A HIGH-ORDER SCHEME FOR COLLISIONAL-RADIATIVE AND NON-EQUILIBRIUM PLASMA

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In this paper we describe a new 3rd-order algorithm for solving the transport equations of plasma in highly non-equilibrium conditions. The plasma is described as a two-temperature, single fluid with the kinetics of collisional and radiative excitation and ionization, and reverse processes. This Collisional-Radiative model is currently limited to atomic plasma and does not include radiative transport. We describe in detail some special techniques for level grouping, scale separation of slow (transported) and fast (quasi-steady-state) level kinetics, and a non-linear transformation of the transported equations of the electronic levels to achieve the desired accuracy. The implementation and testing of the various coupling and relaxation processes are described. The fluid transport is computed using a 3rd-order variant of the MP5 monotonicity-preserving upwind advection scheme [1]. The code is implemented in Java and parallelized through domain decomposition and hierarchical multi-threading; approach and performance are also briefly discussed. The numerical model is validated on various standard test cases, and applied to the simulation of ionizing shock front propagation in Argon. This problem shows a high sensitivity to the kinetics ladder of ionization and population of the excited states, leading to fluctuations of the location of the electron avalanche at the end of the induction zone behind the shock. We show that the collisional-radiative kinetics can reproduce the corrugations of the shock front observed in the experiment. The planned extension of the model to MHD and molecular plasma is also briefly discussed, as well as the application to other plasma conditions of interest.

1. A. Suresh and H.T. Huynh, "Accurate Monotonicity-Preserving Schemes with Runge-Kutta Time Stepping", *J. Comput. Phys.*, **136**, 1997, pp. 83-99.
2. I. I. Glass and W. S. Liu, "Effects of Hydrogen Impurities on Shock Structure and Stability in Ionizing Monatomic Gases", *J. Fluid Mech.*, **84**, 1978, pp. 55–77.