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Plasma expansion in a magnetic nozzle thruster

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A magnetic nozzle rf plasma thruster for space propulsion includes many aspects of physics [1]. The concept is very simple; the high density plasma produced in the source is transported along the magnetic field lines toward the source exit, is expanded along the magnetic nozzle, and has to be detached from the magnetic nozzle. This talk will review our laboratory experiments on the thruster physics. In the source, a portion of the charged particles are lost to the radial wall, where the ions accelerated by the sheath transfer their radial momentum. Measurement of the axial force to the radial wall shows that non-negligible axial momentum is simultaneously transferred to the wall, where the ions are axially accelerated in the core plasma and are lost to the wall [2]. The plasma entering the magnetic nozzle are spontaneously accelerated during the expansion process. The direct force measurement to the magnetic field demonstrates that a Lorentz force arising from the azimuthal internal plasma current and the radial magnetic field can increase the thrust [3]. More downstream, magnetic field lines are observed to be stretched [4] when the plasma flow velocity exceeds 0.2VA, where VA is the Alfven velocity. In the series of the plasma expansion physics, the electron internal energy would be the energy and momentum sources. The thermodynamic behavior of the electrons [5] is also discussed via a measurement of electron energy probability functions. [1] K. Takahashi *et al.*, Rev. Mod. Plasma Phys., **3**, 3 (2019). [2] K. Takahashi *et al.*, Phys. Rev. Lett., **114**, 195001 (2015). [3] K. Takahashi *et al.*, Phys. Rev. Lett., **110**, 195003 (2013). [4] K. Takahashi *et al.*, Phys. Rev. Lett., **118**, 225002 (2017). [5] K. Takahashi *et al.*, Phys. Rev. Lett., **120**, 045001 (2018).