PROPOSITION DE SUJET DE THÈSE

Intitulé : Kinetic Simulation of a Magnetized plasma in an advanced ECR plasma thruster

Référence : PHY-DPhIEE-2018-13
(à rappeler dans toute correspondance)

Laboratoire d’accueil à l’ONERA :
Domaine : PHYSIQUE Lieu (centre ONERA) : Palaiseau
Département : Département Physique, Instrumentation, Environnement, Espace
Unité : Foudre, Plasma et Applications Tél. : 01 80 38 61 71
Responsable ONERA : Paul-Quentin ELIAS Email : paul-quentin.elias@onera.fr

Directeur de thèse envisagé :
Nom : Andrea CIARDI
Adresse : Laboratoire d’Étude du Rayonnement et de la Matière en Astrophysique (LERMA), which is a laboratory of the Observatoire de Paris, UPMC, ENS and CNRS (UMR 8112).
Office: UPMC, 4 Place Jussieu, 75005 Paris, France
Tél. : 01 44 27 76 02 Email : andrea.ciardi@obspm.fr

Sujet :
The future space exploration and commercial exploitation will rely more heavily on plasma thruster since these devices provide significant gains in terms of payload and lifetime. Onera is currently developing a promising new concept of Plasma thruster call ECRA, for 'Electron Cyclotron Resonance Acceleration' which has the potential to overcome several limitation of the current generation of plasma thruster. The ECRA concept consists in an ECR source coupled to a magnetic nozzle that confines and guides the quasi-neutral plasma. It does not require grids or neutralizer, which are the critical components in many current plasma thrusters.

In this context, Onera has started a 3-year European project to increase the power and the performances of the ECRA thruster. For this purpose, advanced numerical codes are developed to model the physical behavior of the thruster. Among these is a Particle-In-Cell/Monte-Carlo Collision code developed by Onera in collaboration with UCLA. This code aims at leveraging the emerging massively parallel computer architectures to perform large scale kinetic modeling of the low-pressure plasma found in electric thrusters, using in particular the Onera supercomputer or other larger HPC systems.

The goal of this PhD project is to apply and strengthen this simulation tool to improve our understanding of the new ECRA thruster design. Among the key phenomena to understand is the transport of magnetized electrons in the source. In the ECRA source region, the axial magnetic field prevent most of the electrons from diffusing radially. However, due to the divergence of the magnetic field applied in the source, some magnetic field lines can intersect the source walls, thereby favouring electron collection at these locations. Depending on the wall material (metal or dielectric), this collection can lead to compensating wall currents that can flow and change the confinement mode of the ECR source.

In addition, this phenomenon is tightly coupled to the way the microwave power is transferred to the plasma, and how the plasma is heated in the resonance zone. Changing the microwave coupling strategy is desirable for several reasons related to the thruster lifetime and power range. However it is first required to understand how the coupling affect the thruster performances in general, and its confinement regime in particular.
The conditions of operations of the thruster, where the electron transport is non-local (due to their large mean free path), their energy distribution is anisotropic, high performance (2D and 3D) warrant high performance kinetic simulations.

This project is tightly coupled to the intense research activity around the ECRA concept. It mainly involves numerical, theoretical and physical analysis. For this purpose, the following steps are foreseen:

* Parametric analysis of the source confinement regime using Onera's Particle-In-Cell code on its local cluster. This may require the development and the testing of a several sub-modules of the code (diagnostics tools).
* Analysis and simulation of alternative microwave coupling strategies, using a Maxwell-PIC approach. Validation of a new Maxwell solver to model the propagation of the micro-wave in the plasma.
* Physical analysis of the simulation results to improve the performances of the thruster.

The simulation requirements and specifications will be devised in close collaboration with the experimenters working on the thruster. Comparison with the experiments will be frequent during the 3 years of the PhD.

The specific developments required for this project will be done in collaboration with the developer team in charge of the code. The candidate will use a dedicated development server, Onera's mainframe (Sator, 20000 cores), and also possibly some European Computing facilities.

The candidate shall be able to work proactively in a collaborative and international environment. He or she shall be familiar with a least a programming language and ideally have some notions in software development. Finally, the candidate shall have preferably a background in plasma science and demonstrate very good learning skills and abstraction capabilities. Collaborations with the Phare code developed at the Observatoire de Paris are possible.

**Collaborations extérieures** : Observatoire de Paris

<table>
<thead>
<tr>
<th>PROFIL DU CANDIDAT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Formation</strong> : Grandes Ecoles ou Master 2 recherche.</td>
</tr>
<tr>
<td><strong>Spécificités souhaitées</strong> : formation plasma souhaitée mais pas indispensable. Une expérience en simulation numérique serait un plus.</td>
</tr>
</tbody>
</table>