Hybrid Particle/Fluid Modeling of Plasmas

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Particle in cell (PIC) methods enjoy great success in modeling devices that include moderately dense plasmas. However, as the plasma density becomes high in a large volume, the number of particles to track becomes computationally prohibitive. Reducing the number of particles by creating larger "macro particles" introduces significant numerical error. Alternatively, high-density plasmas in large volumes can be modeled using a dielectric fluid description. However, such a description is not accurate for non-Maxwellian energy distributions. Some physical processes, such as air breakdown phenomena, involve high-density plasmas with energy distributions that are partially Maxwellian but include a long, high energy tail. The particles in the high-energy tail are those responsible for the majority of interactions that lead to a qualitative change in physical behavior. Thus, a fluid description that neglects the high-energy tail fails to capture the physics of interest. A hybrid plasma description has the potential to capture the relevant physics in a tractable computational time.

The hybrid description envisions using a fluid description for the particles that fall within the Maxwellian energy distribution, and using PIC for the model particles that fall within the high-energy tail. Thus, a plasma fluid description is being added to the Improved Concurrent Electromagnetic Particle in Cell (ICEPIC) code. The PIC and fluid descriptions are tested independently to ensure physical accuracy. Results are presented showing that the particle and fluid descriptions independently produce the correct dispersion relation in hot and cold plasmas in a two dimensional box. Once physical accuracy is established for the individual descriptions, the descriptions are combined. Further testing is planned to ensure that physical accuracy is independent of the fraction of the plasma in each component when the total energy distribution is Maxwellian. Then, distributions with high-energy tails can be tested. The final stage of development is to find appropriate exchange mechanisms to allow particles that have lost energy to be absorbed into the fluid component and vice versa. The exchange mechanisms must not introduce non-physical effects into the model.