§16. Computer Tools for Simulation of Plasma Dynamics

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We maintan several computer codes intended for simulation of plasma dynamics. These codes provide useful basic technology for research at NIFS.

The codes employ consistent models and notations, so they can easily be combined for future applications to plasma simulation.

Ionization and equation of state. Our Saha equation code is used to predict equilibrium plasma thermodynamic properties, such as pressure, energy, entropy and their derivatives, including the adiabatic sound speed. The code includes effects of molecules and/or negative ions. The unique new feature of this code is a representation of ion excited states which can include the effect of millions of excited states, including multiply-excited ions. The code generates absorption and emission opacities. We have used the code for gold, tin, xenon, tungsten and hydrogen in various applications.

Maxwell equation solver. This code calculates interaction of electromagnetic waves with planar targets including reflection, refraction and absorption of s- and p-polarized laser beams. The code can be used to predict energy deposition, and also calculates the phase-shifts used to interpret laser ellipsometry experiments. It is being used to interpret ultra-short-pulse laser experiments on various target materials including Au, Sn, Fe, Mo, W, etc.

Plasma dielectric function. We improved a code (based on previously published formulas) to model high-frequency dielectric function of hot matter. We include atomic polarizability, various condensed-matter effects for hot metals (including melting and boiling), and we modify the result as needed to agree with experiments.

Numerical hydrodynamics. A new planar hydrodynamic code has been tested against results from analytic hydrodynamics, as well as various experiments.

Analytic hydrodynamics. We also can use the Riemann solution of one-dimensional self-similar foil expansion to model the hydrodynamic behavior of laser-heated targets. This method has been extended to include non-ideal equation of state including ionization and recombination.

Electron thermal conduction. We calculate electron heat conduction using an implicit finite-difference method. Thermal conductivity coefficients come from a general-purpose model.

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

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

We list some recent applications:

(1) <u>Pellet ablation.</u> We are performing a hydrodynamic simulation of hydrogen ice-pellet 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.). Some results from this work were published in [1].

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

Reference

[1.] H. Yoneda, H. Morikami, K. Ueda and R. More, Physical Review Letters 91, 075004 (2003).