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Research on Large scale kinetic physics in the double-cone-ignition laser fusion

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In the double-cone ignition inertial confinement fusion scheme, head-on collision of high-density plasma jets is one of the most distinguished features when compared with the traditional central ignition and fast ignition of inertial confinement fusions. The application of traditional hydrodynamic simulation methods becomes quite limited, due to serious plasma penetrations, mixing, and kinetic physics that might occur in the collision process. To overcome such limitations, we proposed a new simulation method for large-scale high-density plasmas. 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, collisional coupling and state-dependent coefficients, which are usually approximately used with different forms in fluid descriptions, are also removed in this method. Energy and momentum exchanges among particles and species, such as thermal conductions and frictions, are modeled by "first principles" kinetic approaches. In fact, such numerical simulation capabilities are also crucial for other laser fusion schemes and laboratory astrophysical research.

Over the past decade, the presenter has been developing the LAPINS code, a numerical simulation code with multi-physics coupling, and the ability to uniformly describe both classical and quantum degenerate plasmas. In this report, apart from introducing the large-scale quantum degenerate kinetic modeling of LAPINS, we will further present its significant applications. Firstly, LAPINS has revealed the crucial role of quantum degeneracy in enhancing the efficiency of laser-to-hotspot energy coupling in the DCI scheme. Secondly, it has discovered the mechanism of stochastic ion acceleration during the nonlinear kinetic evolution of large-scale electromagnetic turbulence.

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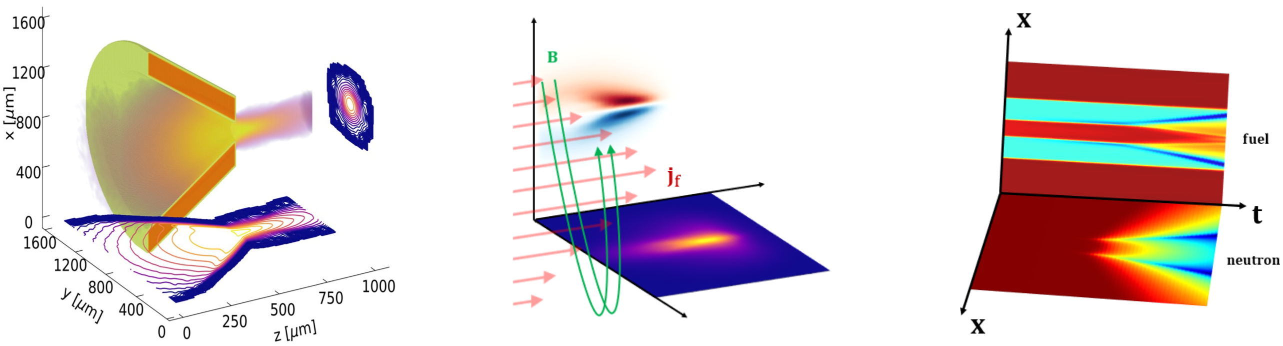

Figure 1: The application of the LAPINS kinetic simulation code in double-cone ignition champions, including the compression and head-on collision, fast heating and burning processes.