05/3201 Numerical simulation of the Helicon Double Layer Thruster Concept

Type of activity: Medium Study (4 months, 25 KEUR)

Background

Researchers at the Plasma Research Laboratory (PRL) of the Australian National University (ANU) have recently shown that a potential drop of a few tens of Volts over a very short length ("double layer") forms at the boundary between a helicon source and a diffusion chamber in the presence of a diverging magnetic field [1]. Since ions generated in the helicon source are accelerated out by this potential drop, this discovery has a promising application as a highly scaleable and durable plasma thruster (no life-limiting acceleration grids are required as in the case of ion engines). The double layer generated by this device is current-free, i.e. electrons are also extracted from the helicon source and no external high current cathode neutraliser is therefore necessary. The research at ANU to date has been focused on electropositive gases as propellant.

The research group at the Laboratoire de Physique et Technology des Plasmas (LPTP) of Ecole Polytechnique in Palaiseau (France) is performing a study under the Ariadna programme on this helicon double layer thruster concept [2]. The aims of this study are to independently verify the ANU experimental results, measure double layer formation and stability under varying operating conditions, investigate scaling laws for use on very high power space missions, and assess the alternative use of electronegative plasma mixtures. Early work by this group has shown that double layers can also form without a magnetic field when traces of electronegative plasmas (e.g. SF_6) are mixed in with electropositive plasmas (e.g. Ar), thus giving potential advantages in terms of lower mass for the spacecraft power and propulsion systems. Under some conditions the double layer is stable, and in others it exhibits an unstable high frequency periodic pulsing behaviour.

Although some progress has been made, our understanding of the double layer formation and its stability, as well as the implications for space propulsion is still far from complete. It is apparent that only a detailed numerical/analytical modelling of the plasma dynamics within the induced electric and magnetic fields, in complement with the experimental work, can lead to a deeper understanding of this physical phenomenon. Such an understanding is necessary to properly validate performance of the double layer in the laboratory equipment and predict its potential for propulsion in the space environment.

Study Objectives

The aim of the study described is to understand the formation and stability of the double layers formed in conditions of the experiments at ANU and LPTP (electropositive plasma with magnetic field, electronegative plasma without magnetic field, diffusion chamber with residual pressure), and to analyse and quantify their performance for propulsion in the space environment (i.e. expanding plasma into free space vacuum).

The theoretical study of the current-free double layer shall be based on a physical and numerical model of the helicon source. The model shall provide the space and time evolution of the electron, positive and negative ion densities/fluxes and of the electric potential. The current density distribution in the device shall also be calculated.

The model shall be applied to the experiments at LPTP and shall be used to assess the relevance of the double layer concept for space propulsion, and to quantify the thrust and specific impulse that can be expected from such a device.

As a summary, specific tasks for the study are:

1) summary of the current understanding of helicon double layer formation & stability with electropositive gases from both theoretical & modelling studies.
2) development of a 2D hybrid fluid Particle-In-Cell model of a helicon source and diffusion chamber or expanding plasma into vacuum; including magnetic field in the presence of both electropositive and electronegative gases.
3) use of the model replicating the boundary conditions and operating parameters close to the experiments at LPTP to:
    a. understand the conditions of formation and stability of the double layer
    b. compare with experimental results obtained at LPTP
    c. quantify thrust, specific impulse and beam divergence
    d. study the feasibility of this concept in the conditions of an expanding plasma into space

Full consideration of the Ariadna study report produced by LPTP [2], and a close interaction with the ACT and groups at ANU and LPTP is encouraged in order to achieve the above objectives and tasks.

Deliverables

- Final report
- Final presentation at ESTEC

References

[1] C. Charles, R.W. Boswell, "*Laboratory evidence of a supersonic ion beam generated by a current-free "helicon" double-layer*". Phys. Plasmas **11**, 1706-1714 2004.

[2] Chabery, P., Plihon, N., Helicon Double Layer Thruster Concept for High Power NEP Missions, final report of ESA/ESTEC contract no. 18852/05/NL/MV, July 2005.