Report: DOE Plasma Science Center Travel Fellowship

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My visit to Princeton Plasma Physics Laboratory (Princeton, NJ) was from February 24th to February 28th, 2014. The purpose of this visit is to make updates for our collaborative work and discuss what can be done in the future with Dr. Igor Kaganovich and Dr. Yevgeny Raitses.

<Overview of the research>

The discharge plasma in Hall thrusters is known to be in a non-equilibrium state due to nonlinear interactions between electromagnetic fields, channel walls, and many types of collisions. In order to control such complex plasmas, transport of the velocity distribution functions (VDFs) of each plasma species must be understood. The conventional particle methods suffer from statistical noise due to the use of discrete macro-particles. My research focuses on developing a direct kinetic (DK) simulation in which kinetic equations are solved and the VDFs are obtained directly on discretized phase space.

1. *Hall thruster simulation:* A 1D hybrid-DK simulation in which a DK simulation is used for heavy species and a fluid model is employed for electrons. [Hara, K. et al. Physics of Plasmas, **19**, 113508 (2012)] Recently, mode transition in a Hall thruster has been studied using the hybrid-DK simulation. The predicted discharge oscillation mode transition in 5-30 kHz range is in good qualitative agreement with experiments by Sekerak et al. in University of Michigan. [Paper in review, Journal of Applied Physics]. A 2D solver is being developed.

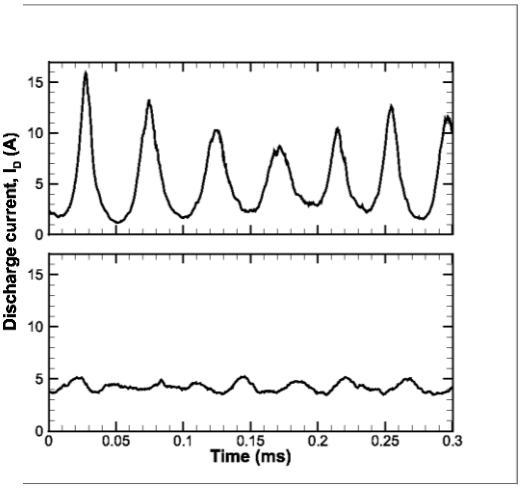

Fig. 1 SPT-100 thruster 1D hybrid-DK simulation. (top) Global oscillation at 5-30 kHz when magnetic fields are small, (bottom) Local oscillation when magnetic fields are large

2. *DK simulation development*: Numerical error is generated and propagates in the calculation domain when solving the hyperbolic partial differential equation. Recently, we have developed a front tracking method that captures the maximum and minimum velocities available in the domain. The particle transport does not occur beyond the fronts, which makes the simulation more accurate and optimizes computational cost. [Paper in preparation]

3. *Other collisionless plasma test cases:* A full-DK simulation, which employs a DK method for both ions and electrons, is used to model the near-wall sheath and nonlinear plasma waves including electron plasma waves, ion acoustic waves, and electron acoustic waves.

<Visit to PPPL>

I had fruitful discussions on current and future projects with Dr. Igor Kaganovich and Dr. Yevgeny Raitses.

1. *Collisionless nonlinear phenomena*: A DK simulation is a very useful tool to investigate nonlinear plasma phenomena. We are interested in the newly proposed plasma wave called kinetic electrostatic electron nonlinear (KEEN) wave. We have discussed whether the KEEN wave is a different nonlinear phenomenon than a standard mode with Dr. Ed Startsev in PPPL.

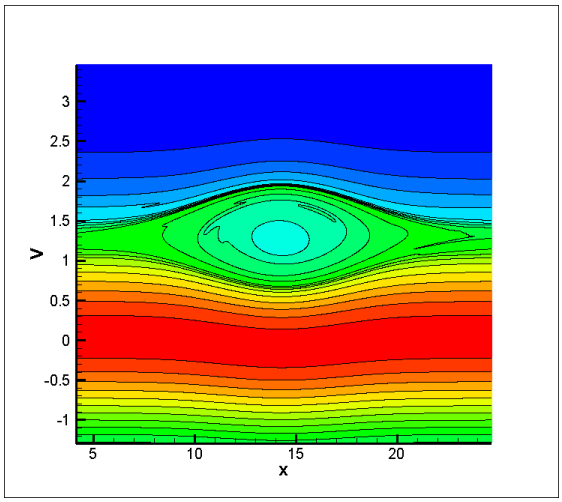

Fig. 2 Electron velocity distribution function on phase space for KEEN wave

2. *Presheath-sheath simulation*. Few simulations have been performed including the presheath. The noiseless DK simulation can be used to analyze the presheath-sheath transition under emitting surface and various distribution functions. There are recent kinetic theories with which the simulation can be verified. We have set a goal to achieve these problems.