DEVELOPMENT OF A HIGH DUTY FACTOR, SURFACE CONVERSION H⁻ ION SOURCE FOR THE LANSCE FACILITY*

A. B. Wengrow, K. N. Leung, M. A. Leitner, M. D. Williams, and D. C. Wutte†
Lawrence Berkeley National Laboratory, Berkeley CA 94720

William B. Ingalls, and Ralph R. Stevens Jr.
Los Alamos National Laboratory, Los Alamos NM 87545

Abstract

The next generation spallation neutron sources, such as the upgrade to the Los Alamos Neutron Science Center (LANSCE) will require high intensity negative hydrogen (H^-) beams. The new LANSCE source in particular will need to generate 40 mA of H^- beam current at a duty factor of 12% (1 ms pulse at 120 Hz). One option that we are currently studying concerns altering the existing LANSCE source to utilize an RF induction plasma discharge. However, before proceeding with any changes a full understanding and optimization of our current prototype ion source was required. This surface conversion source, similar to the present LANSCE source, will be used as a benchmark against which to measure future modifications, as well as to provide direction for those modifications. Results to date along with future plans will be presented.

1 INTRODUCTION

The upgrade of the Los Alamos Neutron Science Center (LANSCE) to 160 kW of beam power to the spallation target will require a corresponding improvement of its H^- ion source. Specifically the new LANSCE ion source will need to more than double its intensity from 16 to 40 mA. In addition, source emittance, reliability, and availability will need to be improved. All of which must be achieved while operating under the facility's prescribed 12% duty factor. While there are many options that may lead to the achievement of these goals, a thorough study of the original R & D prototype source developed at Lawrence Berkeley National Laboratory (LBNL) was necessary. The LBNL source is slightly different in size and configuration from the current LANSCE surface conversion source. Therefore a series of experiments was initiated first to optimize the LBNL source to reproduce the results of the LANSCE source, and second to set a standard to evaluate future modifications. This work furnished a better understanding of how the operating conditions of the source affect H^- production, in addition to providing direction for future source hardware modifications.

2 EXPERIMENTAL SET-UP

The typical multicusp H^- surface conversion source is primarily composed of a plasma chamber and a negatively biased converter electrode [1]. The ions present in the hydrogen plasma (H^+, H_2^+, H_3^+) are accelerated towards the converter surface. H^- can then be formed either through a *back scattering* process [2], or a *sputtering* process [3] when the ions collide with the converter surface. The converter is either composed of, or coated with a low work-function metal such as barium or cesium which greatly enhances the H^- yield [4].

The LBNL source is composed of a stainless steel multicusp plasma chamber 20 cm in diameter and 23 cm in height. A picture of the source and its interior can be seen in Fig. 1. The molybdenum converter has a cross-sectional diameter of 3.8 cm with a spherical face

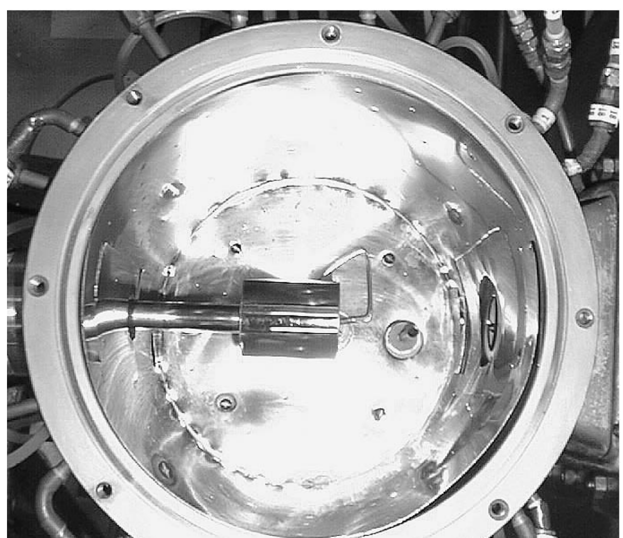

Fig. 1. Close-up of LBNL surface conversion source interior (top down view).

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cut to a 12.7 cm radius of curvature. The converter is typically operated at a DC bias of -250 V. To coat the converter, cesium vapor is injected into the source through a nozzle connected to an oven mounted on the lower end-flange. The cesium neutrals will condense on the water-cooled converter (or any other cool surface), and if ionized they will simply be accelerated towards the converter surface. The plasma is generated by two 1.5 mm diameter tungsten filaments mounted through the top and bottom end-flanges. The plasma is pulsed by switching the filaments' arc voltage with a 1 ms pulse at 120 Hz to produce the necessary 12% duty factor. Arc power delivered to the plasma is controlled by maintaining a constant arc voltage (~ 60 V) while adjusting the filament heater current.

The exit region of the source contains a plasma aperture plate, a beam aperture cone, and a Faraday cup. All three of which are isolated from the source, and from each other. A schematic of the source and its exit section is shown in Fig. 2. The isolation of the plate and cone allows for more complete beam diagnostics than with the Faraday cup alone. The aperture cone has the same dimensions as the LANSCE source, and the same distance to the converter. The major difference between the LBNL source and the current LANSCE source is the magnetic cusp field which crosses the LBNL source's exit aperture. While this does prevent electrons from leaving the source along with the H^- ions, it also perturbs the H^- ion trajectories, making accurate beam measurements difficult.

3 RESULTS AND DISCUSSION

In the process of reproducing the H^- yield of the existing LANSCE source it became evident that a good deal of interdependency existed between the parameters of operation (duty factor, gas pressure, arc power, etc.). Two parameters of interest, namely filament cathode location and the quantity of cesium, were found to greatly influence high H^- yield.

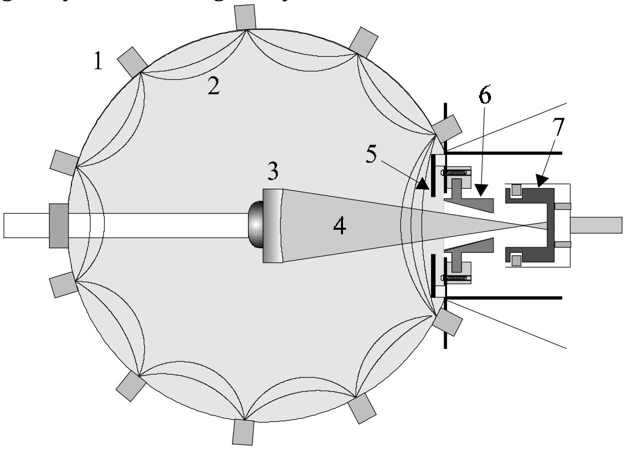

Fig. 2. Schematic of source interior (1. Cusp Magnet, 2. Cusp Field, 3. Converter, 4. H^- Beam, 5. Aperture Plate, 6. Aperture Cone, 7. Faraday Cup).

3.1 Cesium Factors

The amount of cesium in the source and more importantly the amount condensed on the converter surface is a significant factor affecting H^- yield [5]. If there is not enough cesium, the H^- output is low. As the cesium oven temperature is increased, more cesium vapor enters the source, and H^- current increases. However, if cesium injection continues beyond a certain level the H^- yield begins to drop, eventually going to zero as is shown in Fig. 3. In fact, the amount of cesium must be tailored to the very operating conditions of the source. For example, duty factor, arc power, and converter bias all effect what the optimal cesium oven temperature will be.

Along with H^- yield considerations the time required for the source to reach its optimal yield is strongly influenced by the cesium level. The source conditioning time is affected by the time it takes for the cesium to come to an equilibrium within the source. Source conditioning is a lengthy process by which the source is operated until optimal beam is achieved (the current LANSCE source is conditioned for more than 12 hours). In order to reduce the source conditioning time, and to better control the cesium dosage, a molybdenum liner was added to the interior walls of the source. The liner keeps the walls at a high temperature, thus preventing cesium condensation while still maintaining a good electrical contact for the plasma anode. By keeping the interior surfaces of the source warm enough to prevent condensation (except the converter), cesium usage efficiency increases, enabling less cesium to provide the same converter coverage, as well as providing that coverage more quickly. After the addition of the liner, conditioning time for the LBNL source was nearly cut in half without any observable decrease in source performance.

3.2 Cathode Position

High H^- yield was also found to depend on the location of the filament cathode relative to the converter

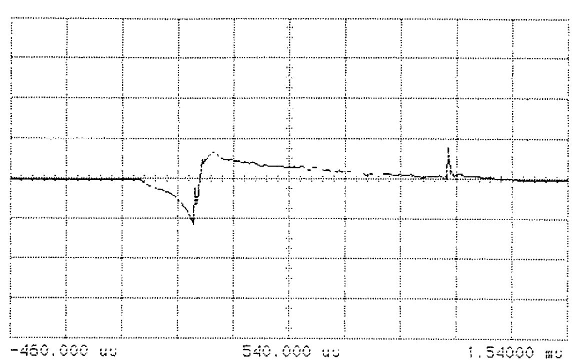

Fig. 3. H^- beam current on Faraday cup with complete over-cesiation, (1 mA per division) 10 mA present before occurrence of over-cesiation.

and to that of the nearest end-flange. Initially, long filaments were positioned away from the cusp field of the end-flanges, and the cathode was in a nearly field-free region with a clear line of sight to the converter face. It was thought that creating the plasma near the converter face and in a field free region, would lead to high H^- yield. This was not the case. The longer filaments consistently performed poorly, yielding no more than 12 mA of total H^- beam current. These filaments were then replaced with a shorter set that were closer to the end-flange with their cathodes roughly parallel to that of the converter surface. With this filament configuration the H^- yield on the Faraday cup was 20 mA, and a total beam current (aperture cone current plus Faraday cup current) of 33 mA was observed.

Due to the geometry of the source it was difficult to separate filament location (with respect to the converter) with that of magnetic filtering effects associated with the cathode in the cusp field [6]. To deal with this problem and to determine the source of the increase in yield, two 10 cm long plasma chamber extensions were added to the source. The extension chambers allow one to change the filament location easily, and the increased space permitted a movable magnetic filter to be added (see Fig. 5). With the extension chambers in place (without filter) and the two filament cathodes in field-free regions, total beam current was increased to 43 mA. It was also observed that with no filter in place as the arc power was increased H^- current approached an asymptotic value.

4 CONCLUSION AND FUTURE PLANS

Future experiments will involve a set of a movable magnetic filters to use in association with the plasma chamber extensions. Previous experiments using a similar source with a barium converter showed that this separation of the plasma chamber into a high electron temperature region and a low electron temperature region dramatically increased H^- production at higher arc powers [7]. This greatly extended the linear

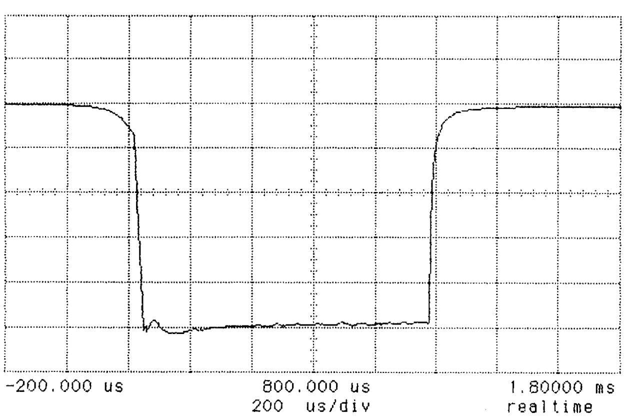

Fig. 4. 20 mA of H^- beam current on the Faraday cup.

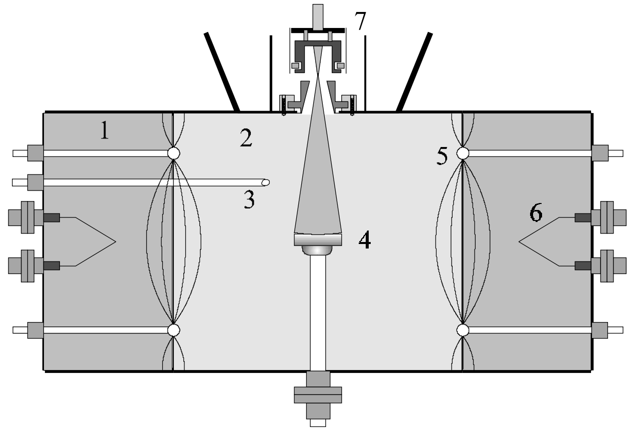

Fig. 5. Source schematic with chamber extensions and magnetic filter (1. High T_e Region with Filter, 2. Low T_e region with Filter, 3. Cesium Nozzle, 4. Converter, 5. Magnetic Filter, 6. Filament, 7. Faraday Cup).

response of the H^- current as a function of arc power unlike the diminishing return problem that was evident without the magnetic filter.

Once these experiments have been completed we will be able to turn our attention to RF induction plasma generation. While it is quite possibly that the new LANSCE source's beam requirements could be met using filament discharge, filament lifetime and reliability are still a concern which RF discharge could easily mitigate. With the increased cesium efficiency of the molybdenum liner and the increased durability of an RF antenna over filaments, source lifetime and reliability should be greatly enhanced along with that of beam current.

5 ACKNOWLEDGEMENTS

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