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A negative ion source test facility

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Progress is being made in the development of an Ion Source Test Facility (ISTF) by D-Pace Inc. in collaboration with Buckley Systems Ltd. in Auckland, NZ. The first phase of the ISTF is to be commissioned in October 2015 with the second phase being commissioned in March 2016. The facility will primarily be used for the development and the commercialization of ion sources. It will also be used to characterize and further develop various D-Pace Inc. beam diagnostic devices. © *2015 AIP Publishing LLC.* [http://dx.doi.org/10.1063/1.4932320]

I. INTRODUCTION

D-Pace Inc. is in the process of installing an Ion Source Test Facility (ISTF) at Buckley Systems Ltd. in Auckland, NZ. Phase I of the ISTF is set to be commissioned in October 2015 while phase II is to be commissioned in March 2016. Phase I will include a single bay/Faraday cage, a phase space/emittance scanner, and a Faraday cup. Phase II will see the addition of a mini beamline and a 1:1000 momentum resolution analyzer/spectrometer system added to the ISTF. The ISTF is going to accommodate both filament powered and RF powered ion sources.

The ISTF will have multiple purposes. It will primarily be used for the development and commercialization of negative ion sources. D-Pace Inc. licensed from the University of Jyväskylä a CW 13.56 MHz RF H^- 30 keV volume-cusp ion source. The goal is to commercialize the ion source and to increase the current from 1 mA to 5 mA DC. We expect to test the first model by early 2016. We also plan to further improve D-Pace's TRIUMF licensed filament powered H^- DC volume-cusp 30 keV ion source to 20-25 mA. Third, D-Pace Inc. plans to investigate the production of heavy negative ion beams such as He^-, C^-, B^-, P^-, and As^- of interest in the semiconductor industry. The ISTF will also be used to characterize and further develop various products under development. This includes TRIUMF licensed devices such as an emittance/phase space scanner, wire scanner, sliding slit Faraday cups, slits, collimators; and D-Pace developed devices such as AC raster scanning magnets, scintillator based beam profile monitors, and low energy transport (LEBT) systems. An optical fiber based beam intensity scanner licensed from the University of Bern[1] shall also be tested and developed. The ISTF will also be used to factory acceptance test ion sources and beam diagnostics devices before shipment to customers. Finally, an analyzer permits energy spectrum measurements to be made or mass spectrometer measurements. In addition to being very useful to D-Pace, collaborative R&D or independent 3rd party experiments will also be possible (Figs. 1 and 2).

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II. ION SOURCE DEVELOPMENT

A. Filament-based H^- ion source

The ISTF will first be commissioned with the TRIUMF licensed volume-cusp H^- source. This will allow us to re-characterize the ion source and improve the output to 20-25 mA DC. Early experiments with the ion source show that the ion source can output beam current higher than 15 mA DC.[2] We also note that the current has been limited by low capacity power supplies and insufficient pumping. The ISTF will have the capacity to test the ion source to the limit of its performance. Basic testing will also be done at the ISTF. This includes filament lifetime measurements, minimum cooling, and power source specifications. The ISTF will help us better understand our technology.

B. 13.56 MHz RF H^- ion source

D-Pace Inc. has licensed a 30 keV CW 13.56 MHz RF H^- volume-cusp ion source from the University of Jyväskylä.[3–5] The present source outputs 1 mA of CW H^- beam current. We plan to first replicate the results of the University of Jyväskylä, then develop the source to over 5 mA for industrial cyclotrons since the emittance tolerance is an order of magnitude larger than the University of Jyväskylä's application. This will be done through increasing the coupling of RF power in the plasma, through increasing the production of the ions and through increasing the extraction of the ions. Improving the coupling of power into the ion source will be done by optimizing the RF impedance matching network, by experimenting with different RF window materials and by improving the wave guiding of the RF to the source. Increasing the production of the H^- will be done by increasing the cusp magnetic field, by optimizing the electromagnetic filter field, by optimizing the plasma and electron density through manipulation of gas

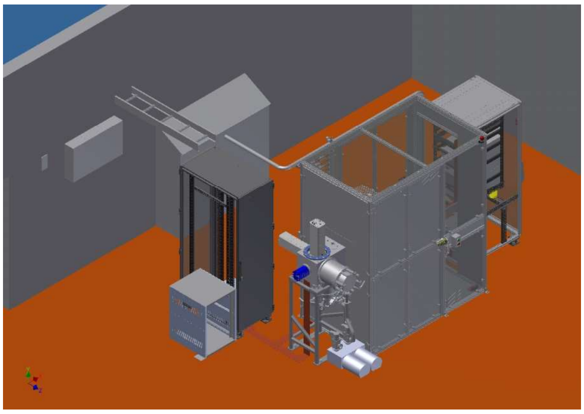

FIG. 1. ISTF Phase I.

flow rates, conductance, and vacuum pumping rates and by experimenting with wall materials to enhance the surface production effect. Finally, improving the extraction of the ions will be done by optimizing the lens apertures and potentials to increase the current while keeping a low emittance, by experimenting with space charge neutralization by injection of neutral inert gas species and by optimizing the electron extraction from the beam. The optimization of the RF ion source will be done after the TRIUMF licensed filament powered H^- volume-cusp ion source has been characterized. Furthermore, we plan to experiment with installing a RF back plate on the TRIUMF source and comparing the results with the University of Jyväskylä RF source.

C. Heavy negative ion source

The ISTF will be very useful for experimenting with the production of heavy negative ions with our volume-cusp ion sources. These ions include He^-, C^-, B^-, P^-, and As^-. The first experiments will focus on He^- and C^- since they are safer and readily available. Helium has negative electron affinity, however, negative helium ions can be produced using charge exchange vapor cells.[6–8] We will be injecting helium gas into both our RF and filament powered volume-cusp ion sources to try to obtain He^- beam. The second set of experiments will be the production of C^- ions. Negative carbon ions are mainly produced via sputtering,[9,10] however, there is evidence that negative carbon ions are produced in hydrocarbon plasmas via electron interactions.[11–13] We will be experimenting with different organic gases such as acetylene and methane. Electron interactions with acetylene gas are expected to produce mostly C_2^- and C_2H^- ions, while methane is expected to produce mostly C^- and CH^- ions. Both C^- and C_2^- ions are of interest for ion implantation purposes. The ions will be analyzed with the spectrometer that is being added in phase II of the ISTF.

III. D-PACE PRODUCT DEVELOPMENT

An important use of the ISTF will be the characterization and development of D-Pace beam diagnostic devices, magnets, and beamlines. An example of such an investigation is of D-Pace's TRIUMF licensed emittance scanner. The existing model uses an opposing V-slits configuration; however, a mating V-slits configuration, as seen in Figure 3, is used for high beam intensity applications. The mating V-slits configuration has better cooling capabilities but there is concern that the added emission of secondary electrons interacts with the ion beam. The ISTF will be used to compare the two configurations and verify the effect of the secondary electrons on the emittance scanner. Thermal measurements will also be performed at the ISTF to determine the specifications needed for a given beam power.

D-Pace has also recently licensed a fiber optic beam profile monitor from the University of Bern.[1] The ISTF will allow us to test the performance of the detector at lower beam energies and with neutral beams. The existing prototype has only been tested over a narrow range of beam types and intensities. Finally, a wide range of experiments with D-Pace's TRIUMF licensed wire scanner will also be possible. This includes thermal breakdown measurements as well as measurements of the wire lifetime.

IV. TURN-KEY SYSTEM

The ISTF will serve as a first step in the production of turn-key ion source systems for industrial applications. We will be able to better determine the specifications needed for our ion source systems.

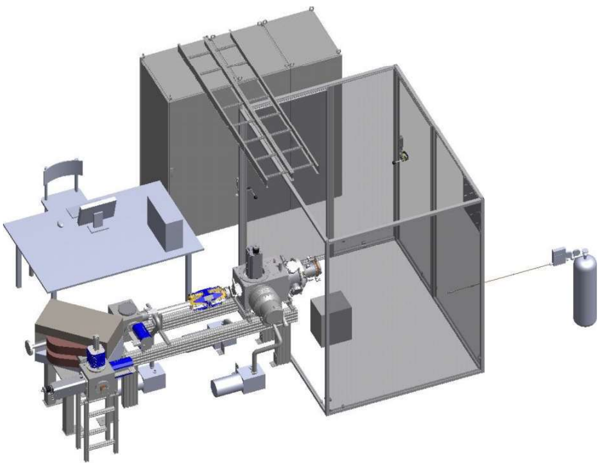

FIG. 2. ISTF Phase II.

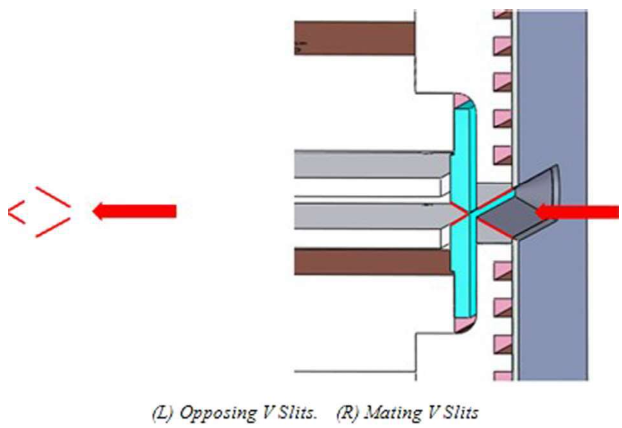

FIG. 3. Slit configurations of the emittance scanner.

V. CONCLUSION

A new negative ion source test facility is being built by D-Pace Inc. The purpose of the ISTF will mainly be towards the development of new ion sources and beam diagnostic devices as well as the optimization and characterization of D-Pace's current and future products. The ISTF will also be used for 3rd party experiments and collaborative R&D.

ACKNOWLEDGMENTS

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