Simulation of Ion Thruster Optics Using a Gridless Poisson Solver

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The focus of this paper will be on the application of a gridless potential solver to ion thruster optics. Ion thruster optics consist of two or three charged plates with many apertures, through which ion are accelerated by the electric fields. The primary focus in computational modeling of ion thrusters is on the operation of the optics and their failure modes. Generally, a single aperture is modeled in the computational domain, and the ion flow is steady state, giving an electrostatic problem. The geometry of the problem can be complex however— there are cusp structures on the inner surface of the apertures, the optics are usually dished such that there is a slight curvature in the plates, and erosion occurs on the optics, creating very irregular geometry.

Direct solution of the electrostatic problem requires N^2 operations to determine the force on each particle, where N is the number of particles. This cost is prohibitive for most systems, so some approximation is taken to reduce the computational work— usually a particle-mesh approach such as particle-in-cell (PIC) or particle-particle-particle-mesh (P^3M). These methods map the particle charges to a grid, and the force in each grid cell is solved for on the mesh. This gives a Nlog(N) computation cost in total, but the grid increases difficulty in resolving the complex geometry in the domain. As an alternative, a gridless approach such as a treecode algorithm may be used. In a treecode, particles are grouped into clusters, which can be treated as single particles at long range. This gives a reduction in computation to approximately Nlog(N).

It is generally accepted that treecodes perform well in unbounded or periodic domains, but the performance of treecodes is largely unknown when Dirichlet or Neumann boundary conditions are needed. This paper will show that a treecode algorithm can give comparable performance to gridded methods in the simulation of ion thruster optics, while also maintaining the ability to simulate complex geometry at little additional computational cost. This will be done through the use of panel methods on the boundaries, where sections of the boundary are treated as particle populations with a constant density. Figures 1 and 2 show a simulation where particles are accelerated in a 2-D domain through an ion optics aperture using a panel method for the boundaries and direct summation for determining particle forces.

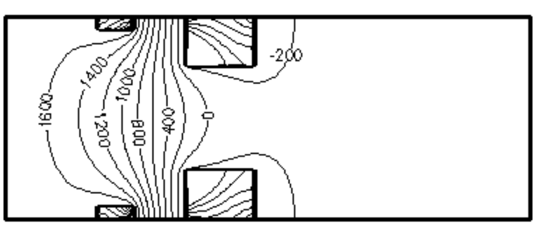

Figure 1. Potential profile, units are in Volts.

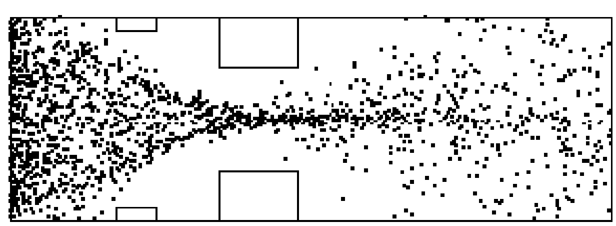

Figure 2. Particle locations in the domain.

In the final paper, results such as these will be presented with comparisons of the treecode algorithm to results from PIC and direct summation in terms of accuracy and computational cost.