A 20 mA H$^-$ ION SOURCE WITH ACCEL-ACCEL-DECEL EXTRACTION SYSTEM AT TRIUMF

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Abstract

During the last three decades, TRIUMF has developed H$^-$ cusp ion sources for the 500 MeV, TR30, TR13 cyclotrons, as well as many other machines. These ion sources can be categorized as high current versions, producing up to 20 mA of DC H$^-$ beam within a normalized emittance (4RMS) of 0.6 π-mm-mrad and low current versions, producing up to 1 mA of CW current within a normalized emittance (4RMS) of 0.16 π-mm-mrad. A new state-of-the-art test stand is being built to further enhance H$^-$ knowledge while improving the brightness and filament life. The preliminary results of the test stand performances, as well as relevant emittance measurements, are discussed.

INTRODUCTION

TRIUMF's 500 MeV cyclotron has been fed by an arc discharge H$^-$ ion source developed in-house 20 years ago. Since then, new additions to TRIUMF like ISAC have required more and more beam current from the cyclotron. To satisfy the growing intensity of experiment demands, the source beam current and brightness needed to be improved. Due to historical reasons, the initial beam energy has been limited to 12 kV and the power to the source filament limited to 2.5 kW. Finding reasonable time slots for beam development has also been difficult due to heavy usage of the ion source. Filament life has been an additional concern as every three weeks there was a loss of two to three shifts due to interruptions for filament changes and re-tuning. Consequently, the need for a state-of-the-art test stand became an increasingly prominent concern. This new test stand was designed to develop a high brightness ion source with a long filament life. One of the unused on-line terminals was chosen to build said test stand so it would be available for use as a hot spare if required.

EXPERIMENTAL SETUP

The test stand was built in a terminal; a metal enclosure of 6 m by 5 m by 3 m (see Fig. 1) built on 300 kV high voltage insulators and additionally powered by a 100 kVA isolation transformer. The test stand was built on rails for easy access to any element in the system. The source is located in a second high voltage enclosure capable of up to 75 kV and powered by a 45 kVA isolation transformer. This secondary high voltage rack consists of several power supplies: a 10 V * 1000 A filament one, a 200 V * 50 A arc one, a 10 kV * 400 mA lens one, and a few other small power supplies, including virtual coil ones. Another 100 kV x 2 kVA transformer is utilized to supply uninterrupted power to the controls and the safety devices at the secondary stage so that the sparking and the vigorous testing will not affect them.

The vacuum system employs four turbo pumps, a root blower and a scroll pump and is capable of reaching 2e-9-Torr in the source side without gas loading.

The beam line (see Fig. 2) is equipped with a cusp source, a 4-electrode extraction system, a focusing solenoid and diagnostic components such as emittance scanners, and a graduated Faraday cup. All the focusing and steering elements are magnetic and no electrostatic elements were used other than in the extraction system.

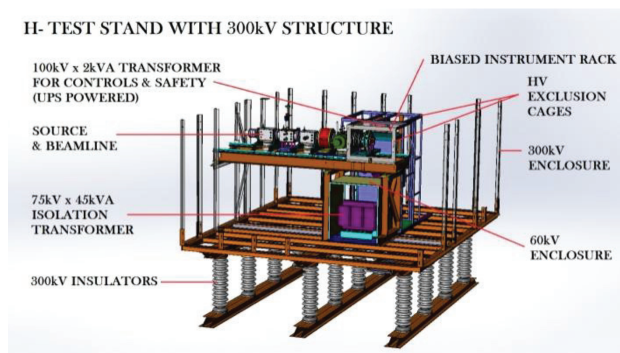

Figure 1: H$^-$ test stand with the 300 kV platform.

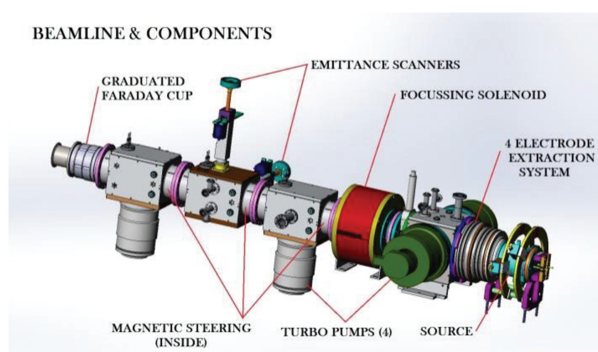

Figure 2: The beam line with the source, extraction system, diagnostics elements and the vacuum components.

The Ion Source (see Fig. 3) employs a 20 row Halbach array type magnetic configuration. Four electro magnets have been built to provide virtual filter magnetic fields so that they can be optimized to various arc voltages and different plasma conditions.

A new accel-accel-decel extraction system is being developed in order to run the source at optimum source extraction voltage for a large range of extracted beam energies with a minimal impact on beam properties. With this extraction system, beam energy can be as low as ~1 keV and as high as 60 keV while source extraction voltage can be at its optimum level within 90 kV.

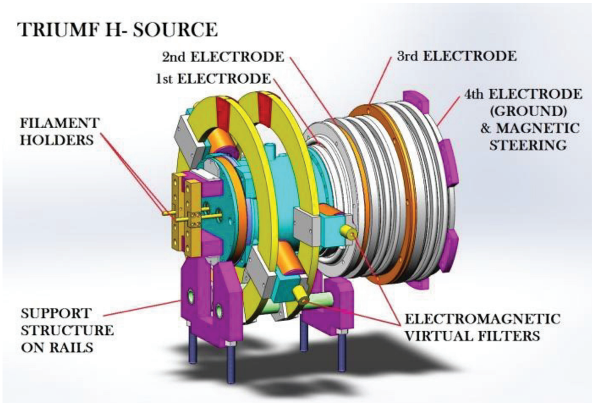

Figure 3: Ion source.

RESULTS & DISCUSSIONS

H$^-$ beam current was studied with respect to various other parameters. Figure 4 shows the H$^-$ beam current versus arc current. While these measurements were obtained, all other parameters were adjusted to maintain manageable electron currents on the 2nd electrode. The H$^-$ current is only limited by the high voltage power supply current capabilities.

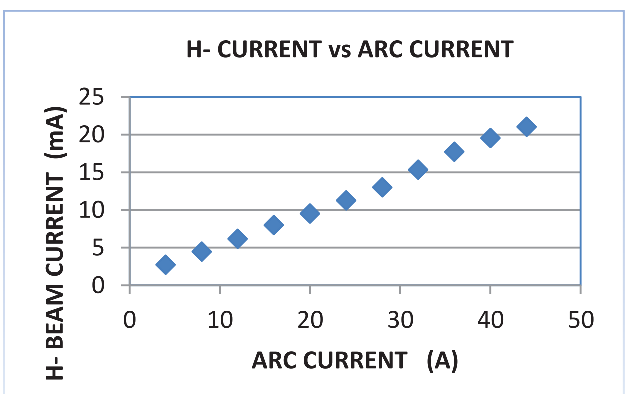

Figure 4: H$^-$ current vs arc current.

Figure 5 shows the comparison of the accel-accel and the accel-accel-decel. During the collecting of these measurements, source bias voltage and the third electrode were varied so that the sum of them was kept constant at 25 kV. It is very clear that the accel-accel-decel system produced much more beam at lower beam energies than standard accel-accel extraction systems. The detailed study of this aspect will be published separately.

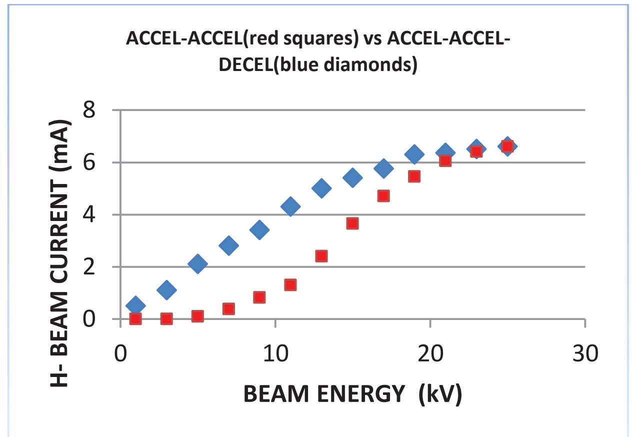

Figure 5: A comparison of the accel-accel and the accel-accel-decel electrode systems.

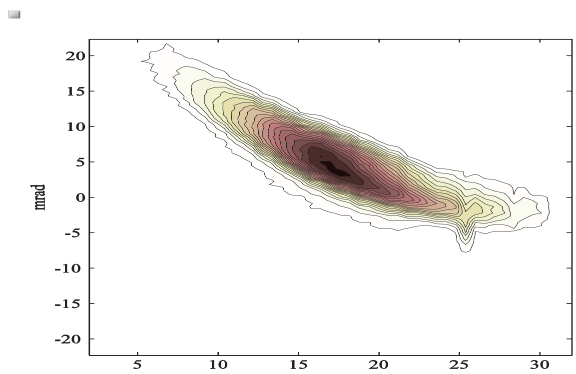

Figure 6: The emittance measurements were performed at 15 mA H$^-$ current at 25 kV. 90%, 86%, 63% and 39% found to be 44, 39, 29 and 20 π-mm-mrad respectively

CONCLUSION

The H$^-$ test stand is fully functional and ready for extensive H$^-$ studies. A 20 mA of H$^-$ beam is extracted so far at 46 A and 140 V. Emittance has been measured at 15 mA H$^-$ current. An accel-accel-decel system has been studied and it has been shown that higher currents can be produced at lower beam energies. A detailed study of the source and the extraction system will be performed in order to improve the source brightness, arc efficiency and the filament life time.

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ISBN 978-3-95450-128-1