"Explorations in the Production of Intense Negative Hydrogen Ion Beams Utilizing Filament-Based Plasma Heated Volume-Cusp Ion Sources without Caesium"

The University of Auckland - Physics - Ph.D. Project Proposal
The University of Auckland Student: To be determined
The University of Auckland Supervisor: Dr. Peter Derrick
Industrial Supervisor: Dr. M.P. Dehnel, CSIO, Buckley Systems Ltd.
Location of Research: Ion Source Test Facility at Buckley Systems Ltd in Auckland, New Zealand

The study of the production of high-current and low-emittance negative Hydrogen ion (H^{-}) beams remains fertile research territory. This is likely due to the large number of mechanisms that must be optimized to create, maintain, and extract such beams bearing in mind that several mechanisms are not well-understood. In addition, studying and improving such beams is becoming critically important for (1) National Accelerator Laboratories such as the Spallation Neutron Source (SNS) in the USA, Rutherford Appleton Laboratory (RAL) in England; and TRIUMF in Canada etc.; (2) commercial radioisotope production for both Positron Emission Tomography (PET), and Single Photon Emission Computed Tomography (SPECT), particularly as relates to the Canadian Government's push to produce Technetium via accelerators rather than reactors; (3) other medical accelerator-based activities, such as Boron Neutron Capture Therapy (BNCT); (4) fusion research at facilities such as ITER in France; and (5) other industrial accelerator-based activities such as ion implantation for purposes of material cleaving.

The proposed project is to significantly increase the beam current output of D-Pace Inc.'s H^{-} Volume-Cusp Ion Source which utilizes a filament-based plasma heating technique, and operates in the 20 – 30 keV kinetic energy range while achieving the lowest beam emittance possible at any given output current level. This is a particular ion source technology with special permanent magnet cusp fields for plasma confinement, filter fields for yielding cold-plasma for enhanced volume-production of negative ions, and tantalum filament materials for enhanced surface production of negative ions near the plasma electrode (it is believed that sputtered material from the filament contributes a surface component to the negative ion production). This source has been licensed from and co-developed with TRIUMF National Laboratory in Canada. At present the H^{-} beam current level produced by this ion source is ~15 mA DC at 30 keV with normalized 4rms emittance ~1 mm-mrad. The industrial goal is to achieve beam current levels in the 15 – 25 mA DC region without Caesium while at the same time progressing discovery science by determining the underlying production reactions, their rates, and competing reactions of destruction.

The student is free to research, explore, and push the boundaries of present knowledge in any of the following areas in an effort to achieve the research goal. These include optimizing: (a) coupling power into the plasma through electronics circuitry techniques, (b) coupling power into the plasma through experimentation on different filament materials and configurations (the magnetic field generated by the filament impacts the plasma quiescence), (c) bulk "hot" plasma region confinement through variations of cusp magnetic fields, (d) "cold" plasma creation and confinement through variations of magnetic dipole field magnitude and orientation in the extraction region for plasma based H^{-} production, (e) plasma and electron density through manipulation of gas flow rates, conductances, and vacuum pumping rates, (f) the contribution of wall material to vibrational excitation and negative hydrogen ion formation by way of varying such materials, (g) plasma ionic purity for H^{-} formation, (h) meniscus shape and beam extraction through adjustments of lens apertures, lenses, and electrostatic potentials, (i) electron extraction through configuration and magnitude adjustments of the sequential dipole magnetic filter fields of opposite sign in the extraction region, (j) non-linear space-charge growth {i.e. minimizing} through various techniques including space-charge neutralization through introduction of other gas species, (k) initial low energy beam transport through appropriate electrostatic or magnetic lensing, (l) horizontal and vertical beam steering to compensate for the off-axis impulses from the various filter fields, and measurement/analysis of photon emission spectrum to determine the reactions involved in negative ion formation and destruction.

Prospective students: Please contact Dr. Morgan Dehnel at morgan@d-pace.com