§ 11. Population Inversion in Non-Equilibrium TPD Plasma by Cluster Injection

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X-ray lasers have been studied extensively for a variety of applications such as chemistry, bioscience and medical science. Recombination scheme is considered to be one of the candidates to demonstrate the x-ray lasers, in which rapid plasma cooling plays an important role to produce the inverted population [1]. Since population inversions between excited states in an ionized helium due to gas contact cooling was found in TPD plasma[2], the population mechanism in non-equilibrium plasma and required conditions for lasing have been studied experimentally and theoretically[3][4]. However, gain coefficient between lasing transition was not enough high to realize the x-ray laser. In order to increase the inverted population density in non-equilibrium plasma due to gas contact cooling, we have adopted a method to inject cluster target into plasma locally. Since the cluster density is the same order of magnitude as that of solid states, it is expected that the plasma electrons quickly lose the kinetic energy through an elastic and in elastic collision with cluster and recombine with ions through a three-body collisional recombination.

The cluster source consists of source chamber with a pulse valve and a skimmer, and target chamber with a detector. By using high pressure jets, clusters can be formed as the flowing gas expands into vacuum. When the gas is sufficiently cooled, the Van der Waals forces create the solid cluster in the gas jets. Laval nozzle with the throat of 0.2mmϕ was used in order to efficiently create high density and large size cluster. The spatial density distributions of gas jets (argon, helium and mixture of helium 30%-argon 70%) were measured with a fast ionization gauge, which was located at 30cm from the nozzle exit.

Fig. 1 shows the normalized spatial distributions of the expanded gases at the nozzle stagnation pressure 16atm. Valve opening time was set to be 0.6ms, so that we could assume that the behavior of pulsed beam was described by that of the continuum flow. According to Hagena empirical law, the average number of atoms within cluster is $\sim 10^4$ for the argon. In contrast to the argon, no cluster was produced in helium beam, because the Van der Waals force was weak. In the case of helium injection, the homogeneous distribution was obtained. On the other hand, for the argon injection, the collimated beam with FWHM of ~30mm was produced. Generally, as the cluster tends to be collected on the beam axis [6], the obtained result can be considered to reflect the cluster distribution. Moreover, for mixture gas, slightly narrower distribution with spread angle of 4° was obtained. Since helium acted as carrier gas and cooled the argon atom, this method was useful to increase the clustering efficiency. In order to create the larger cluster, the optimization of the partial pressure of helium and argon has to be performed.

By using the cluster source developed in the present study, we will attempt to increase the inverted population density between the excited states (n=2-3 transition) of ionized helium ions (lasing wavelength; 164nm).

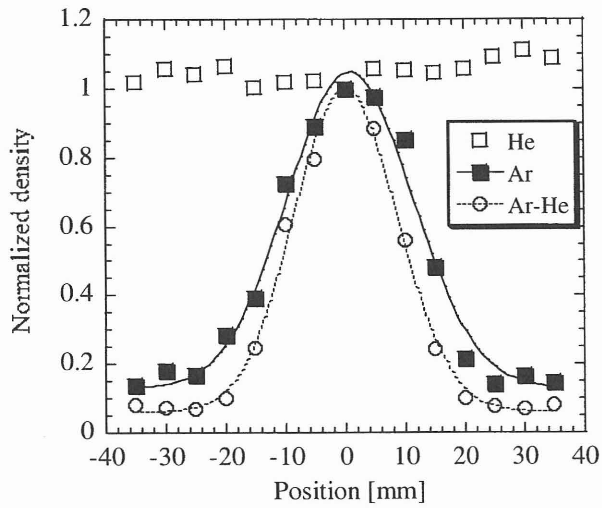

Fig. 1. Density distributions of expanded jets at 30cm downstream from nozzle exit.

References

[1] Elton, R.C., X-RAY LASERS (Academic Press 1990).
[2] Sato, K, et al., Phys. Rev. Lett. **39**, 1074 (1977).
[3] Otsuka, M., et al., J. Quant. Spectrosc. Radiat. Transf. **21**, 41 (1979).
[4] Furukane, U., et al.,J. Phys. D **22**, 390 (1989).
[5] Hagena, O.F. et al. J. Chem. Phys. **56**, 1793 (1972).
[6] Hayes, J.M., Chem. Rev. **87**, 745 (1987).