§16. Comparison of Calculated and Measured Gain of Li-like Recombination X-ray Lasers

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Soft x-ray gain of 4f-3d(154Å) and 5f-3d (106Å) transition of Li-like Al in laser produced plasmas are determined by combined effect of hydrodynamics and atomic kinetics in the recombining plasma. In the present study, firstly, we have calculated temporal evolution of temperature and density of the laser produced plasma. Secondly, we have calculated dynamics of level population and soft x-ray gain using a detailed model of Li-like Al. Finally, we have compared calculated and measured gain to find importance of recombination process from excited states of Li-like Al.

The comparison were carried out for Al-plasma produced by irradiating Al slab target by 16 laser pulses. The wavelength of the laser was 1.053μm, pulse duration was 80ps(FWHM), separated by 100ps. Peak intensity on the target was $1.5x10^{12}W/cm^2$.

Calculation of hydrodynamics were carried out using a 2D laser plasma hydrodynamics code using CIP method[1,2]. It was found that in the case of multiple pulse irradiation, most of the energy of the laser pulses after the second were absorbed in the middle of the blow off plasma produced by the first pulse. Inward pressure gradient was created from the absorption region to suppress the expansion. After 2 to 4ns from the beginning of the laser pulse, when soft x-ray gain was present, it was found that the density profile was rather flat from 400μm to 1mm from the target surface. The electron density and temperature were found to be 5-30eV, and 10^{19} $1/cm^3$, respectively.

Improved atomic kinetics code[2] using a collisional radiative model of Li-like Al was developed to include the effect of recombination from excited states of Li-like ions. During expansion cooling of laser produced plasmas, a He-like Al ion recombines into highly excited states of Li-like ion. Li-like ions in these levels may relax to the ground state($1s^2 2s$) through collisional and radiative processes. However in higher density, they may also capture an electron to form double excited states of Be-like ion. Even these levels could emit satellite lines of He-like resonance lines to relax to the Be-like ground state or come back to Li-like ion stage via autoionization, those states for which collisional excitation and deexcitation were faster than radiative transition and autoionization, their population should be in LTE with Li-like single exited states. Loss of population of Li-like excited states through this process depends on principal quantum number of the levels and density and temperature of the plasma.

In the previous experiments[4], similar gain was measured both for 3d-4f and 3d-5f transition of Li-like Al, whereas calculated gain was 10 times greater for the former transition. It was found that in the present condition, recombination from excited states of Li-like stage preferably reduced the population of lower levels (4f), and the difference of calculated gain of 3d-4f and 3d-5f was reduced.

Recombination from excited states and its inverse process have importance in other recombination and collisional x-ray lasers. In the Ni-like collisional x-ray lasers, excited states of Ni-like ions are considered to be LTE with highly double excited states of Cu-like. Their population may be connected to triple excited states of Zn-like ions, hereafter. Multiple excited ions around Ni-like ions were experimentally evident in typical x-ray laser plasmas, and the present kinetics should be included into the model of those systems.

References
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