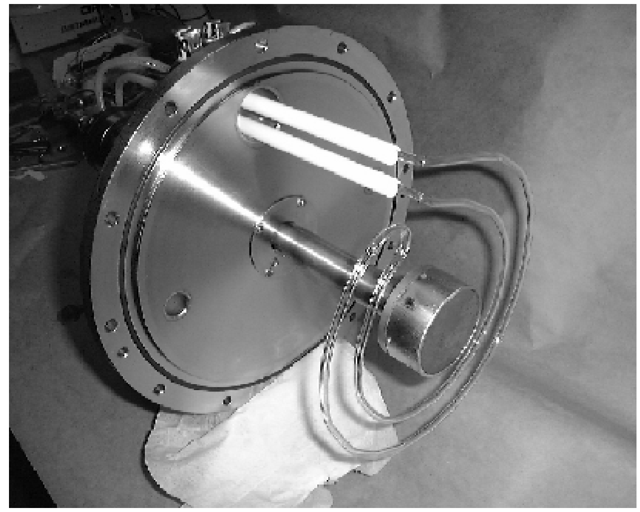

Figure 5: The endplate of the source with the quartz RF antenna. Note that a silver plated copper wire is inside the quartz tube. The antenna is water-cooled. Also shown is the converter.

First operation without cesium injection shows that plasma generation is possible. However, the neutral gas pressure has to be increased compared to operation with filaments. Work is still in progress to optimize the source operation with RF discharges.

4 ACKNOWLEDGMENTS

We would like to thank S. B. Wilde, P. J. Rosado, T. A. McVeigh, P. Wong, L. W. Mills, and P. Kozy for their technical assistance.

5 REFERENCES

[1] C.F.A. van Os, K. N. Leung, and W. B. Kunkel Appl. Phys. Lett. **57** (9), 27 Aug. 1990.

[2] K. W. Ehlers and K. N. Leung, Rev. Sci. Instrum. **51**, 721 (1980).

[3] K. W. Ehlers and K. N. Leung, Rev. Sci. Instrum. **53**(6), 803 (1982).

[4] M. Williams, R. Gough, K. Leung, R. Low, C. Matuk, R. Thomae, S. Wilde, this proceedings