Trapping secondary electrons in ExB drift for an α-generating penning ion source

N Savard[1,2], A Groutso[3], S Melanson[2], D Potkins[2], M Dehnel[2]
University of British Columbia[1]
D-Pace Inc[2]
Buckley Systems Ltd[3]

Abstract

A Penning ion source test stand has been developed by D-Pace to characterize α-ion extraction from a helium discharge with variations in: extraction potential up to 15 kV, gas flow rate up to 30 sccm, and magnetic field confinement up to 1.1 Tesla. A brief summary of the Penning Ion Source design is described. Attempts at extraction of ions leads to severe sparking events on the high voltage insulator due to ExB drifts of secondary electrons. This paper shows the design of two sets of electrodes which together trap most electrons moving towards this insulator due to ExB drifts. This eliminates the severe HV breakdown on the insulator and allows for a more robust operation of the ion source.

Purpose

Penning ion sources are an old technology that were previously used for high charge state ion production before being replaced by ECR sources. Though these ECR sources are often capable of reaching higher currents for high-charge state ions, they are large and expensive. Thus in certain cases where they are only producing α-particles, for example medical accelerators producing isotopes for radiotherapy, it may be possible to replace them with penning ion sources optimized for α-particle production.

For this reason, a self-heated cathode type penning ion source has been developed in collaboration with D-Pace Inc at the ISTF (Ion Source Test Facility) located at Buckley Systems in Auckland NZ. The goal is to be able to characterize the beam output and plasma properties as a function of varying magnetic field (0.4 – 1.0 T), arc current (> 0.7 A), gas flow (5 – 40 sccm), and extraction voltage (up to 15 kV). A 270 mm diameter C-magnet with a 78 mm pole gap was designed for both the confining magnetic field within the source and for 180° mass separation of the extracted ions. The initial design of the ion source had exposed insulators which led to disastrous sparking when operating at high voltages.

Therefore, another ion source design has been completed and manufactured to replace this old design. COMSOL™ Multiphysics was used to simulate electrostatics, particle extraction, and heat transfer of the ion source. It was designed using vacuum spacing and geometries with large curvatures to minimize electric fields and therefore minimize high voltage sparking in the limited pole gap. The puller and anode plates were also designed to be able to extract both helium ions and α-particles for magnetic field variations between 0.4 – 1.0 T.

Trapping Drifting Electrons

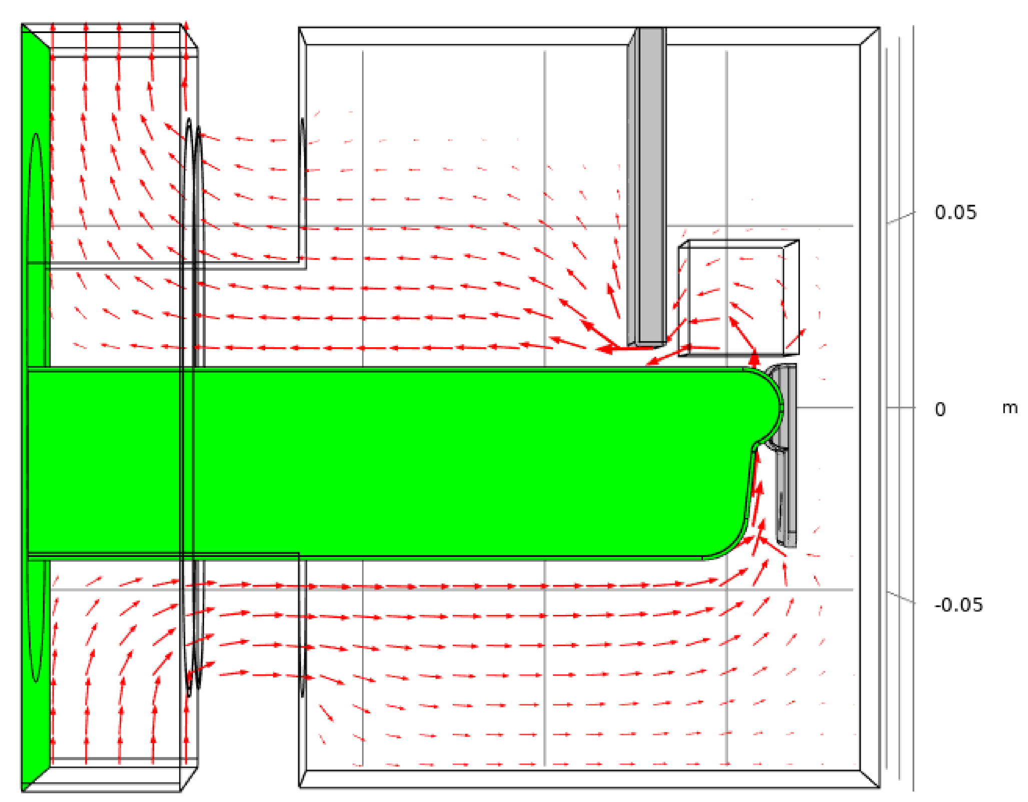

Figure 1: High voltage ion source (green) and grounded components (grey and transparent walls) create ExB drifts shown as red arrows.

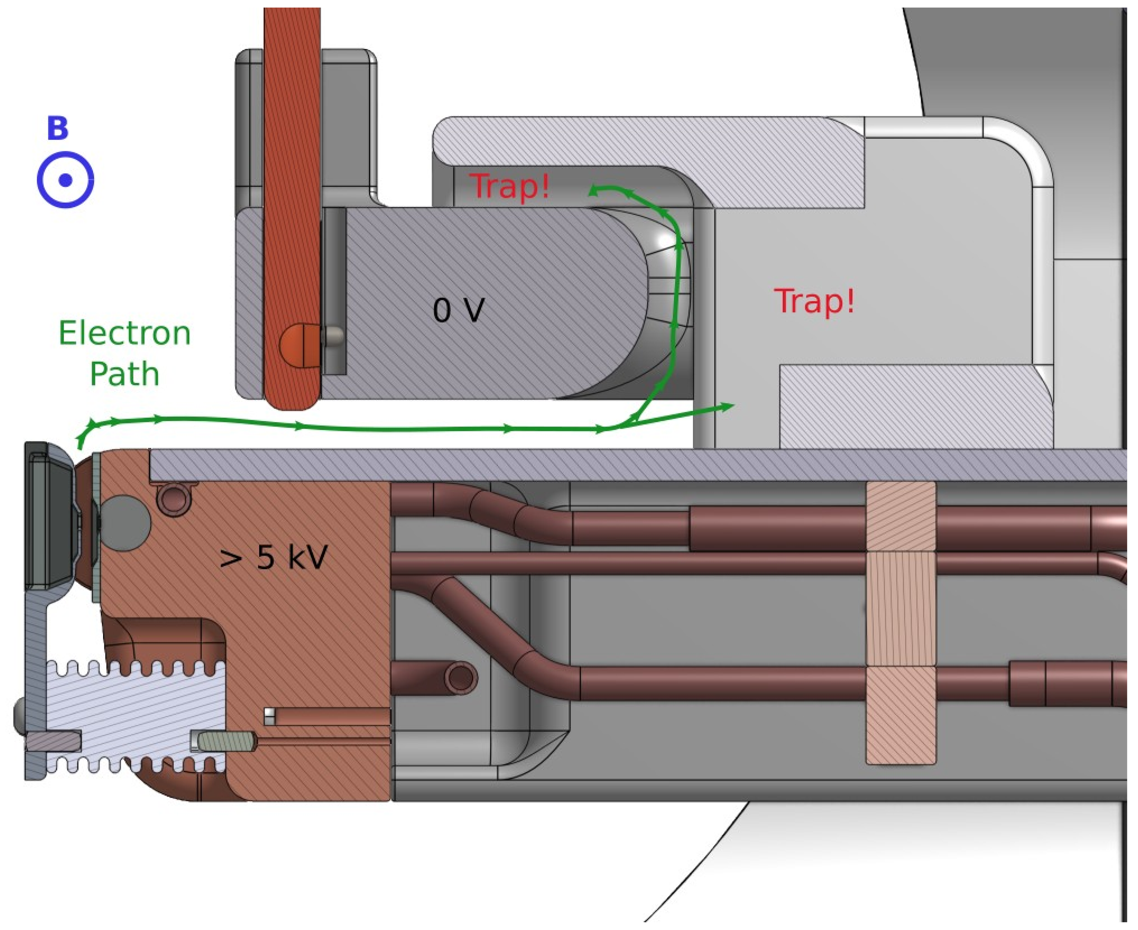

Figure 2: Cross sectional view of electrodes and the electron trapping mechanism.

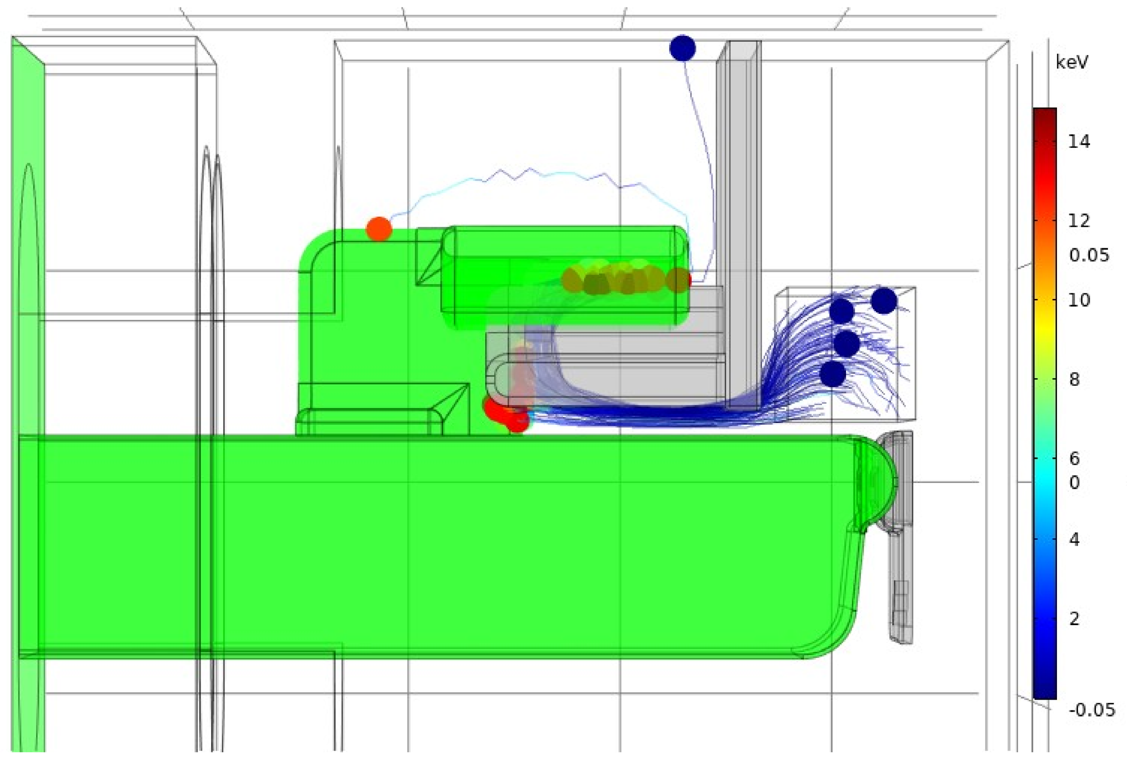

Figure 3: High voltage (green) and grounded (grey and transparent walls) electrodes with electrons released into simulation domain.

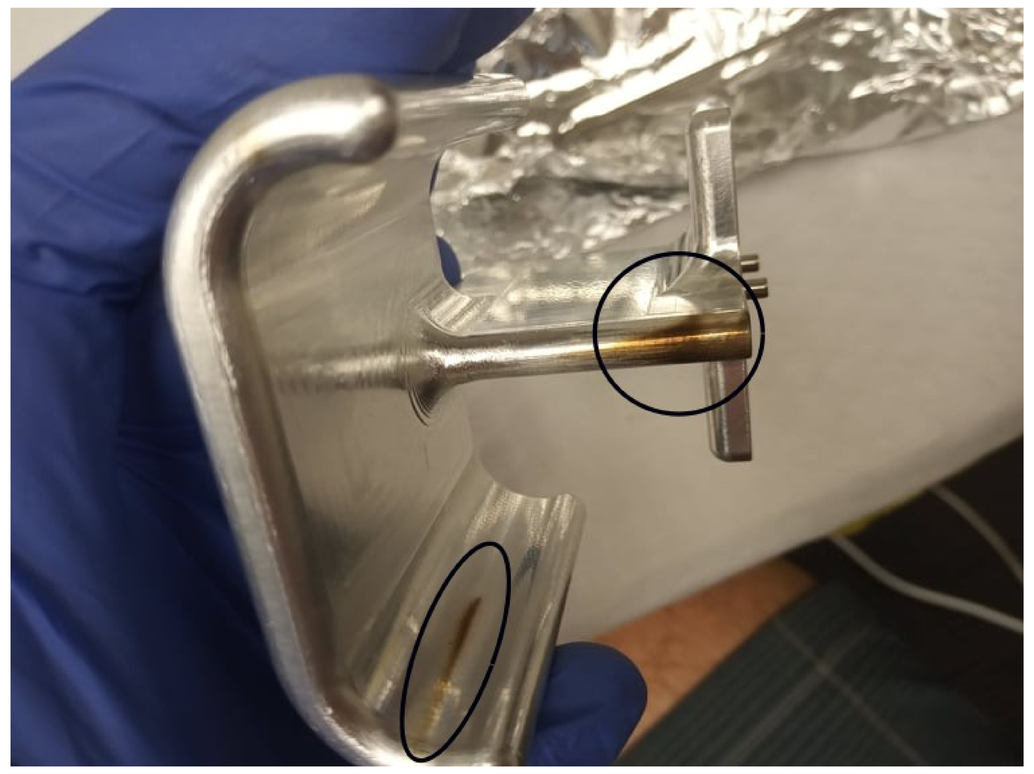

Figure 3: Wing electrode with scorch marks where electrons are dumped.

Results

This new design is able to sustain up to 15 kV without issue, but during ion extraction severe arcs were seen at the back insulator, creating scorch marks and cracking on this component. This is due to electrons following the ExB drift from the static electric and magnetic fields, and eventually collecting on the insulator. To prevent a redesign of the system, additional electrodes were designed and simulated to trap these electrons originating from near the extraction point.

An electrode is added to the beam dump (close to 0 V) with an additional electrode on the high voltage bracket which slightly wraps around the beam dump extension. Fig. 2 shows the expected trajectory of electrons due to their ExB drift, where they either get trapped on the middle portion or curve around under the wings, where the electric field along the magnetic field allows the electrons to get dumped on the wing.

Figure 3 shows the simulation of the electrons being released near the extraction area for operation at 15 kV. 99/100 simulated electrons are dumped onto the wing electrode.

Figure 4 shows the scorch marks of the electrons on the wing electrodes, which correspond exactly to the expected dump points shown in fig. 3. Along with the introduction of an additional blocking piece above and below the beam dump, the ion source is now able to operate up to 15 kV with ion extraction without severe sparking on the back insulator.

Conclusion

The newly designed ion source is able to hold high voltage under all operation conditions due to the focus on vacuum separation and large curvature electrodes for high voltage insulation. Two new electrodes were introduced to combat ExB drifting secondary electrons generating harmful sparking events on the back insulator. These electrodes were successful in reducing this sparking, and consequently the ion source can now operate steadily during ion extraction up to 15 kV.