High Current He$^-$ Injector for Tandem Accelerators

T.M. Hauser, R.E. Daniel, G.A. Norton and J.B. Schroeder

National Electrostatics Corp.
P.O. Box 620310
Middleton, WI 53562, USA

Abstract

National Electrostatics Corp. has designed, built and tested a high current negative ion helium injector for use with tandem electrostatic accelerators. This injector system consists of a NEC Toroidal Volume Ion Source (TORVIS) followed by a rubidium vapor charge exchange cell. The observed He^- beam current after mass analysis was routinely 20 microamps with a maximum beam current of 32 microamps. This compares to the 2 to 4 microamps from a standard RF charge exchange He^- injector.

Positive Ion TORVIS and Charge Exchange

The interior of the TORVIS is separated into two regions using a filtering magnetic field. For negative ion operation, a central magnet is placed on the back plate of the ion source directly opposite the beam exit aperture. This produces a conical region containing slow electrons. The fast electrons are filtered out of this volume reducing destruction of the negative ion. For positive ion operation, the central magnet is not used which allows the faster electrons to depress the formation of a negative ion. In the case of He+ production, magnets are empirically arranged on the back plate to intensify the plasma for helium ionization.

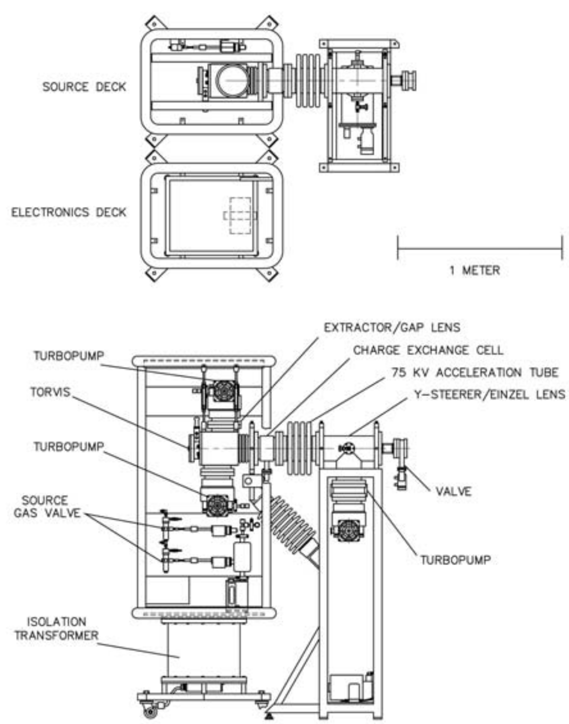
The TORVIS is followed immediately by a differentially pumped extraction/gap lens assembly. One turbo molecular pump rated at 500 l/s pumps directly on the ion source exit. The second 500 l/s turbo molecular pump acts on the gap lens assembly. The entire extraction/gap lens assembly and source are at injector deck potential and insulated for a rating of more than 20 kV from the charge exchange cell. The rubidium charge exchange cell is below deck potential, immediately before the 75 kV acceleration tube. Both the back plate and the exit flange of the TORVIS source are liquid cooled. The entrance and exit of the charge exchange cell are also liquid cooled to prevent rubidium vapor migration. This charge exchange cell is similar to that used on the NEC RF charge exchange sources.

At ground potential, at the exit of the 75 kV acceleration tube, is another 500 l/s turbo pump with a Y steerer and einzel lens in the pump tee. This pumping arrangement allows for a pressure of about 3×10^{-5} Torr at the ion source and about $2\text{-}3 \times 10^{-6}$ Torr at the ground pump tee with the source in operation. The base vacuums with the source off were in the low 10^{-8} Torr region.

As stated above, the rubidium charge exchange cell has liquid cooled entrance and exit flanges. The body of the cell is maintained at about 50^{o}C to allow the condensation of the rubidium on the interior walls of the cell without freezing out. This allows the rubidium to recirculate throughout the cell for a lifetime which is typically longer than 1,000 hours of continuous operation. The rubidium oven is maintained at 230-250^{o}C.

The optics of the He- TORVIS injector is typical of that for injectors into tandem electrostatic accelerators. The source aperture is 4.8 mm and the emittance used in calculations is 5.09 mmmr MeV$^{1/2}$. Although this emittance was not measured, it is a good empirical fit to operational experience. For a beam energy of about 70 keV, the einzel lens is operated between 23 - 25 kV producing a waist with a beam diameter of 4 mm about 1 m from the einzel lens.

The TORVIS source is mounted to the far right followed by the extractor/gap lens assembly pumped by two 500 l/s turbo molecular pumps. The Rb cell immediately follows this assembly at the entrance to the 75 kV all metal/ceramic acceleration tube.



The insulated injector platform is supported on an isolation transformer rated at 100 kV. The injector is pumped by three 500 l/s turbo pumps for a vacuum at ground potential in the 10^{-6} Torr range. The system is designed to provide a beam waist approximately 1 m from the einzel lens.

Experimental set up - The injector is in the background directly behind the +/-30° mass analyzer magnet. The negative ion beam current is measured in a suppressed, high power, tantalum Faraday cup in the foreground.

Performance

Testing was performed at the NEC factory in Middleton, Wisconsin. The negative ion beam current was measured after 30° magnetic analysis in a suppressed Faraday cup. In addition to the analyzed beam, x-ray levels were monitored during all beam running. At 2 m from the ion source, x-ray radiation was generally in the range of 1-2 μSV/hr.

The results of the beam tests are shown in Table 1. For these tests, the source deck bias was about 60 kV for an analyzed beam energy of about 65 to 70 keV. Although the primary beam of interest was He-, the injector configuration also allows the production of H- and ^{2}H-. These tests were performed with the rubidium charge exchange oven off and the extractor voltage reversed from that used for the He- beam.

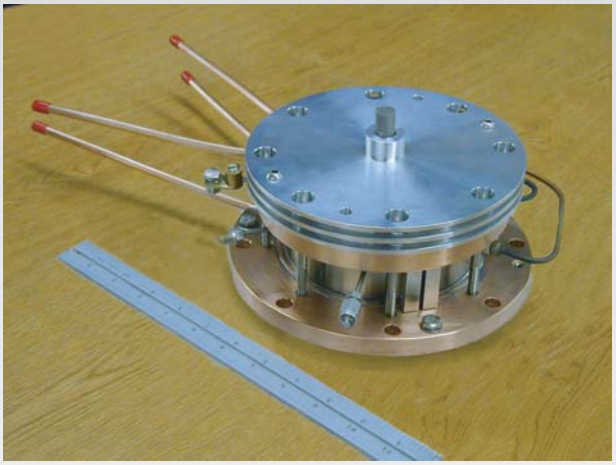
Although the He+ beam current was not directly measured, based on the expected charge state fraction, it is assumed that the He+ beam is on the order of 1-2 mA. [2] All beam currents stated were measured for 1 to 4 hours. At the end of the beam test, the ion source was turned down voluntarily, the source did not fail.

This injector is the second high current, TORVIS based He- injector built. It is presently under going installation at the RUHR-Universitat Bochum, Dynamitron-Tandem-Laboratorium. It will be used on the 4 MV tandem Dynamitron.

Table 1
Injector performance when optically configured for He-.

ARC V/A	Filament A/V	Extractor kV	Focus kV	Rb Oven °C	Pressure @ source (TORR)	Beam Current μA
104/6.7	83/12.7	6.4	8.7	230	2.6×10^{-5}	31.4 He^-
93/6.6	85/13.7	2.1	17	N/A	3.2×10^{-5}	223 H^-
108/6.9	82/13	1.8	15	N/A	4.8×10^{-5}	155 $^2H^-$

Beam current is measured after 30° magnetic analysis in a suppressed Faraday cup at a beam energy of 65 keV to 70 keV.



The Negative Ion TORVIS has a double walled cylindrical housing containing almost 500 samarium cobalt magnets each 6.3 mm in diameter. Both the back plate and beam exit aperture plate are liquid cooled.

Negative Ion TORVIS

The TORVIS is a compact source in a 5" diameter housing containing about 500 rare earth magnets. The source is immediately followed by a differentially pumped extractor/gap lens assembly. This DC TORVIS was adapted from the pulsed volume ion source developed at Brookhaven National Laboratory by Prelec and Alessi [4,5].

The purpose of the negative ion TORVIS is to inject H- and ^{2}H- into a tandem Pelletron with suitable emittance for an efficient transmission to produce H+ and ^{2}H+ beam in the 5 to 8 MeV region. The primary application has been Pulsed Fast Neutron Analysis (PFNA). There are now four of these sources in routine use. The time between servicing is over 1000 hours of beam time while producing more than 300 μA of ^{2}H-. Detailed performance and operating parameters are described elsewhere [6].