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IFE/P6-01: Particle Simulation of Fusion Ignition

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A new molecular dynamics (MD) particle simulation code has been developed to study inertial fusion ignition physics including effects of a non-Maxwellian ion velocity distribution. 10,000 DT ions at density 100 g/cc and temperatures of several keV are followed for 10 to 20 psec. The simulation includes ion-ion collisions, electron-ion coupling and emission and absorption of radiation. Fusion reactions produce energetic alphas which deposit energy to electrons and ions and the plasma self-heats to 20-30 keV.
This simulation using realistic particles and interactions poses the scientific challenge of including quantum processes (fusion, radiation) in a classical particle simulation and the computational challenge of following the calculation for long enough to see significant plasma self-heating. The paper gives a detailed discussion of special physical and numerical techniques which make it possible to do such a simulation.
The molecular dynamics is carefully compared to hydrodynamic simulations of small plasma volumes to test both codes. The most important new physics in MD simulations is the possibility to include a non-Maxwell ion velocity distribution f(v); fusion reaction rates are very sensitive to the high-energy tail of f(v), which depends delicately on plasma transport and equilibration processes.
Although equilibrium ion-pair correlation is not strong in multi-keV plasmas we find substantial dynamical correlations caused by alpha-particle energy transfers. It is found that calculations starting from a variety of initial conditions evolve to follow a unique self-heating trajectory, an ignition attractor.
Calculations starting with 3 keV DT heat to ignition within a few psec after a pulse of energetic ions are injected; this shows that fast ions are quite effective for fast ignition of pre-compressed DT. A series of such calculations are performed to determine the threshold ion deposition heating required to ignite DT fuel within the short time of peak target compression.

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