§29. Study of Ni-like Ta Collisional X-ray Laser

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Amplification of the 4.483nm laser line has been demonstrated [1] in the Ni-like Ta plasma produced by a $500ps$ pulsed 0.53 μm laser. Using the matrix-block method [2] to solve the numerous Coupled Rate Equations (**CRE**) in a Ta plasma, we present the effect of velocity gradient on gain of the 4.483nm line when the reabsorption of resonance lines is considered and discuss the effect of Autoionzation and Dielectronic capture (**A&C**) on the fractional population of Ni-like Ta ions in this paper.

The plasmas created by a ns pulse laser usually evolve on a time scale much longer than that for atomic processes, and the Steady State (**SS**) is therefore a good model. Hence, we solve the **CRE** in the **SS** in this paper. In the **SS** , the distribution of ions and the population of levels are functions of N_e and T_e only.

The model includes singly- excited states up to principal number $n = 10$ and doubly- excited states up to $n = 5$ for all ions except detailed levels in $n = 4$ of a Ni-like ions. There are 1409 states in total in our model.

When the reabsorption of resonance lines by the escape-factor method is considered, gain in the **SS** is a function of ρ_e as well as N_e, T_e and T_i. Here, T_i is the ion temperature and ρ_e is the escape-factor of the resonance line emitted from the lower laser level. If we use only the doppler width to calculate ρ_e and assumes that the velocity gradient is known and $T_i = 0.5T_e$, then the gain is only a function of N_e and T_e. In Fig.1, we present contour lines of the 4.483nm laser line gain in plasmas with velocity gradients of $10^9/s$ and $10^{10}/s$ respectively. Roughly, velocity gradient is about $10^9/s$ in the plasmas pumped by a ns pulse laser, and $10^{10}/s$ when pumped by a 100ps pulse laser. As is shown, the maximum gain decreases remarkably and the optimum region for gain obviously moves to the low N_e region in the plasmas with the lower velocity gradient of $10^9/s$.

The critical N_e is $4 \times 10^{21} cm^{-3}$ when plasmas are pumped by a $0.53\mu m$ laser. If we choose a gain $g > 5cm^{-1}$ for a velocity gradient of $10^9/s$, then the optimum region for gain is $8 \times 10^{20} cm^{-3} \leq N_e \leq 4 \times 10^{21} cm^{-3}$ and $1kev \leq T_e \leq 3kev$ as can be seen in Fig.1. This result agrees with Ref.1.

In Fig.2, we show contour lines of the fractional population of Ni-like Ta ions P_g^{28} in **SS** in the N_e/T_e plane when **A&C** are included in the **CRE** and are not included, respectively. As is shown, there is a remarkable decrease in the ionization of Ta plasmas in the optimum region for gain of the 4.483nm line when **A&C** are included.

In our model, only **A&C** between ground states $(m-1, g)$ and doubly-excited states (m, k) of all ions are included in the **CRE**, while those between singly-excited states $(m-1, i)$ and doubly-excited states are neglected. As presented in Ref.3, Resonance Excitation processes (**RE**) from the ground state of Ni-like Ta ions influence the population of the two laser levels relative to the ground state, and further influence gain. But in Ref.3, only resonance -excitation processes to n=4 and 5 of Ni-like Ta was taken into account, while that of all other ions was neglected. The neglected processes can seriously influence the population of all ions and the gain region. Moreover, the **RE** magnifies the effect of **A&C** on the inversion because it neglects resonance de-excitation and the processes of collisional excitation and de-excitation in the Auger branching ratio.

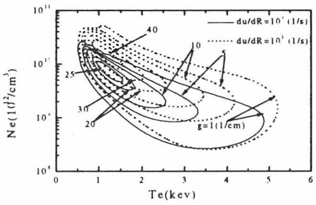

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Figure 1. Contour lines of the gain g for a 4.483nm laser line in a Ni-like Ta collisional x-ray laser, obtained in **SS** by considering the reabsorption of resonance lines using the escape-factor method. The velocity gradients are $10^9/s$ (dotted lines) and $10^{10}/s$ (solid lines), respectively.

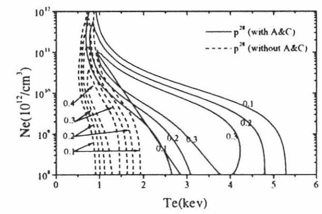

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Figure 2. Contour lines of the fractional population of Ni-like Ta ions P_g^{28} in **SS**, with (solid lines) and without (dotted lines) **A&C** in the **CRE**, respectively.

References

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