§29. Development of High Speed Calculation Method of Collisional-Radiative Model in Plasmas

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Extensive studies based on the collisional-radiative model have been recently focused on the recombining plasmas, which undergo a quite rapid transition from the ionizing phase due to rapid cooling of the plasmas, to develop the x-ray laser. Generally, an impractiably long time is needed for numerical calculation to solve simultaneously the rate equation describing the temporal evolution of each excited-level population, the energy equations and the charge neutrality equation for high density plasma changing rapidly in their states. We call this the full-level calculation. In a previous paper, we proposed a modification of the quasi-steady state (QSS) approximation which neglects time derivatives of the excited-level populations above a certain level *m*.[1] We also developed a fast calculation procedure in that a set of linear equations was derived from a nonlinear equation with respect to the electron density, stemmed from the charge conservation and rate equation for the excited levels above the certain level.

In the present study, we apply our modified QSS approximation to a laser-produced hydrogen plasma in which the ionization process is developed quite rapidly and brought into the recombining phase. Numerical calculations are carried out for a hydrogen plasma in the initial electron temperature of 1 eV and density of 5×10^{14} cm^{-3}, which is heated by laser with pulse width of 10^{-8} s and with power of 10^5 W/cm^2. Three kinds of calculation scheme are performed: the full-level calculation, our modified QSS and the usual QSS approximations. An improvement is also made by using the higher order implicit difference method in calculation of the various rate coefficients and their derivatives with respect to the electron temperature at every step of integration of our equations. The plasma is rapidly heated up to 20 eV from 0.1 to 1 ns. Figure 1 shows a calculated example by the modified QSS approximation for the corresponding temporal evolution of the electron density and the level populations.

Relative error with respect to the full-level calculation is estimated to be 1.5 % at the largest. On the other hand, relative error by the usual QSS approximation amounts to 3000 % in the ionizing phase. The computational time for the modified QSS approximation is reduced by two orders of magnitudes compared with the full-level calculation.

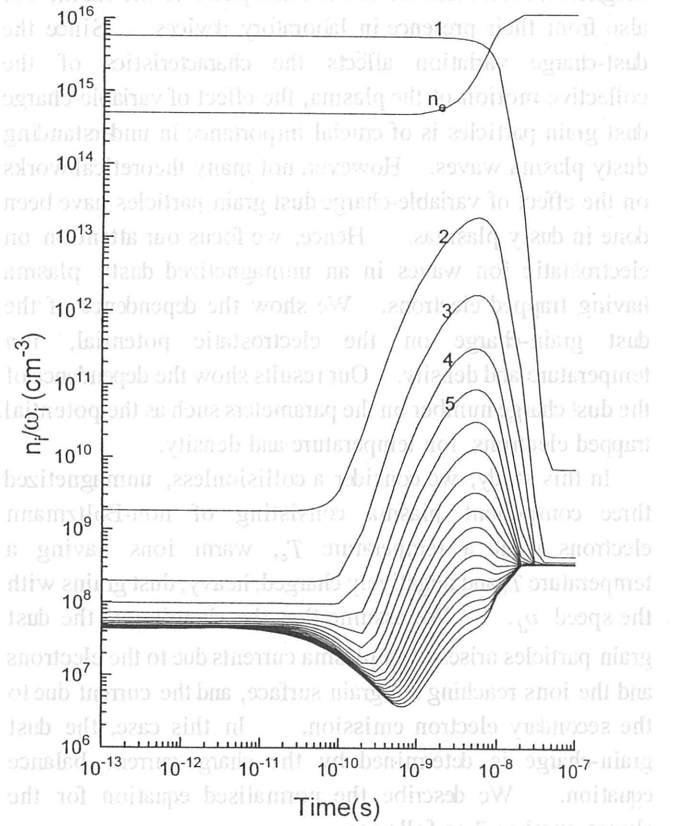

Fig.1. Temporal evolution of the level populations of hydrogen atoms in laser-heated plasma.

Reference

1) U. Furukane and T. Oda: Jpn.J.Appl.Phys. **36** (1997) Pt I pp.840-846.