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BREAKTHROUGH OF INERTIAL ELECTROSTATIC CONFINEMENT CONCEPT FOR ADVANCED SPACE PROPULSION

Abstract

The activities of Inertial electrostatic confinement (IEC) research for propulsion application in IRS started from 2009. A breakthrough on the theoretical explanation of working principle in 2017 IEPC enabled the proof-of-concept of IEC thruster for next generation space exploration. [1] Several advanced IEC propulsion concepts have been proposed accompanying with the working principle which demonstrated a wide-spectrum application from atmosphere-breathing electric propulsion for very-low-earth orbit to fusion propulsion for deep-space manned mission.

IEC is a concept proposed by Phillo Farnsworth for fusion application in 1950s. The idea is using extremely high electric potential on a pair of concentrically aligned spherical grid structure: the inner one serves as cathode while the outer one as anode/ground. The high potential gradient allows electron field emission on cathode surface. These electrons are driven by the strong electric field with an outward vector and equipped with high kinetic energy which allows the production of ions between two spherical grids. These ions are driven inward to the center of IEC by the applied electric field. Due to the high transparency of cathode grid, ions can easily pass through the grid gate due to their inertia. This further forms a condensed, positively charged plasma cloud within the cathode grid, known as virtual anode. The virtual anode starts to drive cathode emitted electrons inward to the center of IEC. If the potential gradient of virtual anode is large enough, a spherical double layer is formed within the cathode grid.

Spherical double layer (SDL), as known as fireball, is a stable condition forming by dynamics of electrons and ions. The formation of SDL is resulted from the appearance of non-neutral plasma, which creates localized electric field and forces the charged particles nearby hastened along with the local electric field gradient. In general, the local electrons and ions fly toward each other and reach momentum balance. The SDL can offer both intensive ionization and confinement of ions at the same time which provide the advantage to suppress erosion from ion bombardment. Furthermore, distortion of the SDL by manipulating the applied electric field gradient are the key to achieve plasma extraction from core of IEC. This permits the applications of IEC device goes from neutron generation to electron/ion source, which opens the door to space propulsion.

[1] Y.-A.Chan and G. Herdrich, “Inertial Electrostatic Confinement: Innovation for Electric Propulsion and Plasma Systems,” in 35th International Electric Propulsion Conference, Atlanta, GA, U.S.A, 2017.