§14. Comparison of Calculated and Measured Gain of X-ray Lasers

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We have investigated the atomic data and atomic model required for the development and optimization of efficient short wavelength x-ray lasers using the recombination, electron collisional excitation, and x-ray photopump scheme.

In the electron collsional excitation scheme, high gain is obtained using small pump energies for the 4d-4p transition within a wavelength range between 50Å and 200Å. To obtain lasing, a solid target is irradiated by an intense laser pulse to produce high temperature plasma where the target atom is ionized to Ni-like stage and excited to the lasing level. The atomic model must include the detailed atomic structure of complex multiple charged ions among wide range of charge state[1].

In the Ni-like ions, the electron collisional excitation from $3d^{10}$ ground state to low lying one electron excited states which belong to $3d^9 4p$, $3d^9 4d$, $3d^9 4f$ configurations are the most important for the determination of the soft x-ray gain. These configurations should be considered level-by-level. Calculation of detailed jj-level structure can be carried out by various atomic physics codes. The codes using the Multi-Configuration Dirac Fock method such as Grasp[2] and Kim-Declaux can calculate energy levels with an error of less than 1% even for levels for which both electron correlation and relativistic effect are significant as $3d^9 4p$. The code based on the parametric potential method such as HULLAC[3] calculates energy levels less accurately but with still sufficient accuracy for most of applications by the use of configuration interaction (CI).

These codes also provide rate coefficients of radiative decay, collisional excitation and deexcitation, collisional ionization and three body recomibination, radiative recombination. To develop a good collisonal radiative model, not only accuracy of the each rate coefficient, but completeness of the set of the rate and consistency between them are necessary. In complex ions, many autoionizing levels exist above the ionization limit. By calculating autoionization rate for these levels, effect of dielectronic recombination, excitation autoionization, resonant excitation and other processes should be included. Although calculations based on the distorted wave(DW) methods provide large number of data quickly, quantitatively there are still considerable uncertainties of the rate coefficients, mainly due to inability of experimental verifications. Comparison between calculated collisional excitation rates from HULLAC with those from Zhang[4] and Berrington[5] for simpler Be-like Ne shows good agreement for major cross sections. Evaluation of rates for higher-Z elements by comparison with existing database and EBIT experiments are in preparation.

Although M-shell and N-shell ions other than Ni-like ion with multiple open shells have significant population which has strong impacts on the calculation average charge, they have too complex level structure which require averaging technique before included in the collisional radiative model. We combine the detailed atomic model constructed from HULLAC and other atomic data code calculations, and a simplified in-line atomic model based on the screened hydrogenic model[6]. With proper choice of screening constant, the model can predict nl-dependent energy level with an error of less than 15%. To improve the accuracy of calculated population with this model, we found that inclusion of large statistical weight of excited states of M-shell and N-shell ions, as well as improvement of oscillator strength to calculate collsional and radiative rates by considering Z-dependence and effect of number of equivalent electrons are necessary.

The atomic model developed in this study is being used to design efficient transient collisional x-ray lasers using thin foil targets irradiated by two short laser pulses[7].

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