

H⁻ ION SOURCE DEVELOPMENT FOR HIGH PERFORMANCE*

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Abstract

The Los Alamos Neutron Science Center (LANSCE) at Los Alamos has the capability of accelerating both H⁺ and H⁻ ion beams. Several User Programs rely exclusively on H⁻ ion beams and have done so for more than 20 years. To enhance these programs, an active H⁻ ion source development program is ongoing with the goal of improving source performance (e.g. increased beam current, increased beam brightness, improved reliability and availability, increased source lifetime, etc.). A program to increase H⁻ beam current to 28-35 mA will be discussed.

LANSCE H⁻ PRODUCTION SOURCE

The H⁻ production source used at LANSCE is shown in Fig. 1. The source is of the multi-cusp class with filament driven discharge and biased converter where H⁻ ions are formed on a Cesium covered converter surface and accelerated by a converter bias voltage towards an outlet aperture [1, 2].

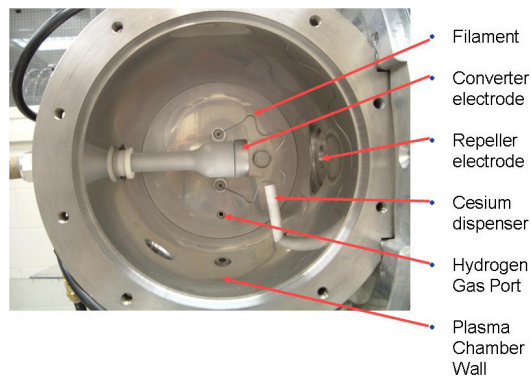


Figure 1: Interior view of the H⁻ ion source showing the elements of the multi-cusp filament driven cesiated surface converter. Not shown are the cusp magnets mounted externally on the cylindrical chamber wall.

The LANSCE source typically delivers a 16 mA pulsed (60 Hz) H⁻ beam with a lifetime of 35 days. Development efforts are focused on a number of issues. The primary goal is to increase the H⁻ output beam current from 16 mA to 28-35 mA. Increased beam current is not sufficient unless it is achieved with minimal transverse emittance growth, leading to increased beam brightness. Secondary development goals in support of user programs are beam availability, operational reliability, source lifetime, etc.

*Work supported by the US Department of Energy under Contract Number DE-AC52-06NA25396

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H⁻ ION SOURCE DEVELOPMENT

For H⁻ ion source development, LANSCE has a dedicated facility called the Ion Source Test Stand (ISTS) which is shown schematically Figure 2. Key components for the ISTS include a development ion source, an electrostatic column, an ion optical beam transport, and a set of beam diagnostics, including transverse emittance scanners for both horizontal and vertical measurements. Lastly, the ISTS can be readily reconfigured to accommodate a variety of ion source development experiments. A utilization goal for the ISTS is an operational availability >25% during the calendar year.

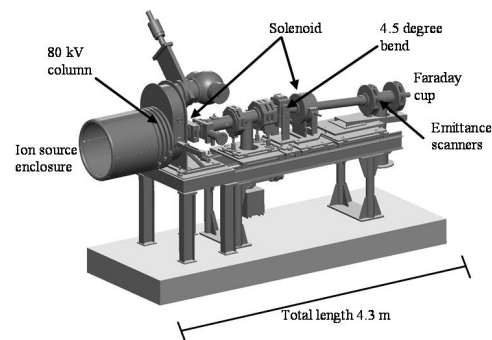


Figure 2: Layout of the ISTS facility [3]. The ISTS is dedicated to H⁻ ion source development.

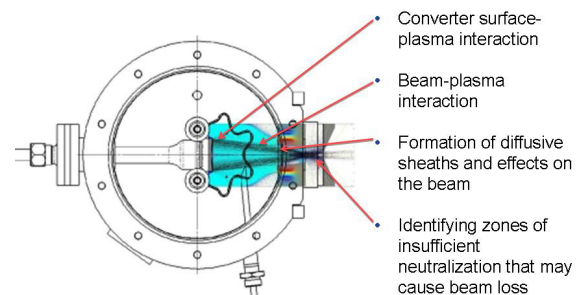


Figure 3: H⁻ ion source regions of interest in beam formation are highlighted. Note that beam extraction goes from left to right [4].

Figure 3 provides a schematic view of the regions of interest for H⁻ beam formation in the LANSCE H⁻ ion source [4]. In general, the physics case for a given development activity, which aims to increase H⁻ ion source output beam current, is based on its impact on the highlighted regions in Fig. 3.

PATH TO HIGH PERFORMANCE

A proposed path leading to enhanced performance of the LANSCE surface converter H⁻ ion source has been developed. Given below are a number of proposed experiments to be performed on the ISTS, including the physics case for each experiment and the expected benefit or outcome of each experiment. The experiments have been categorized as near or far term depending upon their expected impact on improved source performance.

Near Term

The first experiment would involve increasing the converter voltage. The physics case is based on the assumption that increasing the energy of sputtering ions and H⁻ leaving the converter would lead to reduces losses of H⁻ caused by surface image charges [5]. The expected outcome would be increased output current from the source. No mechanical modification of the source would be required for this experiment.

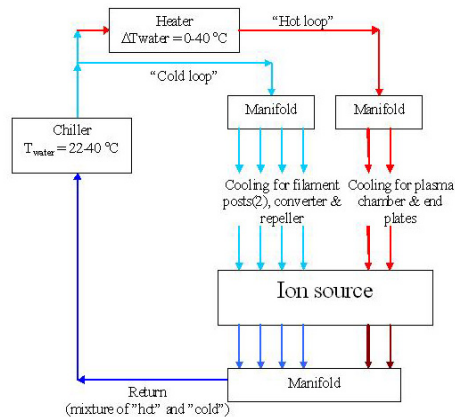


Figure 4: Arrangement of the ISTS water cooling system to accommodate warm source walls experiment [6].

Heating of the source walls (end plates and cylinder wall) while cooling the filament posts, converter and repeller would be another experiment. The physics case is based on the assumption that warm chamber walls will decrease condensation of the Cesium on the walls, leading to increased Cesium vapour pressure and enhanced sputtering of H⁻ ions from the converter [6]. The expected outcome would be an increase in beam current for a given discharge power. To perform this experiment requires that the source cooling system be modified as shown in Fig. 4.

The present LANSCE H⁻ production source operates with two tungsten [7] filaments. Modifying the source body to accommodate a third filament is another proposed experiment. The physics case is based on increasing the emission area for electrons, which would cause the discharge current and plasma density to increase, resulting in enhanced production of H⁻ ions. Again the expected outcome of this experiment is increased output beam current from the source. A conceptual view of a three filament source is shown in Fig. 5.

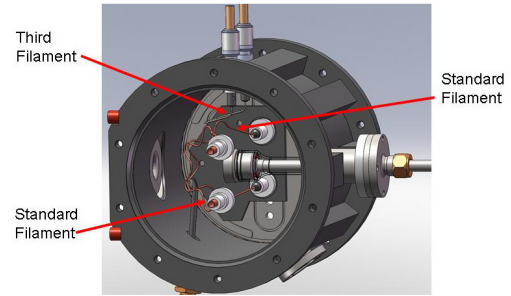


Figure 5: Proposed filament configuration for a three filament H⁻ ion source.

Improved control of the converter temperature is another development experiment. The physics case is based on the observation that even small temperature deviations on the converter surface may cause variations of the hydrogen coverage which affects the H⁻ yield. Better cooling of the converter could provide greater control of temperature variations across the surface. The expected benefit is more uniform conditions for H⁻ production on the whole surface area of the converter. Fig. 6 shows the design of the improved converter cooling channels.

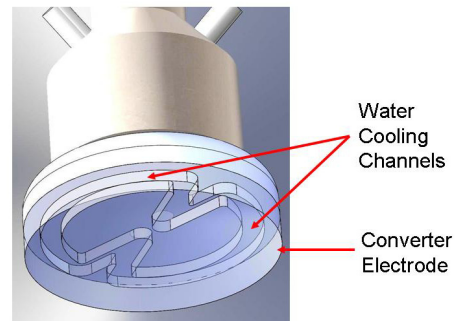


Figure 6: Model of the new water cooling channels for the converter electrode in the LANSCE H⁻ ion source.

Lastly, alternating the direction of current flow through the filaments is an additional development activity for the near term. Reversing the direction of the filament heating current, e.g. every few minutes, is expected to reduce the so-called Tungsten electromigration causing irregularities in the filament shape that lead to filament failure [8]. The expected benefit from this approach is a reduction in hot-spot formation and mitigation of filament warping, leading to improved filament lifetimes.

Far Term

A number of development activities will follow the above. For example, the Cesium reservoir needs to be the coldest spot of the Cesium oven assembly in order to prevent uncontrolled bursts of Cesium into the ion source. A proposed two “two-heater” oven would provide better

Cesium control during the source start-up phase every 35 days.

Using thicker diameter filaments would increase the emission area of electrons which would cause the discharge current and plasma density to increase. This would enhance production of H⁻ ions.

Reducing the diameter of the extraction aperture limits the emittance of the H⁻ ion beam. If this is combined with increased current density it leads to increased beam brightness and better beam quality.

An alternative to actively heating the walls of the LANSCE H⁻ ion source would be to install a hot-liner. Such a device would prohibit accumulation of Cesium on the source walls, resulting in lower Cesium consumption rates. If the temperature of the liner exceeds 970 °C practically all Cesium will be ionized on the surface of the liner. This could enhance the sputtering of H⁻ from the converter. The expected benefit would be better control over the Cesium coverage of the converter.

ION SOURCE DEVELOPMENT STATUS

Preliminary progress has been made on two of the development activities discussed above, namely increasing the converter voltage and heating of the source walls (cylindrical wall and end plates).

The H⁻ ion source output beam current was measured as a function of the peaked converter voltage (~250 to ~450 V) for four different discharge currents (31, 35, 40 and 41 A) [5]. It was observed that the beam current was virtually independent of the converter voltage, however, it did depend on the discharge current or plasma density. Unfortunately transverse emittances were not performed due to technical difficulties with the emittance equipment.

An initial experimental study of the effect of heating the plasma chamber walls on the LANSCE surface conversion H⁻ ion source has been conducted [3]. It was observed that increased wall temperatures led to increased extracted beam currents. In particular increases of 14 °C in the heating loop shown in Fig. 4 led to an increase in extracted beam current from ~16 mA to ~18 mA. Accompanying transverse emittance measurements were consistent with little or no emittance growth. These results suggest that elevated wall temperatures can be used to for improving the brightness of the H⁻ ion beam.

FUTURE DEVELOPMENT PLANS

Development efforts will continue to follow the road map of experiments outlined above. In the near term experimental studies of the effect of a third filament and

of improved cooling of the converter electrode will be of the highest priority. Both studies require hardware modifications to the H⁻ ion source as depicted in Figs. 5 and 6. These modifications are in progress and development experiments are expected to resume in the near future.

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