Modeling Electrode Plasma Effects in Particle-in-Cell Simulation of High Power Devices

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A new method for including electrode plasma effects in particle-in-cell simulation of high power devices is presented. It is not possible to resolve the plasma Debye length, $\lambda_D \sim 1 \mu m$, but using an explicit, second-order, energy-conserving particle pusher avoids numerical heating at large $\Delta x/\lambda_D \gg 1$. Non-physical plasma oscillations are mitigated with Coulomb collisions and a damped particle pusher. A series of 1-D simulations show how plasma expansion varies with cell size. This reveals another important scale length, $\lambda_E = T/(eE)$, where $E$ is the normal electric field in the first vacuum cell in front of the plasma, and $T$ is the plasma temperature. For $\Delta x/\lambda_E < \sim 1$, smooth, physical plasma expansion is observed. However, if $\Delta x/\lambda_E \gg 1$, the plasma “expands” in abrupt steps, driven by a numerical instability. For parameters of interest, $\lambda_E \ll 100 \mu m$. It is not feasible to use cell sizes small enough to avoid this instability in large 3-D simulations.

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