H⁻ BEAM EMITTANCE ANALYSIS IN A MULTICUSP ION SOURCE

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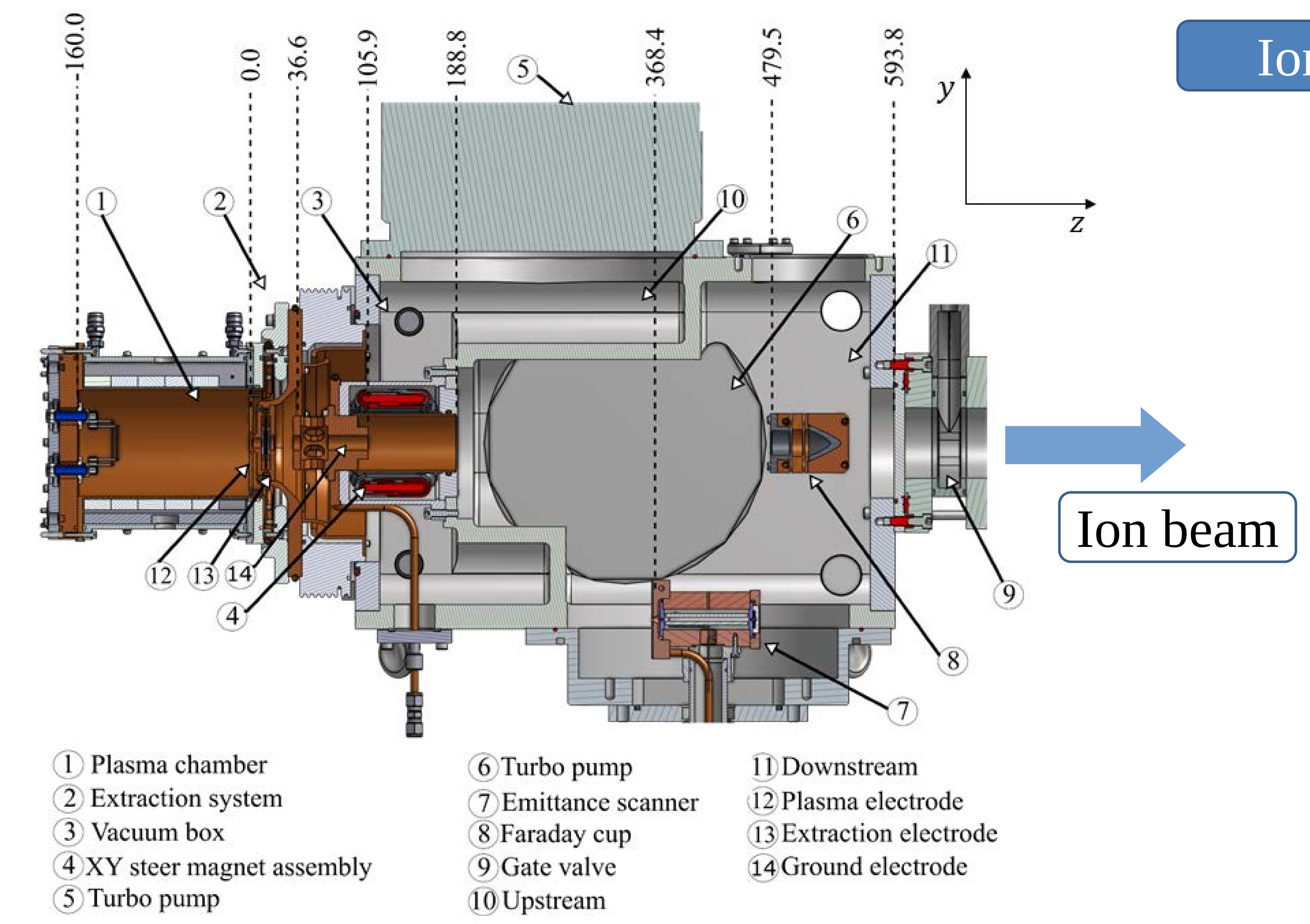
Abstract

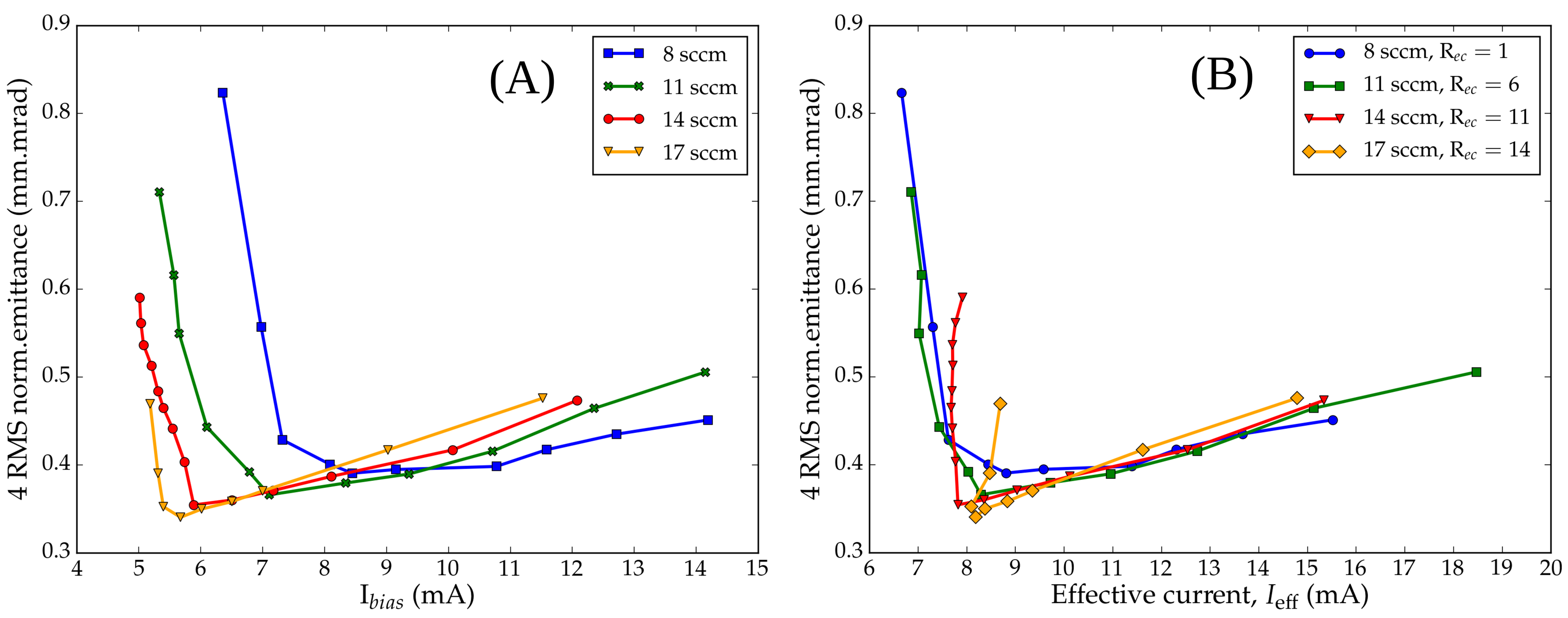
Emittance of the ion beam extracted from an ion source is dependent on the initial focusing action at the plasma sheath. The properties of the plasma sheath is further dependent on the local electric fields and charge densities around the sheath. Experiments are conducted for creating different sets of conditions around the plasma sheath in an H^- multicusp filament ion source and the resulting emittance of the extracted H^- ion beam is measured. Variation of beam emittance under different plasma densities, electrode voltages and gas flows are analyzed.



Ion source details

- The section view of D-Pace's TRIUMF licensed multicusp ion source is shown here
- Plasma is sustained by thermionic emission from Ta filaments.
- The negative ion source has a three electrode extraction system consisting of plasma (12), extraction (13) and ground electrode (14).
- Bias current (I_{bias}) indicates the amount of negative ions reaching the ground electrode region.
- Beam energy at the ground electrode is 30 keV .
- Co-extracted electron current is measured at the extraction electrode.
- Beam emittance is measured at 368 mm from plasma electrode, using D-Pace ES4 emittance scanner.
- Emittance minimum should be observable in most of the ion source systems, indicating the optimum plasma sheath shape.

Gas flow and beam emittance



30 keV energy, Extraction electrode: 3.5 kV, Plasma electrode: 5 V

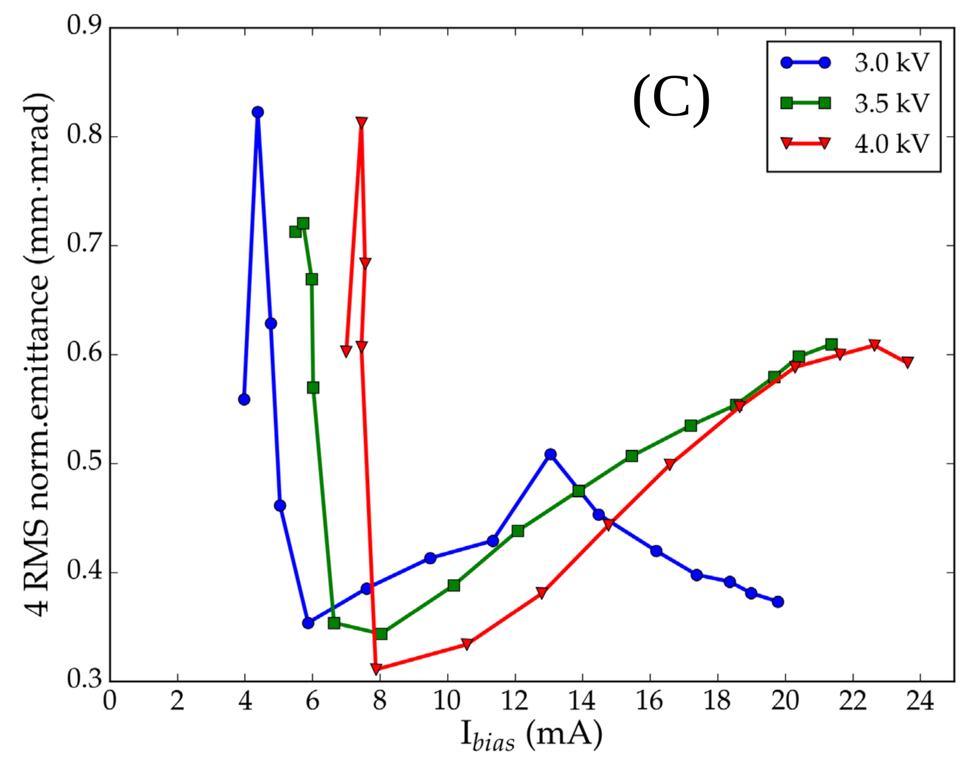
(Fig: A) Variation in emittance for different gas flows and beam currents. The emittance minimum moves to lower beam current values as gas flow increases. Since the electrode potentials are constant, it can be seen that gas flow influences the negative ion and electron density around the plasma sheath, which further affects the beam emittance.

In order to directly relate charge densities at the plasma sheath and beam emittance, we can define an effective current[1], I_{eff} at the plasma sheath using electron density correction factor, R_{ec} and ion density correction factor, R_{ic} and the co extracted electron current , I_e and negative ion current, I_{bias}

$$I_{\mathrm{eff}} = R_{ic} I_{\mathrm{bias}} + R_{ec} I_e \sqrt{m_e / m_H},$$

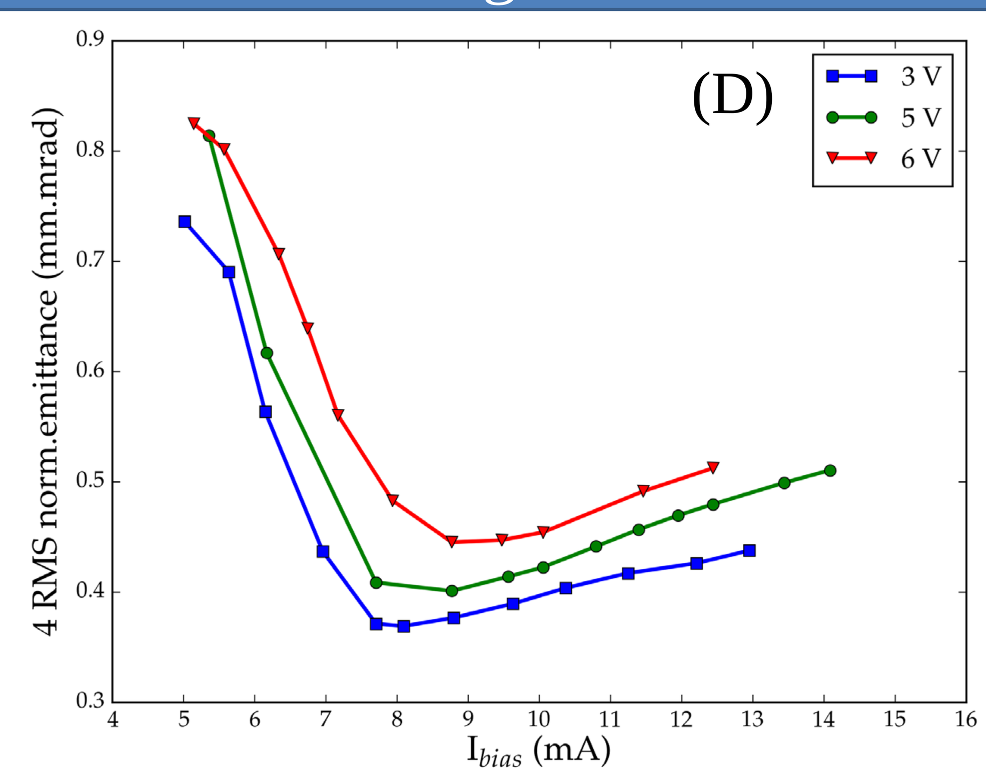
(Fig: B) Variation in emittance in terms of I_{eff}. The emittance minimum appears at the same location, if we use R_{ec} values 1,6,11,14 for 8 -17 sccm gas flows. This shows that the real electron density at the plasma sheath is different from that measured as the co extracted electron current.

Extraction electrode voltage and beam emittance



30 keV energy, Gas flow: 15 sccm,, Plasma electrode: 5 V

Plasma electrode voltage and beam emittance



30 keV energy, Gas flow: 8 sccm,, Extraction electrode: 3.5 kV

(Fig: C,D) Variation in emittance for different electrode potentials are shown. It can be seen that both extraction and plasma electrode potentials, influence the beam emittance values.

Summary

- The beam emittance under different conditions of gas flows, extraction and plasma electrode potentials and arc currents were studied.
- The results indicate that the H^- and electron currents measured at the electrodes are not a true representation of the charge densities at the plasma sheath.
- This also suggests differences between the transport of negative ions and electrons from the plasma sheath to extraction in the ion source.

[1] Kalvas, Taneli, and J. Lettry. "Deviation of H− beam extraction simulation model." In *AIP Conference Proceedings*, vol. 2052, no. 1, p. 050007. AIP Publishing, 2018.

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