Structure-preserving scheme for multi-temperature hydrodynamic model

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Hydrodynamics is the most essential component to dictate the implosion physics of inertial confinement fusion (ICF). Electrons in the ablator absorb illuminated lasers or x-rays, and then the implosion dynamics is driven. The fact means that the ions and electrons are thermally nonequilibrium, so that a one-fluid two-temperature approximation has been used in many radiation hydrodynamics (RHD) codes. However, the one-fluid two-temperature model is written by the nonconservative partial-differential-equations (PDEs). Some codes discretize the nonconservative PDEs directly and the global conservation of energy is usually violated [1,2]. Another way of discretization solves the conservation laws of the mass, momenta and total energy, and a nonconservative electron energy equation [3]. In this way, the global conservation of energy is strictly satisfied even in the discrete form but the Rankine–Hugoniot relationship is violated when solving the shock tube problem. In other words, the electron temperature is not solved accurately when the flow field has the discontinuities.

Our strategy to conquer such a difficulty is to discretize the conservation laws and deform them into the nonconservative form using the structure-preserving operations, which connect the nonconservative PDEs with the conservation laws. Our latest results show that a numerical scheme developed by such a strategy can maintain the error of global energy conservation at the round-off level and can solve the shock tube problem of the one-fluid two-temperature model accurately [4]. That means not only the global conservation but also the local conservation is exactly satisfied even in the discrete form. Therefore, the structure-preserving operators are the suitable approach to construct an accurate RHD code because the transfer coefficients of radiation fields strongly depend on the electron temperature. In the work, however, the structure-preserving scheme have been developed on the one-dimensional Cartesian coordinate, so the cylindrical and spherical schemes are required to simulate the ICF implosion of the laser fusion and z-pinch. Until the conference, we will develop a structure-preserving scheme for the one-fluid two-temperature model in the cylindrical and spherical coordinates and compare the numerical results with the exact solutions of the Noh problem.

References

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