

Rotating Plasma Effects in Cylindrical Hall Thrusters

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The cylindrical Hall thruster features high ionization efficiency, quiet operation, ion acceleration in a large volume-to-surface ratio channel, and performance comparable with the state-of-the-art conventional Hall thrusters [1]. The magnetic field of the cylindrical Hall thruster also differs from conventional annular Hall thrusters in that significant numbers of electrons can be trapped through magnetic-electric mirroring. The cylindrical thruster configuration is shown in Fig. 1.

Recently, by overrunning the discharge current, these thrusters also featured very significant plume narrowing (see Fig. 2), accompanied by significantly enhanced efficiencies [2]. Moreover, the regimes featuring the exceptional efficiencies are characterized by increased electric field in the thruster channel, plasma plume narrowing, and certain differences in temperature and density profiles [3].

When overrunning the discharge current, the inserted electrons bounce in the magneto-electric trapping region, spending most of their time near the endpoints of their orbits, and at least part of the time near the birth region at cathode. In particular, these populations both rotate and drift, even into regions of increased electron potential energy and decreased kinetic energy. That restricts the electron density and temperature profiles that can form. This picture appears to support many of the experimental observables.

In particular, a corollary to the isorotation theorem may appear to explain the unusual temperature effects observed in the PPPL cylindrical Hall thruster in the very promising current overrun regime. Magnetic surfaces with azimuthal symmetry that are also equipotential surfaces necessarily isorotate. The corollary to this theorem is that particles moving along magnetic surfaces lose twice in kinetic energy what they lose in the isorotational energy in going to surfaces at smaller radii. In addition to explaining the temperature anomaly in this regime, the rotation effects go a long way to explain not only the extreme plume narrowing in the current overrun regime, but also the rather remarkably small plume divergence even in conventional operation of the cylindrical thruster.

This work was supported by the AFOSR and US DOE.

- [1] Y. Raitses and N. J. Fisch, *Parametric Investigations of Non-Conventional Hall Thruster*, *Physics of Plasmas* **8**, 2579 (2001).
- [2] Y. Raitses, A. Smirnov, and N. J. Fisch, *Enhanced Performance of Cylindrical Hall Thrusters*, *Applied Physics Letters* **90**, 221502 (2007).
- [3] Y. Raitses, A. Smirnov, and N. J. Fisch, *Effects of enhanced cathode electron emission on Hall thruster operation*, to appear in *Physics of Plasmas* (2009).

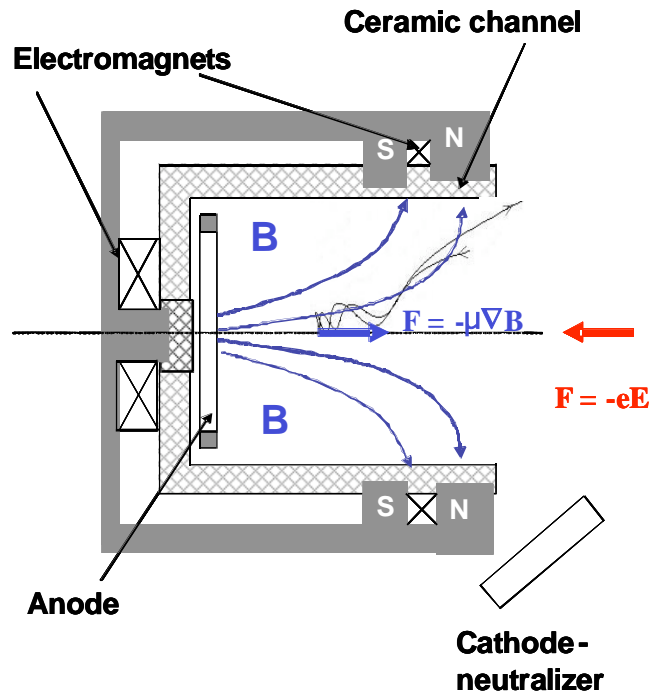


Fig. 1. The cylindrical Hall thruster: schematic and principle of operation.

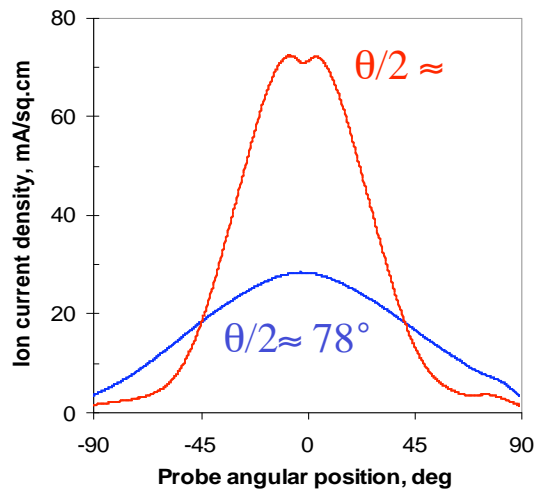


Fig. 2. Plume narrowing in the cylindrical Hall thruster current overdrive regime [2].