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The Construction of Simulation Algorithms for Laser Fusion

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Abstract. In this work, we will present a system of numerical simulations for inertial confinement fusion, which consists of a series of one-dimensional, two-dimensional and three-dimensional codes. Our efforts have been made to develop 2D and 3D computer simulation codes, forming a 2D simulation capability so with the key physics issues in laser fusion can be separately simulated mainly by a LARED family containing six different 2D (and partially 3D) code series. The models and the characteristics of the main codes will be described, and some simulation results using the LARED family will be presented.

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Key words: Laser fusion, numerical simulations, LARED.

1 Introduction

Laser fusion, belonging to inertial confinement fusion (ICF), uses a high power laser as a driver to implode capsules filled with fusion fuel and produce thermonuclear energy. The capsule implosion is driven by either electron ablation (direct drive) or radiation ablation (indirect drive). In the direct drive, the laser beams are aimed directly at the capsule. In the indirect drive, the laser energy is first absorbed in a high-Z enclosure, a hohlraum. The hohlraum wall converts most of the laser energy into x rays which ablate the capsule at the hohlraum center and drive implosion.

Substantial progress has been made in the past and it is likely that the ignition condition will be achieved in the laboratory within the next decade. The target design of ignition used in both the National Ignition Facility (NIF) in the US [1] and the Laser

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Table 1: Description of the LARED code family.

Names	**Function**
LARED–P	2D and 3D PIC parallelized code for laser plasma interaction.
LARED–H	2D non-LTE radiation hydrodynamic ALE code for Laser-target coupling and hohlraum physics.
LARED–R	2D code for radiation transport
LARED–I	2D code for indirect driven approach implosion dynamics, ignition and burn propagation.
LARED–D	2D code for direct and indirect driven approach implosion dynamics, ignition and burn propagation.
LARED–S	2D and 3D Eulerian code series for hydrodynamic instability.

Mega Joule (LMJ) in France [2] is preferable to the indirect drive approach because the x-ray drive is of high uniformity and easy to be used for other applied and basic researches such as in high energy density physics.

Physics of laser fusion involves very complicated physical processes, in particular for the indirect drive approach including the hohlraum physics and capsule physics. The hohlraum physics includes laser propagation and absorption, laser-plasma nonlinear interaction, non-local electron heat conduction, hohlraum plasma dynamics, non-LTE atomic physics, x-ray conversion and radiation transport, and hohlraum radiation field uniformity. The capsule physics includes radiation ablation, drive symmetry and hydrodynamic instability, and ignition physics. These processes with different characteristic length scales and time scales are coupled and compete with each other. Laser fusion is therefore a complicated multi-material, multi-physics (more than one physical process) and high non-LTE issue. It has been realized that computer simulations are useful in better understanding laser fusion physics, in helping the design of experiments and in analyzing the complicated results.

A system of numerical simulation for ICF research has been set up in our institute, which consists of a series of one-dimensional (1D), two-dimensional (2D) and three-dimensional (3D) codes. The 1D code series is relatively all-round in physical modeling and has been used successfully in a variety of applications. In the last decade, much effort has been made to develop 2D and 3D computer simulation codes, forming 2D simulation capability so that the key physics issues on laser fusion can be separately simulated mainly by a LARED code family containing six different 2D (and partially 3D) code series. Our simulation capability for the indirect drive laser fusion and some other applications are illustrated in Fig. 1; while some useful descriptions of the LARED codes are summarized in Table 1. In the LARED codes, LARED-H is a two-dimensional non-LTE radiation hydrodynamic code for laser-target coupling and hohlraum physics modeling. Using the hohlraum radiation drive provided by the LARED-H calculation, we can perform simulations on capsule implosion and other application problems such as hydrodynamic instability, radiation flux, opacity, equation of state (EOS), and so on. The capsule implosion process is simulated by both LARED-I and LARED-D which are two-dimensional radi-