Particle-in-cell modelling for head-on collisions of large-scale high density plasmas jets

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In the double-cone ignition (DCI) inertial confinement fusion scheme, head-on collision of high density plasma jets is one of the most distinguished feature when compared with traditional central ignition and fast ignition inertial confinement fusions. However, the traditional hydrodynamic simulations become limited, due to serious plasma penetrations, mixing and kinetic physics that might occur in this process. To overcome such limitations, in this paper, we propose a new simulation method for large-scale and high density plasmas, with an ingenious kinetic-ion and kinetic/hydrodynamic-electron treatment. This method takes advantages of modern particle-in- cell simulation techniques and binary Monte Carlo collisions, including both long-range collective electromagnetic fields and short-range particle-particle interactions. Especially, in this method, the restrictions of simulation grid size and time step, which usually appear in a fully kinetic description, are eliminated. In addition, the needs of collisional coupling and state-dependent coefficients, that are usually approximately used with different forms in fluid descriptions, are also eliminated in this method. Energy and momentum exchanges among particles and species, such as thermal conductions and frictions, are modelled by "first principle" kinetic approaches. The correctness and robustness of the new simulation method are verified, by comparing with fully kinetic simulations at small scales and purely hydrodynamic simulations at large scale. Following the conceptual design of DCI scheme, the colliding of two plasma jets with initial density of 100 g/cc, initial thermal temperature of 50 eV, and counter-propagating velocity at 300 km/s is investigated by using this new simulation method. Quantitative values, including density increment, pre-heated plasma temperature, and conversion ratio from colliding kinetic energy to thermal energy, are obtained in this investigation: density increment is ~ 3, plasma heating is ~ 400 eV and conversion ratio is ~ 81.2%. These values might serve as a reference for the future detailed studies.

References

[1] Zhang J, et al. 2020 Double-cone ignition scheme for inertial confinement fusion. *Phil. Trans. R. Soc. A* **378**: 20200015.