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Effects of axial magnetic field in a magnetic multipole line cusp ion source

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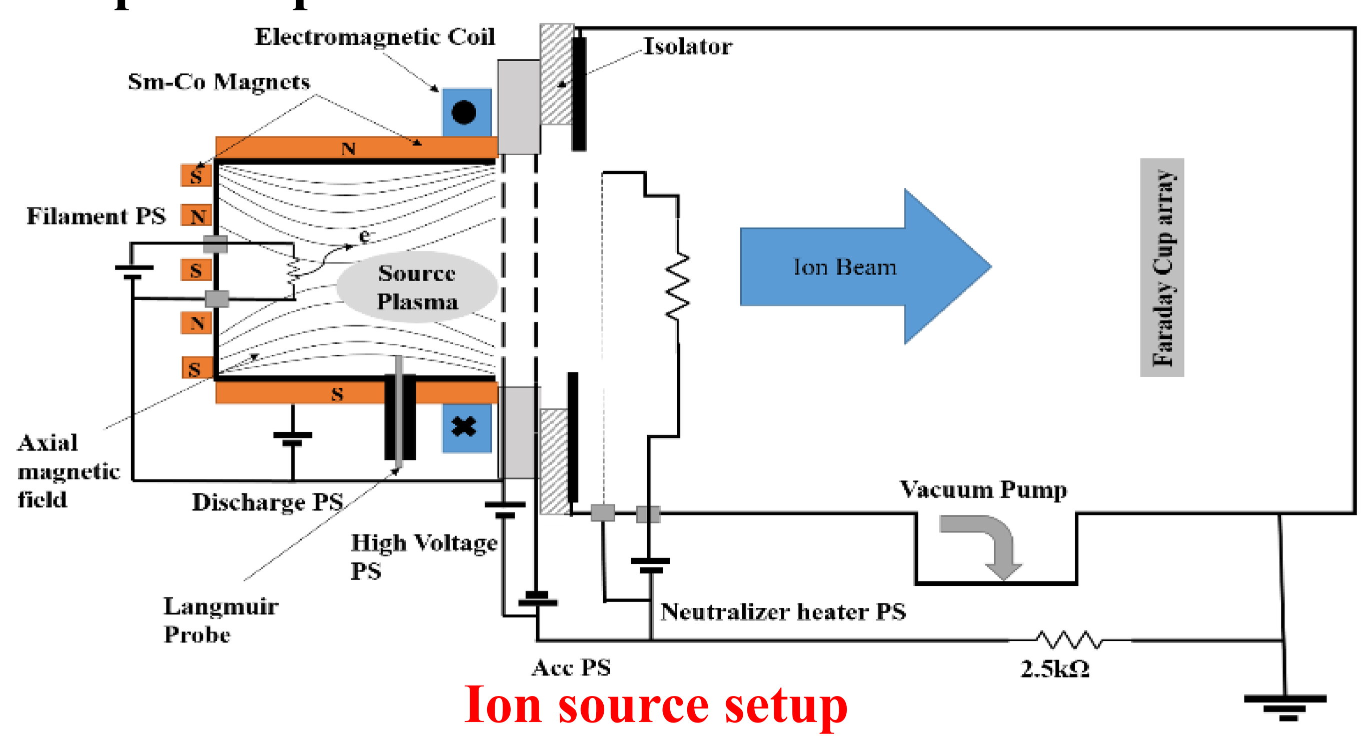
Abstract

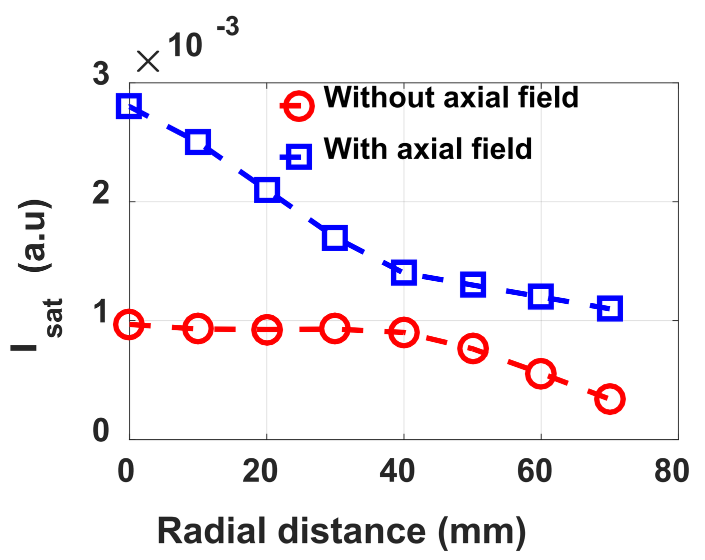
❖ Experiments have been performed to study the effects of axial magnetic field on plasma and ion beam parameters in a magnetic multipole line cusp ion source. Studies performed on ring cusp[1] and Kaufmann type ion sources suggest that the axial component of magnetic field helps in improving the ion extraction current at low discharge power. The line cusps ion sources have been used since long to produced uniform beams, however, they lack axial component of the magnetic field. These ion sources generally suffer from low efficiency possibly due the absence of axial magnetic field. In this work, an additional magnetic coil is added at various axial positions between the back-plate and the plasma grid of the multipole line cusp ion source. We have investigated the effects of axial magnetic field on the discharge efficiency and source parameters like beam current, divergence and uniformity in the multipole line cusp ion source. The beam profiles are obtained using an eleven channel faraday cup array to estimate the effects of the axial magnetic field on beam uniformity and divergence. Initial studies suggest a reduction of beam divergence with increasing axial magnetic field. A significant rise in the beam current and the discharge current is also observed when the axial magnetic field is increased. Particle trajectory simulation using the CST-Studio[2] suite is utilised in understanding the role of confinement of primary electrons behind the improved performance of the ion source.



Ion source setup

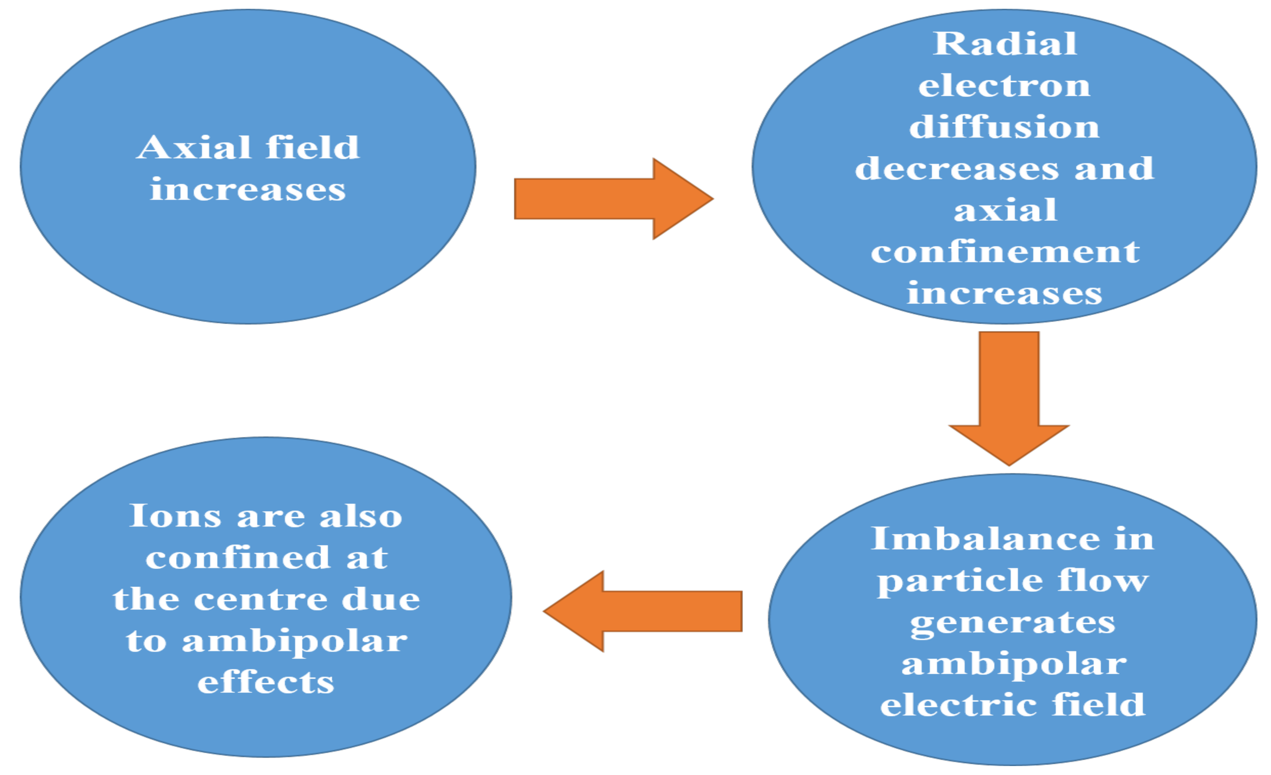
Experiment with axial Magnetic field

Ion saturation current profile

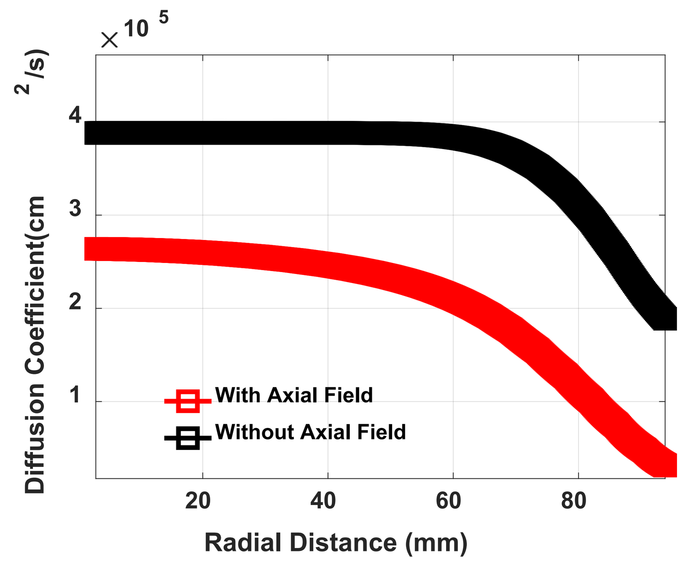


$$D_{\exp} = \frac{2 * v * q^2}{L}$$

Where v is the thermal velocity of the ions 405m/s at 300K
L is the arc length (Radius of the plasma chamber-10cm)
q is the e folding length (20cm) obtained from the ion saturation current profile[3]



❖ Theoretical ion diffusion coefficient calculated for different values of axial magnetic field is given by



$$D_{+} = \frac{D}{(1+(\omega_c \tau)^2)}$$

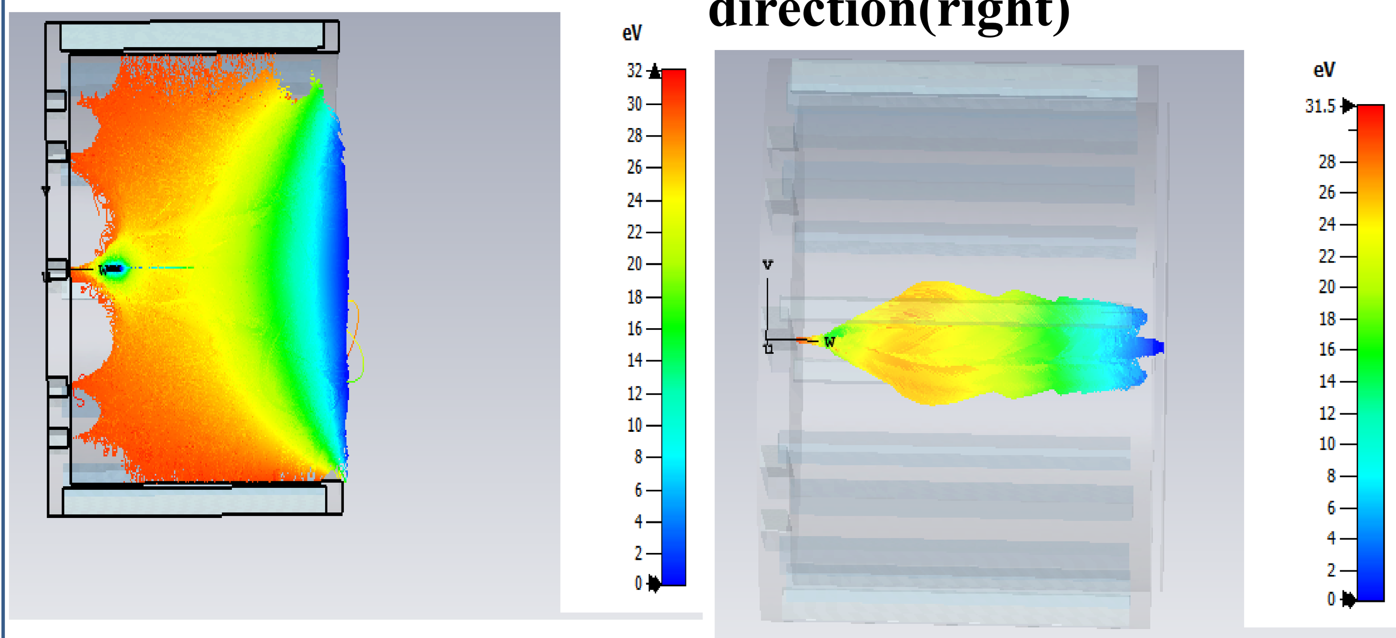
where
D is the ion diffusion coefficient in absence of magnetic field
ω_c is the ion cyclotron frequency
τ is the mean collision time between ion and neutrals

•The ion saturation current increases by 3 times due to the axial confinement of primary electrons.

•The experimental ($6.49\times10^4 cm^2/s$) and theoretical $1.25\times10^4 cm^2/s$ to $4\times10^5 cm^2/s$ diffusion coefficient agree well within certain order.

CST simulations

a) : No axial Magnetic field (b):Axial magnetic field out direction(right)



•The axial field confines the primary electrons along the source axis and prevents radial diffusion.
•The axially confined electrons cause more ionization along the axis of the source.

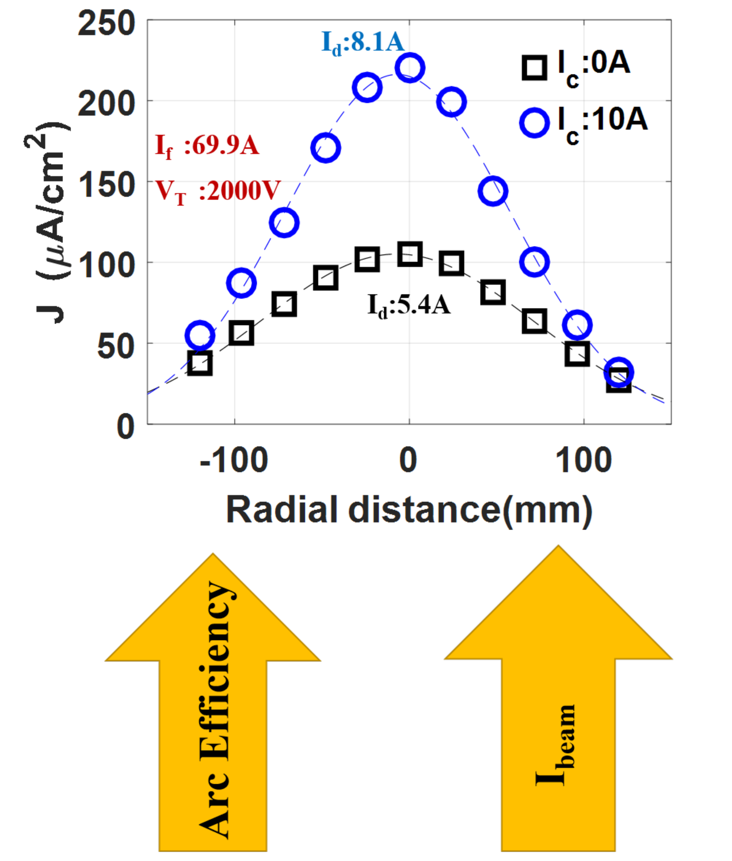
Arc efficiency improvement

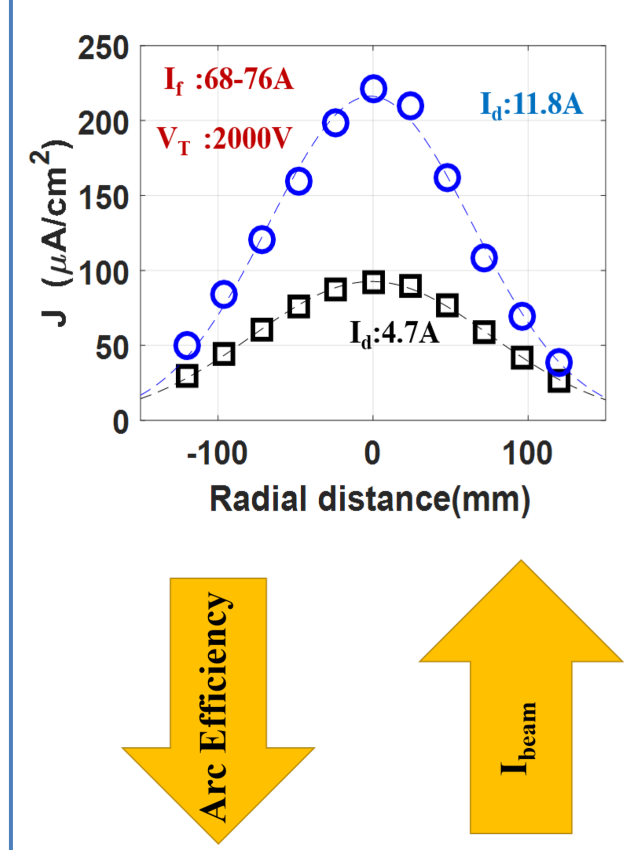
Discharge current is given by

$$I_{discharge} = neS_L V_b$$

S_L :Loss area for Ions
n :Plasma density V_b: Bohm velocity e:electronic charge

- Same current density/beam current achieved at lower discharge current by applying the axial magnetic field.

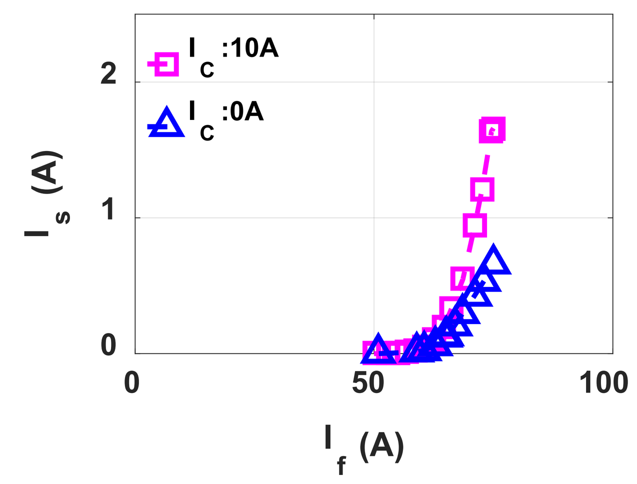


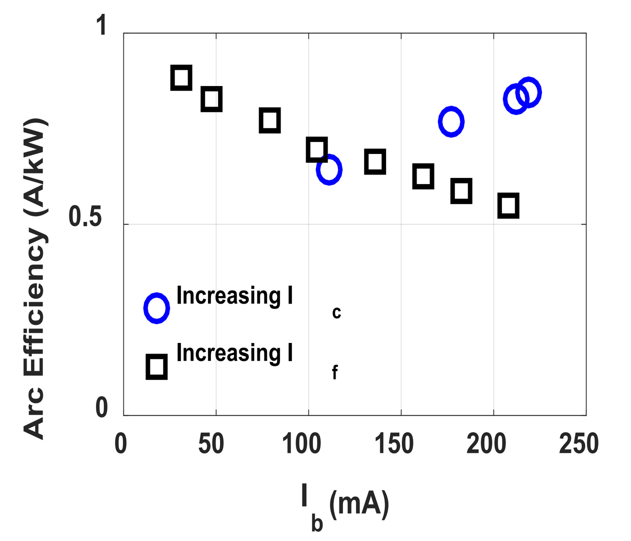


Richard Dushman relationship → Plasma Density n → I_{Beam}, $I_{Discharge}$

$$j_e = AT^2 e^{\frac{-e\phi}{kT}}$$

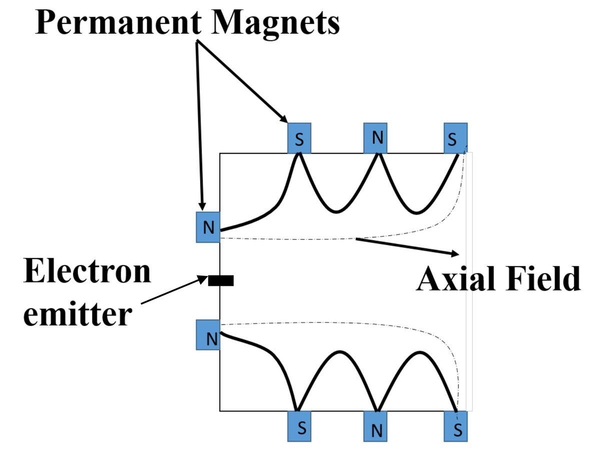
Electron Confinement by axial field → Plasma Density n → I_{Beam}, $I_{Discharge}$





$$Arc\ Efficiency = \frac{I_b}{P_{discharge}}$$

Effect of axial magnetic field



Ring Cusp Source

Ring cusp→ Weak Axial B→ Better discharge performance

Line cusp→ No axial field→ Lower discharge performance

- ❑ Axial confinement improved discharge performance.
- ❑ Filament electron emission can be enhanced without increasing filament temperature.
- ❑ Filament lifetime can be enhanced by axial magnetic field.

References

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3) Simon, A. Diffusion of arc plasmas across a magnetic field. *J. Nucl. Energy* (1958) doi:10.1016/0891-3919(58)90120-7.