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Macroparticle combination algorithm for plasma PIC simulation

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The efficient simulation of plasmas via the particle-in-cell (PIC) algorithm requires that the macroparticle density be isotropic, while the physical density can vary significantly in space and time. This isotropic macroparticle density ensures good statistics in reactions and charge deposition while maintaining ideal computational load balance. Especially in the case of cascade ionization, when the physical density of electrons locally grows exponentially in time, the macroparticle density must be managed so that it does not also increase. This is accomplished through macroparticle recombination, where multiple macroparticles are combined into fewer macroparticles. We present a novel algorithm for preserving the momentum, energy, flux, charge, and phase space distribution of the original particles during this recombination process. Conservation of these quantities is important when the distribution function of the particles is non-Maxwellian, and especially when it is multi-modal. This new algorithm will be discussed in detail, and plasma simulations benefitting from its unique conservation properties will be shown. These simulations will include a simple example of crossing beams, as well as a complex simulation of plasma generation in the C100 SRF cavity for in situ cleaning. In both of these cases, there are discrete populations of electrons with different temperatures and mean velocities that must be preserved to accurately model the system.

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