IEPC-2005-301

Nonambipolar Electron Source for Neutralization of Ion and Hall Thrusters

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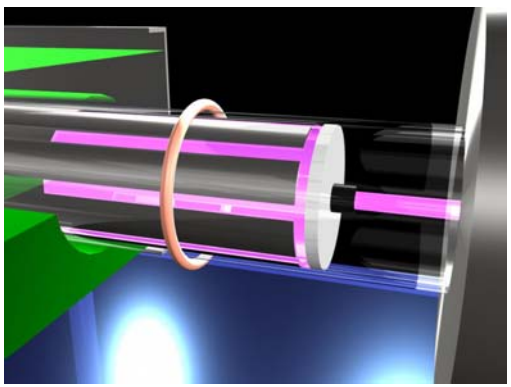
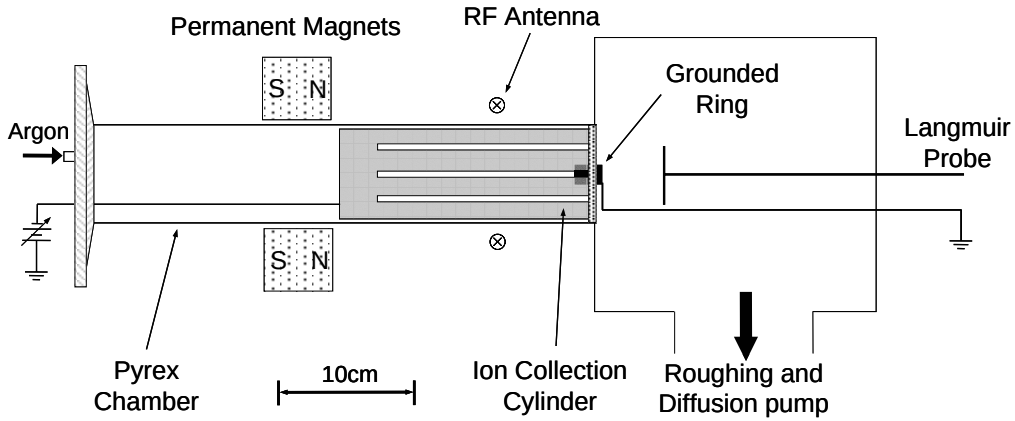
Presented at the 29th International Electric Propulsion Conference, Princeton University, October 31 – November 4, 2005

Abstract

Significant progress has been made in the characterization of the necessary parameters required to create an effective Radio Frequency (RF) plasma based electron source. Such a device has the promise of longer operational lifetimes and comparable current densities to hollow cathodes. The operational lifetime of hollow cathodes is ultimately limited by cathode deterioration. RF sources provide an alternative approach that does not consume electrode material while providing electrons. A gas utilization of 1500% was achieved with 1.2 Amps of extracted electron current through a 0.25cm^2 aperture with 340W of RF power and an Ar flow rate of 1.1 sccm. Permanent magnets provided an axial magnet field of 80 Gauss at the grounded ring. Although larger electron extraction currents are possible with larger exit apertures, up to 3.75 Amps with a flow rate of 14 sccm Ar and an exit area of 1.23cm2, the gas utilization ultimately is reduced. The Nonambipolar Electron Source (NES) operated without a magnetic field with a maximum extracted electron current of 1.6 Amps. However, even modest magnetic fields (<150 Gauss) significantly improve the electron current extraction and gas use. Experimental evidence from NES suggests that the total amount of electron current that can be extracted is equal to the random electron flux and is limited by the the plasma density and the ion loss area provided in the source.





Schematic illustration of the plasma chamber containing NES with supporting vacuum hardware. The magnets are removable and are not present in some configurations.

Ion and Electron Losses

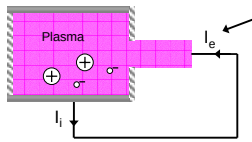
Electrons are not lost to the ion collection cylinder because the difference in potential between the source plasma and the ion collection cylinder always satisfies $e\Delta\phi/T_e >> 1$ within NES.

$$J_{0i} = n_{0i} e \alpha \sqrt{\frac{T_e}{m_i}} \qquad J_{0e} = \frac{n_{0e} e \alpha}{4} \sqrt{\frac{8T_e}{\pi m_e}}$$

$$A_i / A_e \approx \sqrt{m_i / m_e}$$

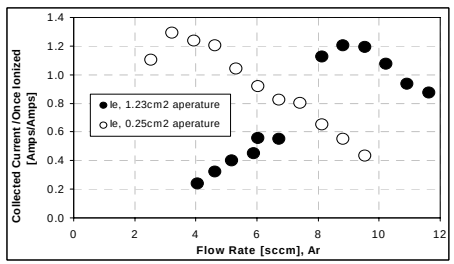
Argon: $A_i > A_e\sqrt{m_i/m_e} \approx 350cm^2$

Xenon: $A_i > A_e\sqrt{m_i/m_e} \approx 630cm^2$

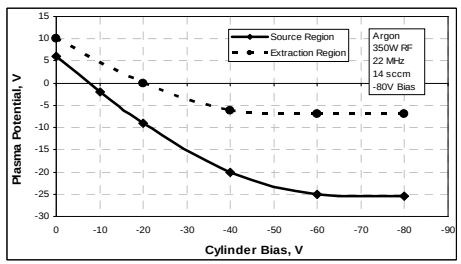


- Electron flux is out of the plasma
- High Nonambipolar electron loss in system

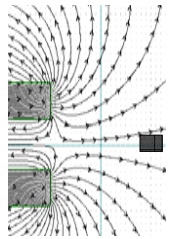
Aperture Size

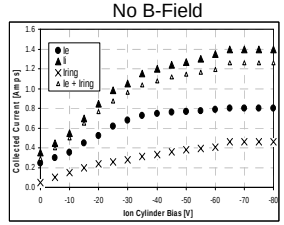


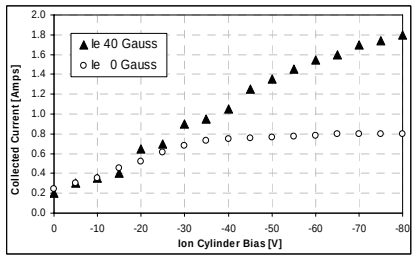
Sheath Behavior

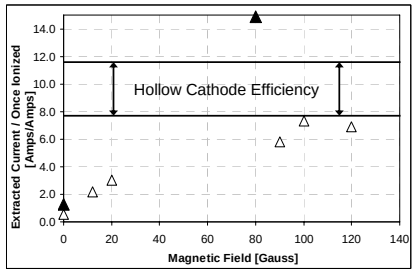


Magnetic Field Effects









Conclusion

Electron extraction current scales with:

- Plasma density
  - RF Power
  - Neutral flow rate
- Confinement
  - Magnetic field
- Ion & electron loss areas
- DC bias on ion collection cylinder