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INFLUENCE OF PLASMA ELECTRODE APERTURE SIZE ON BEAM EMITTANCE FROM A MULTICUSP ION SOURCE

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Abstract

D-Pace's TRIUMF-licensed multicusp filament ion source is capable of producing H^- beams up to 17.4 mA. In most cases the beam is transported to the entrance of an accelerator or a magnet for further applications. The emittance of the beam extracted from the ion source should be maintained as low as possible to reduce the beam losses to the walls of the transport pipes. The beam emittance from the ion source can be controlled by changing the aperture diameter of the plasma electrode. The current study deals with the range of H^- beam emittance that can be achieved from D-Pace's filament ion source, using plasma electrodes of different aperture sizes. The corresponding beam currents and the electron to ion ratios are also reported.

INTRODUCTION

Emittance is one of the most important quality parameters of an ion beam. A beam of very high emittance can suffer considerable loses during its propagation. The value of beam emittance is mostly determined by the initial focusing action at the plasma sheath which is the boundary layer between the quasi neutral plasma and the extraction region where mostly negative charges are present. The shape and location of the plasma sheath is determined by properties of the plasma, geometry of the electrodes around the plasma and electric potential on the electrodes. A picture of the plasma electrode assembly in the ion source is shown in Fig. 1.

The section view of D-Pace's TRIUMF-licensed multicusp filament ion source and extraction system is shown in Fig. 2 [1]. The ion source is capable of producing H^- beams up to 17.4 mA at an emittance of about 0.7 mm·mrad [2]. Plasma is sustained inside the plasma chamber of the ion source via thermionic emission from electrically heated Ta filaments. H^- ions are generated inside the plasma mostly through volume production methods [3]. As shown in the figure, the extraction system consists of the plasma electrode, the extraction electrode and the ground electrode. The plasma electrode and the extraction electrode are biased positive with respect to the plasma chamber for negative ion extraction. The co-extracted electrons are deflected on to the extraction electrode, before reaching the ground electrode, by the perpendicular magnetic field created by the magnets in the extraction electrode. Beam emittance is measured at about 368 mm downstream from plasma electrode, by D-Pace ES4 emittance scanner. This is an Allison-type emittance scanner which measures the beam intensity as a function of position (y) and angle (y′) simultaneously. Background electronic noise in the emittance data measurment is eliminated by discarding the beam intensity values below 4% of the maximum value. The Faraday cup is located at about 480 mm from the plasma electrode and can measure beam current (I_{FC}) with beam size up to 55 mm diameter.

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EXPERIMENTAL DETAILS

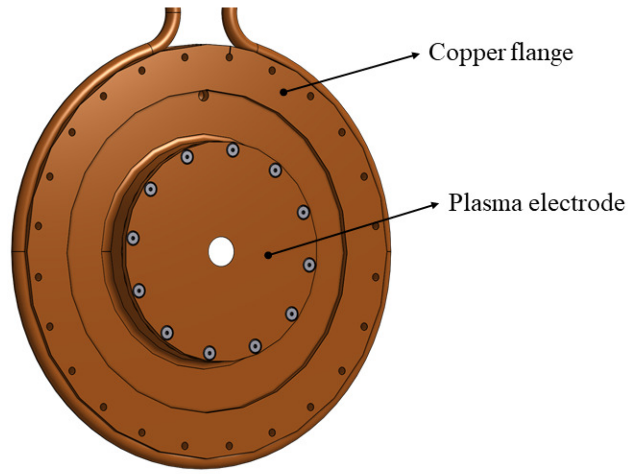

Figure 1: Picture of copper flange and plasma electrode. Ion beam is extracted through the aperture on the plasma electrode. 13.0 mm aperture is used for regular operations.

An experimental study was conducted in H_2 plasma to study the range of beam emittance values that could be obtained from D-Pace's filament ion source. Plasma electrodes of different aperture dimensions (8.0 mm, 11.5 mm, 13.0 mm and 16.0 mm) were used for this study. A picture of the plasma electrode and the copper flange is shown in Fig. 1. The ion beam is extracted through the aperture on the plasma electrode. The 13.0 mm aperture size is used for the regular experiments. The ion source had to be vented and opened before each experiment for replacing the plasma electrode.

H^- beam currents were measured at the Faraday cup for the different plasma electrodes and the results are shown in Fig. 3. The beam energy was fixed at 30 keV. The gas flow and electrode voltages were optimised for obtaining the maximum beam current at a fixed arc current. As can be seen from the graph, the beam current decreases as the size of the aperture decreases. I_{FC} decreases from 16 mA to about 9 mA, when the aperture size changes from 16 mm to 8 mm, for a fixed arc current. This result is expected as the effective plasma sheath emission area reduces as the aperture size decreases. This can be better understood with the help of IBSimu [4] simulations results shown in Fig. 4. The figure

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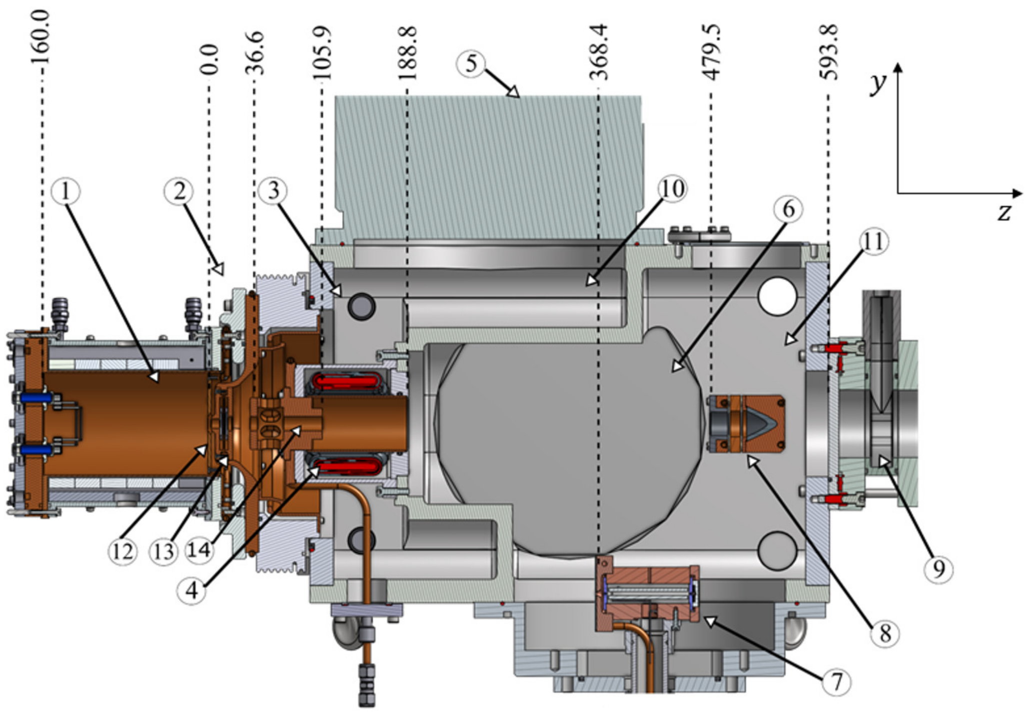

Figure 2: Section view of D-pace's TRIUMF licensed filament ion source and extraction.

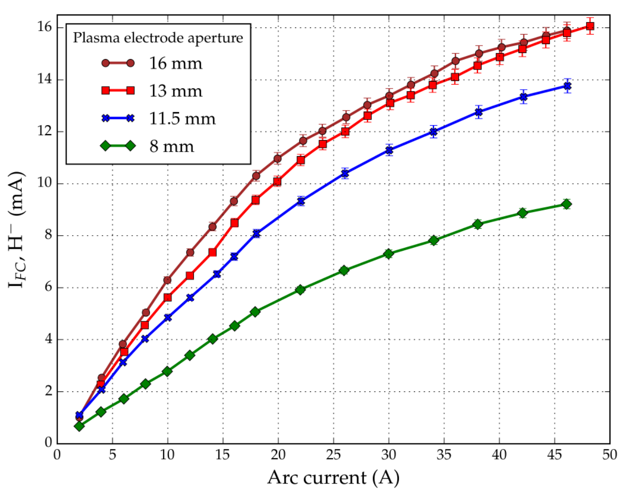

Figure 3: H$^-$ beam currents measured on the Faraday cup for different arc currents, using plasma electrodes of different aperture sizes. The arc voltage was set at 120 V and 30 keV beam energy was used.

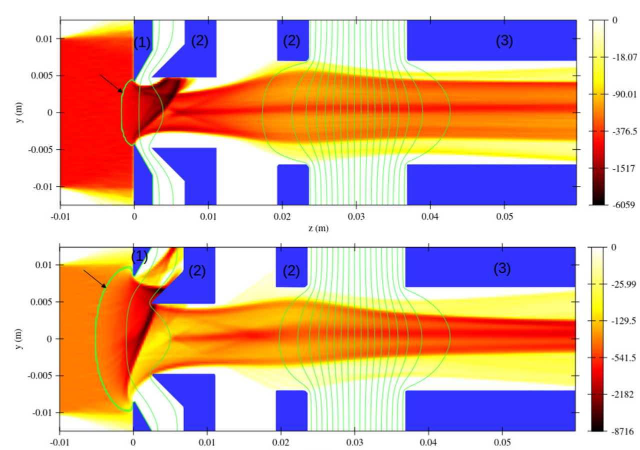

Figure 4: 2D IBSimu current density simulation results showing the location of plasma sheath, for (top) 8 mm and (bottom) 16 mm apertures. The simulated conditions correspond to about 8 mA of I_{FC} for both apertures. The plasma (1), extraction (2) and ground electrodes (3) are shown in blue color. Electron flow towards the extraction electrodes can also be seen.

shows the simulation results for an I_{FC} value of about 8 mA, from 8 mm and 16 mm apertures. The simulations use the same electrode voltages as obtained in experiments, except for the plasma electrode (0 V). The reduction in the plasma sheath area is evident from the simulations for the 8 mm aperture compared to the 16 mm aperture. The co-extracted

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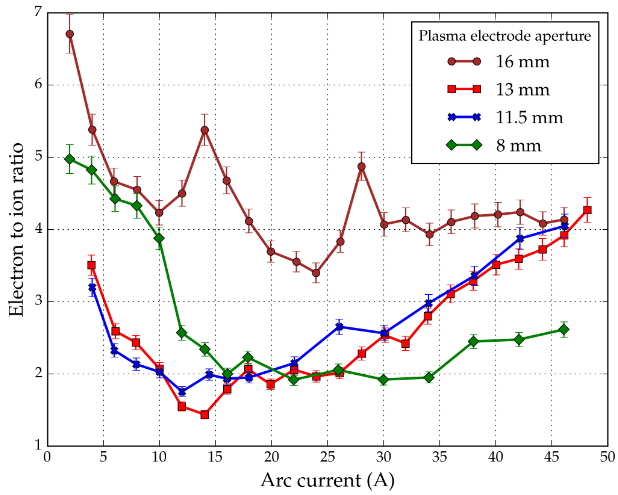

Figure 5: Electron to ion ratios obtained for different arc currents and plasma electrodes.

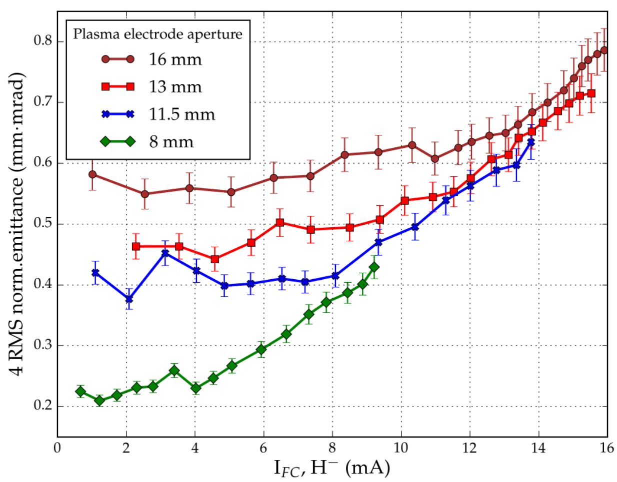

Figure 6: Beam emittance measured by the emittance scanner for the different beam currents in the experiment.

electron flow towards the extraction electrode can also be seen in the simulations.

The electron to ion ratios obtained in the experiments are shown in Fig. 5. The ratios are considerably higher for the 16 mm aperture size and it denotes more co-extracted electrons from the plasma. This was evident during the experiment, as it was difficult to keep the co-extracted current under control without saturating the extraction electrode power supply. The extraction electrode power supply saturates above 150 mA and hence irregular values of electrode voltages and gas flows were needed to keep the co-extracted current under control. This is the reason for the appearance of peaks in the electron to ion ratios for the 16 mm aperture size. This also led to loss of beam currents.

The corresponding 4 RMS normalized beam emittance values obtained from the experiments are shown in Fig. 6, for the different I_{FC} values mentioned in Fig. 3. As can be inferred from the graph, a smaller beam emittance can be achieved for a fixed beam current by using the plasma electrode with a smaller aperture. For example, the 8 mm aperture can generate an 8 mA beam with an emittance value of 0.38 mm·mrad, whereas it is 0.6 mm·mrad for the 16 mm aperture size. But, it should also be noted that the arc currents and hence the plasma densities required for the smaller apertures are much higher than that required for larger apertures, for achieving a fixed value of I_{FC}, as shown in Fig. 3.

CONCLUSION

The experiment outlined in the current paper reports the beam emittance values that can be obtained from D-Pace's TRIUMF-licensed filament ion source, by using plasma electrodes of aperture dimensions 8.0 mm, 11.5 mm, 13.0 mm and 16.0 mm. The results indicate that the emittance of H^- beam can be reduced by using smaller plasma electrode apertures. The reduction in the plasma sheath area while using smaller apertures is also demonstrated using IBSimu simulations. The corresponding electron to ion ratios are also reported.

ACKNOWLEDGEMENT

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