§17. The Composition History of Non-equilibrium Plasma: Rate Equations vs. Time-Dependent Equilibria

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One of the most reliable methods for the determination of nonequilibrium-plasma parameters is based on comparison of time-dependent spectral line intensities with predictions of detailed kinetic models. Here we report on results obtained with our newly developed time-dependent collisional-radiative code designed for studying the behavior of nonequilibrium both Maxwellian and non-Maxwellian plasmas. Calculations are performed for a neon plasma with account of all charge states (total of 101 terms, mainly for high-charge-state ions).

The kinetic processes under consideration are ionization, excitation and deexcitation by electron impact, spontaneous radiative transition, photo-recombination, and three-body recombination. In order to enable calculations with arbitrary electron distribution functions we use energy-dependent cross-sections to obtain the rates of collisional processes. Most of relevant data on electron-ion collisions were taken from the NIFS Atomic Database or calculated with the "ATOM" code by L.A.Vainshtein.

In many cases where plasmas with time-varying electron density and temperature are modelled it is assumed that at each instant the plasma is in equilibrium that can be collisional-radiative (CRE), coronal (CE) or local thermodynamical (LTE). Here, we present results for fully time-dependent calculations, as given for example, in Figure 1, where the population ratio (1s2p ^{3}P)/(1s2p ^{1}P) for He-like Ne IX is presented. This ratio is calculated for ion density N_i=10^{19} cm^{-3} and triangular profile of temperature: linear increase from 5 eV at t = 0 to 1 keV at 10 ns, and then linear decrease to 5 eV at 20 ns.

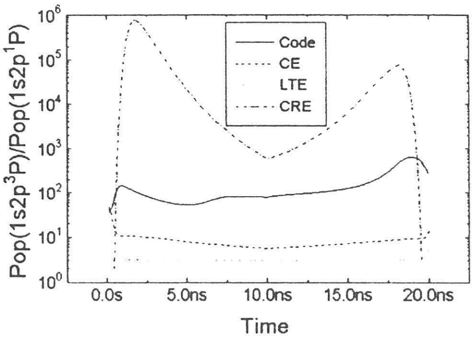

Fig. 1.

The ratio presented in Figure 2 is calculated for a linear rise in N_i from $5\cdot 10^{19}$ at t = 0 to $2\cdot 10^{20}$ cm^{-3} at 0.5 ns followed by a linear decrease to $5\cdot 10^{19}$ cm^{-3} at t = 1 ns. A similar triangular profile of the temperature with 100 eV at t = 0 and T_e = 500 eV at maximum (0.5 ns) has been taken. This model can be relevant to formation of hot and dense plasmas.

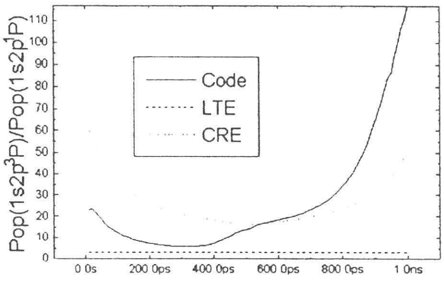

Fig. 2.

One can see that the ratio of populations obtained with rate equations and with various equilibrium models may differ by a few orders of magnitude. Plasma parameters derived from these ratios will also differ significantly.