PROGRESS REPORT OF H⁻ ION BEAM PRODUCTION AT THE LANL ION SOURCE TEST STAND*

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Abstract

As part of the Los Alamos Neutron Science Center (LANSCE) the Ion Source Test Stand (ISTS) is a flexible, stand-alone facility used for H^- ion beam source development and studies of low energy beam transport. It consists of a surface converter ion source with a multi-cusp permanent-magnet plasma confinement structure, an 80-kV high-voltage electrostatic extraction column, a low-energy ion beam transport line, and beam phase-space diagnostics. After resolving several technical issues, the ISTS was successfully restarted during the summer of 2012. Since then we have performed several long duration experiments. A development program is ongoing with the goals of improving source performance (e.g. reliability, availability, increased current, etc.) and beam transport efficiency (beam neutralization at low energy, beam dynamics with/without noble gas injection, etc.). Several enhancements to performance are being investigated in order to achieve a forthcoming upgrade requirement of LANSCE operations in 2014: beam current of 16-18 mA, 120-Hz operation at a duty factor of 10% and a source lifetime of greater than 28 days. We present a short description of the ISTS apparatus, obtained results and forthcoming experiments.

H⁻ ION SOURCE TEST STAND

The ion source test stand (ISTS) (Figure 1) was developed to perform H^- beam research in support of operation of H^- source of LANSCE user facility [1, 2]. It is a replica of the 80 keV injector in the H^- dome of LANSCE which is used to accelerate beam to 750 keV using a Cockcroft-Walton high-voltage generator. The ion beam optics consists of a four electrode electrostatic accelerating column (Pierce electrode -80 kV, extraction electrode -67 kV, column electrode -27 kV and grounded electrode), two focusing solenoid magnets separated by a distance of 1.9 m, two emittance measurement stations (IDEM02 and IDEM03), an electrostatic beam deflector, and a 4° bending magnet to separate H^- beam from electrons (see Fig 1). Beam current is measured by a calibrated current monitor and Faraday cup. The beam line is equipped with a residual gas analyzer (RGA) to characterize outgassing processes and a noble gas injection subsystem (Ar, Xe, etc.).

The first long ISTS run (over four weeks) was successfully performed during August and September 2012. The H^- ion beam was extracted in the range of 10 to 14 mA using a pulsed source gate of 835µs with repetition rate of 120 Hz (or ion source duty factor of 0.102).

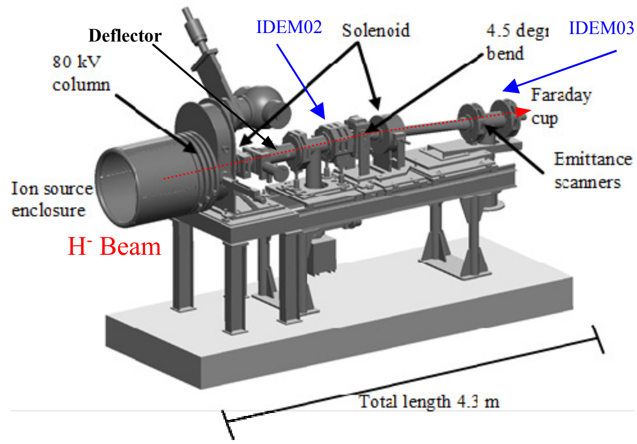

Figure 1: Schematic layout of the H^- ion source test stand.

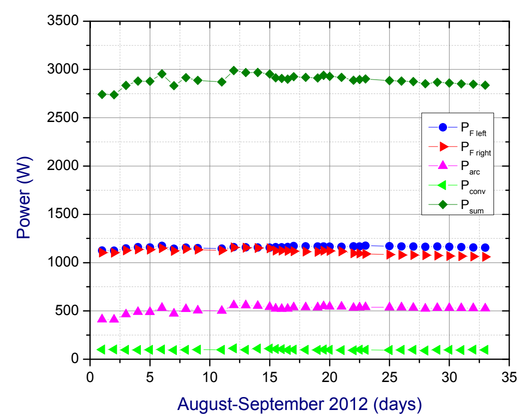

Figure 2: Source of power losses in the H^- ion source includes thermal dissipation of the two filaments, arc discharge and converter electrode loses at 120 Hz.

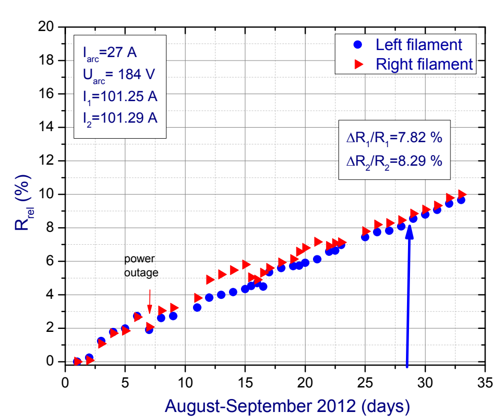

Figure 3: Recorded filament relative differential resistances (R1 - right filament and R2 - left filament).

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A set of standard operational parameters for the ISTS set were applied to achieve a nominal working regime for the ion source and beam transport at low energy of 80 KeV. The thermal power distribution is shown in Fig. 2. The total source power was less than 3 kW. The tungsten filament relative differential resistances were recorded during the entire run cycle as a diagnostic tool for the source lifetime. First preliminary data of the filament differential resistance of ~8.0% presented in Fig. 3 indicates that the a typical LANSCE H^- ion source will be able to last over 28 days at a high duty factor (0.102). In fact, the differential resistances of both filaments after 33 days did not exceed an empirical criterion for catastrophic failure of 12 % total increase in filaments resistance for this type of H^- surface converter ion source. Comprehensive tests of ion source reliability in "production like" operation conditions are underway. Detailed analysis of the source lifetime and filament differential resistance is described in Ref. [3]. The ISTS was used to produce a lower H^- ion beam at 35 keV in order to study H^- beam neutralization effects for the first time. Some recent results are described below.

SPACE-CHARGE NEUTRALIZATION STUDY

Beam emittance scans were performed using the IDEM02 and IDEM03 beam emittance stations. A typical emitance scan using the standard slit-and-collector emittance-measurement system is presented in Fig. 4. During beam measurements, the electrostatic deflector pulse was kept constant at a repetition rate of 4 Hz and pulse length of 625 µs, while emittance measurements were sampled within a 50 µs gate with variable delay of τ = 10 - 580 µs with respect to the beginning of the deflector pulse, reproducing different values of beam pulse at both stations. All measurements were performed at standard working vacuum pressure of $1.6 \cdot 10^{-6}$ Torr. The H^- beam intensity was 9.3 mA for beam energy of 80 keV. The purpose of this experiment was to determine the level of beam space charge neutralization as a fuction of tme in the beam pelse. Figures 5 and 6 show the variation of beam parameters versus beam pulse. The beam parameter values of are stabilized after 100 - 150 µs.

Determination of the level of compensated space charge was done through comparison of results of measurements and simulation. These results indicate that 100% neutralization is achieved after 120 µs for a beam energy of 80 keV, while the same level of neutralization is achieved after 200 µs with a beam energy of 35 keV achieves. The beam neutralization results are described in detail in Ref. [4].

HIGH CONVERTER VOLTAGE EXPERIMENTS

The extracted H^- beam current was tuned by adjusting converter voltage in the range from 220 to 500 V for a discharge current of 26 A. For each point a corresponding cesium oven temperature (200 to 240 C) was allowed to stabilize over several hours (3-4 hours per point) to get

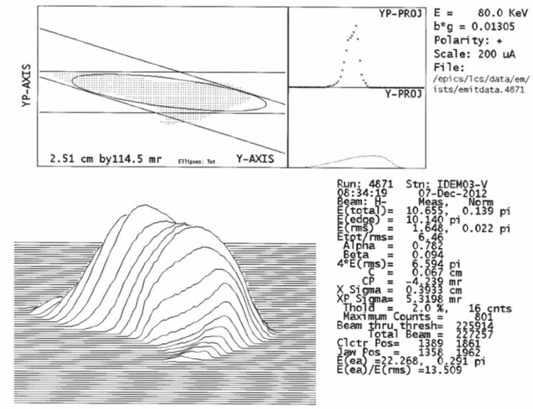

Figure 4: Characteristic transverse phase space data (H^- beam vertical emittance scan recorded using IDM03).

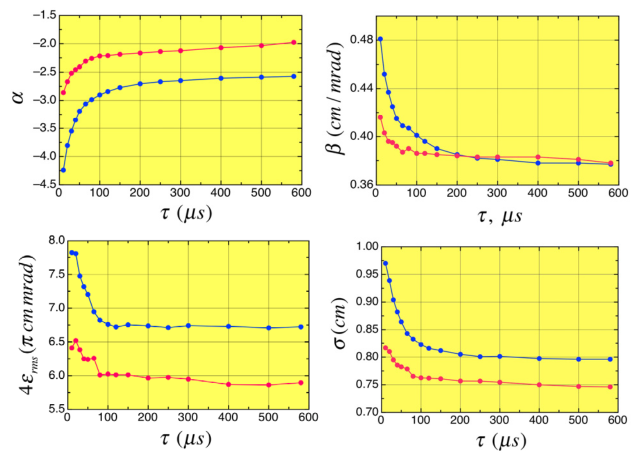

Figure 5: Parameters of 80 keV beam at IDEM02: (blue) horizontal, (red) vertical.

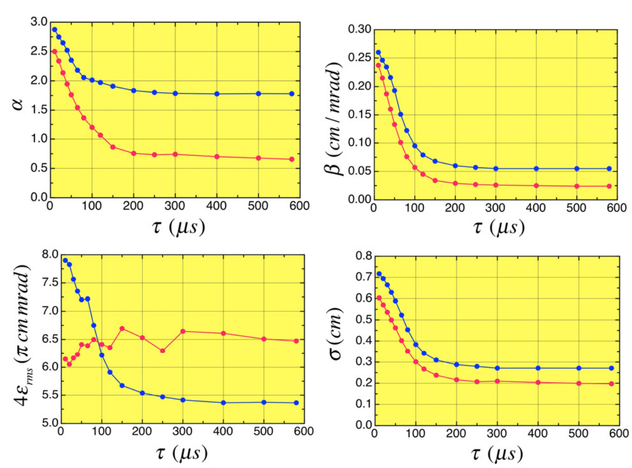

Figure 6: Parameters of 80 keV beam parameters at IDEM03: (blue) horizontal, (red) vertical.

the maximum output current. Optimal converter voltage increases with increasing cesium oven temperature (see Fig. 7A). Similar temperature dependence was measured and discussed in the previous ISTS work described in Ref.

[5]. We have observed H^- beam current increases up to 30 % with elevated converter voltage (Fig. 7B). The new results are in agreement with theoretical models, but different from results recorded before at the ISTS [5]. Previous beam intensity measurements were independent of high converter voltage and emittance measurements were not taken. In our set of measurements we were able to record emittance scans using both EM stations. Transverse emittance dependence on elevated converter voltage is shown in Fig 8A. Total emittance values are constant over the converter voltage range of 250 to 450 V, except for IDEM02 scans in vertical direction. 7 to 11 π-cm-mrad, 4-rms emittance increase in the vertical direction was measured on the second station. Beam brightness was constant for the whole range of high voltage (see Fig 8. B). We plan to repeat the same measurements with extracted beam over the beam current range of 16 -18 mA (production level for LANSCE) and converter voltages up to 600 V. We expect to see an increase of H^- beam currents up to 21 - 23 mA. We hope that the new experiments will resolve disagreements between different experimental results and theoretical models for the formation of H^- ions on the surface of negatively biased electrode (converter).

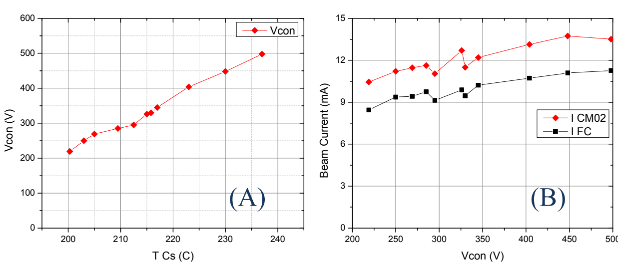

Figure 7: (A) The "peaked" converter voltage as a function of cesium oven temperature. (B) Beam currents measured using current monitor and Faraday cup as a function of converter voltage.

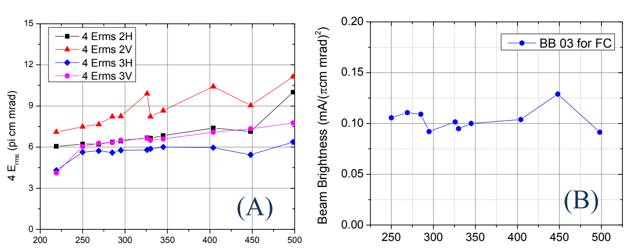

Figure 8: (A) Emittance measurements performed at IDEM02 and IDEM03 stations as a function of elevated converter voltage. (B) H^- beam brightness as a function of converter voltage.

ISTS DEVELOPMENTS PLAN

The H^- ion beam development plan for better performance consists of 28 different proposals. They are compatible with a previously described development plan for the ISTS [6]. The plan includes some of the following proposals:

- Improvement by elevating source body temperature by reduction the water flow in the source body/ side plates cooling loops or increasing input water temperature.
- Optimizing converter geometry and position.
- Modification of the converter electrode water cooling channels for more uniform current density production over the electrode surface.
- Addition of an inner hot liner (screen) for better control over Cs coverage of the converter and reduction in Cs dissipation.
- Installation of a third filament for higher discharge currents, plasma density and enhanced production of H- beam.
- Investigation of thicker filament diameters for increased electron emission area, higher discharge current and higher extraction of negative ion beams.
- AC versus DC voltage driven filament heating for prolongation of source lifetime and higher extracted beam currents.
- Continued space charge neutralization experiments: 80 keV/35 keV H^- beam transport at different values of beam pulse length, different vacuum pressures, and different residual gases (by injection of heavy noble gases Ar, Kr, Xe into transport beam line).

These development efforts are expected to enhance performance of the LANSCE surface converter ion source in the long term. Upcoming, near-term ISTS experiments will focus on demonstrating reliable 120 HZ source operations for >28 days in support of 2014 LANSCE operation requirements.

ACKNOWLEDGEMENT

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