# ENHANCED H$^-$ ION SOURCE TESTING CAPABILITIES AT LANSCE*


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*Abstract*

As part of the on-going beam-current upgrade in the Proton Storage Ring (PSR) at the Los Alamos Neutron Science Center (LANSCE), the current available from the H$^-$ injector will be increased from the present 16 to 18 mA to as much as 40 mA. A collaboration between the Ion Beam Technology Group at Lawrence Berkeley National Laboratory (LBNL) and the Ion Sources and Injectors Section of LANSCE-2 at Los Alamos National Laboratory (LANL) has been formed to develop and evaluate a new ion source. A new Ion Source Test Stand (ISTS) has been constructed at LANSCE to evaluate candidate ion sources . The ISTS has been constructed to duplicate as closely as possible the beam transport and ancillary systems presently in use in the LANSCE H$^-$ injector, while incorporating additional beam diagnostics for source testing. The construction and commissioning of the ISTS will be described, preliminary results for the proof-of principle ion source developed by the Berkeley group will be presented, and future plans for the extension of the test stand will be presented.


## 1 INTRODUCTION

The surface-conversion H$^-$ ion source used to supply production beam at LANSCE has been in use since 1984. References [1] and [2] describe the development of this ion source. A new collaboration between LBNL and LANL has been formed to develop an ion source [3] capable of providing 40 mA of H$^-$ beam to the LANSCE linac. A new test stand has been constructed at LANL to provide a place to evaluate the new ion source before it is moved to the equipment dome of the LANSCE H$^-$ Ion Injector. The test stand has been constructed to duplicate as closely as possible the low energy column and beam transport system presently installed in the equipment dome of the H$^-$ Injector.

## 2 H$^-$ ION INJECTOR BEAM TRANSPORT

The 750 keV beam produced by the H$^-$ Injector is obtained from a surface-conversion H$^-$ ion source on an 80 keV transport system located inside the equipment dome of a 670 kV Cockcroft-Walton. As shown in the schematic representation in Figure 1, the transport system inside the dome consists of an 80 kV accelerating column and a two-solenoid transport. A beam deflector between the two solenoids permits changing the length and repetition rate of the beam pulse delivered to ground while the ion source remains operating at a 10 to 12% duty factor (835 to 1000 μsec pulse length at 120 Hz rep rate). Beam diagnostic devices in the dome consist of four current monitoring toroids placed along the 80 keV transport and slit and collector emittance gear capable of measuring emittance in the horizontal and vertical planes. The emittance station is located mid-way between the two transport solenoids.

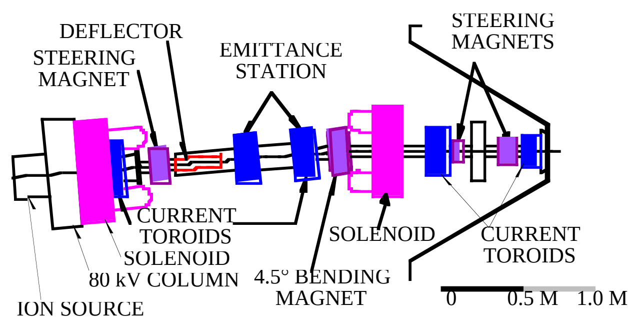


Figure 1. Schematic depiction of the major components of the 80 keV beam transport inside the LANSCE H$^-$ Ion Injector.

## 3 ION SOURCE TEST STAND CONSTRUCTION

Constructing ISTS to duplicate the configuration of the existing H$^-$ Ion Injector is highly desirable. Not only can the test stand provide an emergency supply of critical components for the injector while LANSCE is in production, but also unforeseen surprises, when a new ion source is finally moved to the injector, can be minimized by the experience gained in operating the source on a nearly identical beam transport. A test stand that closely duplicates the conditions of the H$^-$ Injector dome also provides a place for off-line testing of ancillary equipment [4] that might be considered for use in the dome.

The ISTS is located in the same room that had housed an old H$^-$ test stand. That stand [5] was completely removed except for its 50 KVA isolation transformer and isolated electronics racks, which were relocated in the room to provide space for the new, larger ISTS. The


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existing 2000 l/s turbo pump and attendant backing pumps were returned to service on the new test stand.

To begin experiments with beam early in the development of the new ion source, the construction of the initial ISTS transport was terminated at a Faraday cup installed just after the mid-transport emittance station. The remainder of the transport, including a bending magnet and second transport solenoid, will be installed later. An additional diagnostic station will also be added to measure the emittance at a distance from the transport equivalent to the entrance of the 670 kV column in the $H^-$ Injector. The ISTS as presently constructed contains sufficient diagnostic gear to allow comparison of ISTS beam experimental results with those routinely performed during LANSCE beam production cycles in the $H^-$ Ion Injector dome. Figure 2 shows the ISTS in its present configuration.

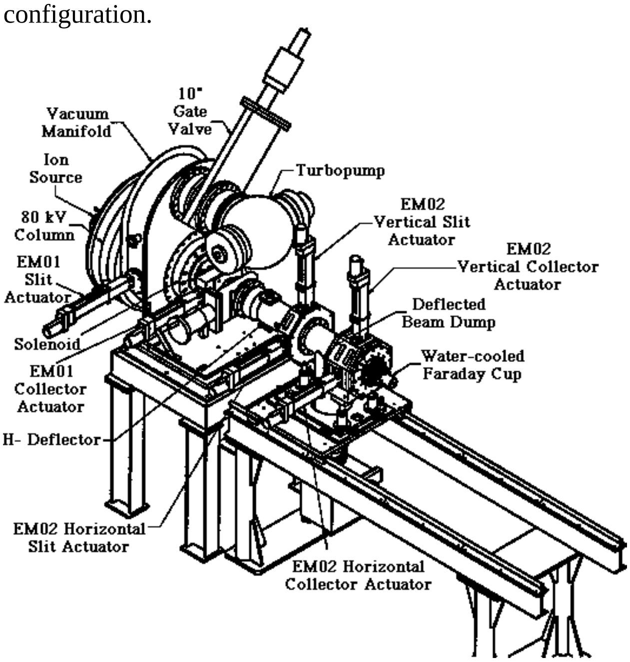


Figure 2. Isometric drawing of the beam line components assembled for the first phase of construction of the ISTS.

## 4 BEAM DIAGNOSTICS

### 4.1 Emittance Measurements

Slit and collector emittance gear identical to the gear in the $H^-$ Injector dome was installed on the ISTS in the same relative location along the beam transport. On ISTS this gear is referred to by the acronyms EM02H for horizontal and EM02V for vertical plane. The test stand has an additional diagnostic station, not found in the $H^-$ dome, which is used to measure the horizontal-plane beam emittance directly after the 80 kV accelerating column. This gear is referred to as the EM01H gear. There is no space available to install vertical plane actuators. A water-cooled carbon slit capable of withstanding the full duty factor of the anticipated beam (almost 400 watts) is mounted in the side of the main vacuum manifold directly after the 80 kV column. The corresponding collector is mounted just downstream of the x-y steering magnet, which follows the first focusing solenoid. Use of this diagnostic thus requires turning off the solenoid and steering magnets.

It was long thought that the 80 kV accelerating column was causing emittance growth in the dome transport, but use of this new diagnostic on the ISTS has demonstrated that the measured beam at the exit of the accelerating column is almost exactly that of the geometrical admittance of the ion source. The capability to measure emittance directly after the 80 kV accelerating column provides us with data which can be compared to ray-tracing simulations of the column dynamics. Another contribution [6] to these proceedings discusses some of these results.

### 4.2 Steering Magnets and Current Toroids

In the $H^-$ Injector dome there are three sets of steering magnets located along the 80 keV transport and four current monitoring toroids. The ISTS has, at present, only one set of steering magnets, located immediately downstream of the first focusing solenoid. The primary use of the steering magnet is to sweep electron contamination out of the ion beam during emittance measurements at EM02. This same technique is used in the $H^-$ Injector during emittance measurements.

In the $H^-$ Injector the first two current toroids are located directly downstream of the first focusing solenoid and directly after the collectors of the emittance gear located at the mid-point of the transport. On ISTS we have exactly duplicated the second current toroid, but the inclusion of the EM01H emittance diagnostics on ISTS precluded the inclusion of a beam current toroid immediately downstream of the first solenoid. A toroid was mounted inside the vacuum manifold on ISTS and provided useful beam current information during the initial commissioning of the test stand. It did not survive the transition to a source with higher apparent electron content and has subsequently been removed.

## 5 COMMISSIONING

Following the cessation of LANSCE accelerator operations in mid-August of 1997, injector personnel concentrated on getting the new ISTS assembled and operational. One of the LANSCE production ion sources was mounted on the test stand for initial commissioning experiments. First beam was transported to the end of the transport on September 25, 1997 and operation of the beam current monitors and the EM02 gear was verified.

Beam current was measured at the exit of the 80 kV column and directly after the EM02 emittance gear by current toroids (1.6 m apart) with apertures of approximately 7.5 cm. The 80 keV beam is dumped into a Faraday cup with an entrance aperture of 4.4 cm. located 15 cm. after the second toroid. An additional indication of beam current is provided by monitoring the total current drain on the 80 kV beam energy supply. Representative data of such measurements are presented in Table 1.

Table 1. Beam current measurements along the ISTS 80 kV transport. The steering magnet has been adjusted to remove the electron contamination for the data shown in the last two columns.

| 80 kV supply drain current, mA | 80 kV column toroid, mA | Toroid after EM02 station, mA | Faraday Cup Beam Dump, mA |
|---|---|---|---|
| 20 | 20 | 7.9 | 7 |
| 30 | 28 | 6 | 6 |
| 50 | 45 | 16 | |
| 40 | 33 | 16 | 15.6 |
| 40 | 32 | 15.2 | 14.8 |

Several hundred emittance measurements have been made to commission the operation of the ISTS emittance diagnostics and compare the results with those routinely obtained over the years in the $H^-$ Injector dome. Agreement between $H^-$ Injector dome data and ISTS data has generally been acceptable; emittance on ISTS is generally 5 to 10% larger than historical measurements in the dome. A sample of better agreement is presented in Table 2.

Table 2. Comparison of mid-transport emittance measurements for the ISTS and the $H^-$ Injector dome.

| Parameter | ISTS | $H^-$ Injector |
|---|---|---|
| Date/Plane | 5-Dec-97/H | 2-May-92/H |
| Run Number | 265 | 3003 |
| E(Tot) Measured | 7.305 | 7.627 |
| E(Tot) Normalized | 0.095 | |
| E(RMS) Measured | 1.218 | 1.116 |
| E(RMS) Normalized | 0.016 | |
| Alpha | 0.263 | 0.083 |
| Beta | 0.361 | 0.445 |

The calculated mismatch factor [7] is 0.16

Once satisfied that measurements of emittance and beam current on the test stand were in agreement with similar measurements made in the $H^-$ Injector dome, we proceeded to test the proof-of principle (POP) ion source [3,8] that has been developed at LBNL. Further discussion of the development of this source is given elsewhere [3] at this conference.

## 6 INITIAL POP ION SOURCE TESTS

The Ion Beam Technology Group at LBNL developed a proof-of-principle ion source capable of producing the desired beam current of 40 mA in the Fall of 1997 [8]. The configuration of this early POP ion source evolved into the "Axial" source delivered to Los Alamos and mounted on ISTS earlier this calendar year. At LBNL at least 40 mA of 250 eV $H^-$ current has been observed in a biased Faraday cup located directly after beam exits the ion source. In early experiments with this source we have obtained good agreement with this result in that we have observed up to 33 mA of 75 keV $H^-$ beam through the current toroid and Faraday cup at the end of our present transport. Because the Axial source is a POP device, it does not lend itself to extensive experimentation with, for example, changes in alignment. Future measurements of its characteristics have been deferred.

## 7 FUTURE CONSTRUCTION

Assembly of components to complete the ISTS is underway. We will next mount a bending magnet and second solenoid to complete the duplication of the devices in the $H^-$ Injector dome. The beam line will end with a third emittance station for studies of emittance growth and beam dynamics. Additional beam diagnostics such as current toroids will be placed along the added beam line.

## 8 SUMMARY

We have assembled and commissioned a test stand for $H^-$ ion sources which closely duplicates the existing low-energy transport located in the LANSCE $H^-$ Ion Injector equipment dome. The new test stand allows off-line measurement of ion source performance with direct comparison of results to the existing injector. The new test stand not only provides a locale to study the performance of next-generation $H^-$ ion sources for LANSCE, but also serves as ready source of spares of critical components of our existing injector. It offers the opportunity for evaluation of $H^-$ ion sources for others who might wish to use this new capability.

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