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Plasma for space applications

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Among established and emerging plasma technologies for space applications are electric propulsion for satellites, plasma contactors for preventing charge accumulation on spacecraft and electrodynamic tethers. This talk will be focused mainly on electric propulsion which utilizes electric power to ionize and accelerate propellant, thereby generating thrust. The main advantage of using electric propulsion for spacecraft orbit control over chemical rockets is the larger jet velocity (~10–100 km/s), which enables significant savings in the propellant mass. By 2021, about 3000 electrically propelled satellites have been launched [1]. The most common form of electric propulsion technology on these satellites is the Hall thruster, which generates thrust by electrostatically accelerating ions in crossed electric and magnetic fields (ExB), which are applied in a quasineutral. Over the last 60 years, research and development efforts have been focused on 0.5-10 kW power level Hall thrusters. The on-going rise of higher power capabilities onboard satellites and the miniaturization of components open the possibility for new electrically propelled space missions including, for example, constellations of miniaturized satellites (e.g. CubeSats) and high power interplanetary missions. These new space missions and applications require Hall thrusters scaled down in size and up in power to operate efficiently with a high thrust density (thrust-to-thruster frontal area) at lower (<100 W) and higher (>100 kW) power levels, respectively. Most of the existing Hall thrusters operate with thrust densities of ~ 10 N/m^2. In a recent theoretical study, the fundamental limit of Hall thrusters was predicted to be at least 10 times higher [2]. This would imply much more compact thrusters suitable to the above applications are possible. In order to achieve this predicted limit, there is a strong need to address a number of plasma science challenges associated with cross-field transport and instabilities, plasma-wall interactions, and ionization relevant to high thrust density operation. Alternative ExB thruster configurations may be needed to operate in these extreme regimes. This talk will briefly discuss these challenges and their potential solutions.

References:
[1] B. R. Frongello et al., "Spacecraft Electric Propulsion at an Inflection Point", ASCEND 2021, Las Vegas, ND/Virtual, November 2021
[2] J. Simmonds, Y. Raitses, and A. Smolyakov, "A theoretical thrust density limit for Hall thrusters", J. Electric Propul. 2, 12 (2023)

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