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100X Speed-up of Particle-In-Cell (PIC) Langmuir Probe Simulation[1] GREGORY WERNER, University of Colorado, Boulder, ANDREW CHAP, THOMAS JENKINS, Tech-X Corp., JOHN CARY, University of Colorado, Boulder, and Tech-X Corp., SCOTT ROBERTSON, University of Colorado, Boulder
— Interpreting Langmuir probe data in real-world conditions can be very difficult— e.g., with non-ideal geometries, space charge and non-zero electric field (in the absence of the probe), collisionality, secondary emission, etc. With enough computational power, PIC simulation can precisely characterize probe responses to various plasma conditions, self-consistently including non-ideal effects, thus helping to interpret real probe data. Unfortunately, PIC simulation can be prohibitively expensive, partly because the cost scales with the square root of the ion/electron mass ratio, $\sqrt{m_i/m_e}$. Fortunately, the steady-state Vlasov-Poisson system scales trivially with ion mass, so probes in electron-ion plasma can be equivalently simulated in electron-positron plasma, speeding up computation by $\sqrt{m_i/m_e}$, e.g., by more than $100\times$ for argon ions. The resulting solution yields the correct self-consistent charge density and electric potential for the electron-ion system. This approach is equivalent to the speed-limited PIC (SLPIC) method with a particularly simple speed-limiting function; moreover, SLPIC provides a systematic treatment for speeding up simulation by $\sqrt{m_i/m_e}$ while accurately treating collisionality, secondary emission, and magnetic fields.

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