§ 15. Computer Tools for Simulation of Plasma Dynamics

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We review some recently developed computer codes intended for simulation of aspects of plasma dynamics. These codes provide new technology for research at NIFS.

Today these are independent subroutine packages (sometimes used together, as described below), but they employ consistent models and notations, so they can easily be combined for future applications to plasma simulation. Each subroutine has clearly identified input and output variables, expressed in generally consistent units. (The units selected include eV for temperature, photon energy and for atomic processes, cm for distances, MKS units for electromagnetic fields, and Joules/gram for energy densities.)

Ionization and equation of state. We have written a new Saha equation code, which forms all thermodynamic quantities (pressure, energy, entropy) and their derivatives, including the adiabatic sound speed. The code includes the effects of negative ions. It has been used for gold and hydrogen in various applications.

Maxwell equation solver. We have written a subroutine which calculates the refraction and absorption of s- and p-polarized electromagnetic waves interacting with planar targets. This subroutine can be used to predict laser energy deposition. The subroutines also calculate phase-shifts used to interpret laser ellipsometry experiments.

Analytic hydrodynamics. We use the Riemann solution of one-dimensional self-similar foil expansion to model short-pulse laser-heated targets. This solution has been extended to include non-ideal equation of state taken from the Saha subroutine.

Numerical hydrodynamics. We wrote a simple planar hydrodynamic code and tested it using results from the analytic solution.

Electron thermal conduction. A previously written code calculates electron heat conduction, using an implicit finite-difference method.

Plasma dielectric function. We improved a subroutine (based on previous published formulas) to model high-frequency electrical conductivity of laser-heated metals. We include various condensed-matter effects for hot metals (including melting and boiling).

Semiclassical atomic model. We have a code which provides approximate atomic data for high-charge ions. This code can be used as an average-atom (AA) thermal-equilibrium (LTE) code for opacity and equation of state, and can also provide LTE data on specific ion charge states by solution of the Saha equation. The code is based on a relativistic semiclassical (RWKB) approximation for solutions of the Dirac equation in a self-consistent field.

Particle dynamics. We have written a code which solves Newton's equations for an electron or ion in a specified electromagnetic field. Combined with Monte Carlo sampling, this enables us to study kinetic processes.

We can list some recent applications:

(1.) <u>Pellet ablation</u>. We are performing a hydrodynamic simulation of hydrogen ice-pellet ablation at conditions of LHD pellet fueling experiments. The purpose is to explain recently observed hydrogen spectra showing time-dependent Inglis-Teller limit (M. Goto et al., unpublished).
(2.) <u>Short-pulse laser interaction</u>. We have analyzed USP laser experiments performed at the University of Electro-communication (with H. Yoneda et al.).
(3.) <u>X-ray line source</u>. We analyzed a novel X-ray line source developed at the Korean Basic Science Institute and succeeded to reproduce the main behavior of this device. (S.-G. Lee et al.)
(4.) <u>Anomalous recombination in magnetic fields</u>. We recently made first calculations to explore the possibility of inverse motional Stark ionization, and to see if such an effect can explain anomalous recombination phenomenon observed in experiments performed on a European Storage-ring.

Whatever the results of these individual applications, it is important that the codes are compared to experimental data from various types of real plasmas.