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Lithium-like aluminum ion recombination plasma X-ray laser at 15.5 nm

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X-ray laser is applied to many scientific and engineering fields such as X-ray microscope, X-ray photoelectron spectroscopy, X-ray lithography, and X-ray holography. Because the plasma-excited X-ray laser is driven by the stimulated emission phenomenon of multiply-charged ions in laser generated plasmas, a driver laser system with an extremely high output energy was necessary. Therefore, the development of a compact and high-repetition X-ray laser, which can be operated and maintained even in a university laboratory, has been carried out. As major lasing scheme of the X-ray laser, there are two methods, that is, transient collisional excitation scheme and recombination plasma scheme.

In the recombination plasma scheme that we focus on, a relatively light element is ionized by laser irradiation onto the metal or gas target and high-temperature and high-density plasma is generated. When the hot, dense plasma is rapidly cooled due to an adiabatic expansion, a non-equilibrium plasma is created, where a three-body recombination process dominate over the other processes. Subsequently, the electron captured into highly-excited states are subjected to collisional deexcitation, resulting in the transition into lower states. Consequently, a population inversion between lower levels is generated.

The groups of RIKEN and Toyoda Institute of Technology have adopted the recombination plasma scheme and observed the soft X-ray amplification (Li-like Al 3d-4f, 15.5nm) in a high-density Al plasma generated by 16 pulse trains of Nd:YAG laser system. In this study, the similar recombination plasma scheme was employed and lasing experiments were conducted for optimization of laser oscillation on Li-like Al soft X-ray laser.

The pumping laser system was a compact Nd:YAG laser (pulse width: 10 ps or 100 ps, pulse interval: 200 ps, total output energy: 2 J for 10 ps laser, 3 J for 100-ps laser, 16 pulse trains), line focusing onto the Al target by a prism array. The laser intensity was 3×10^{11}~1×10^{12} W/cm^2 (focusing size: 0.05 mm×11 mm). Soft X-rays from the laser plasma was measured by a grazing incident spectrometer with a flat field grating.

Figure 1 shows the gain coefficient estimated by the 100-ps laser pulse trains (lasing transition: Li-like 3d-4f 15.5 nm). The gain coefficients are g=8.6 cm^{-1} and 5.5 cm^{-1} , which is much higher than the value obtained by the previous experiment (g~3.2) [1,2].

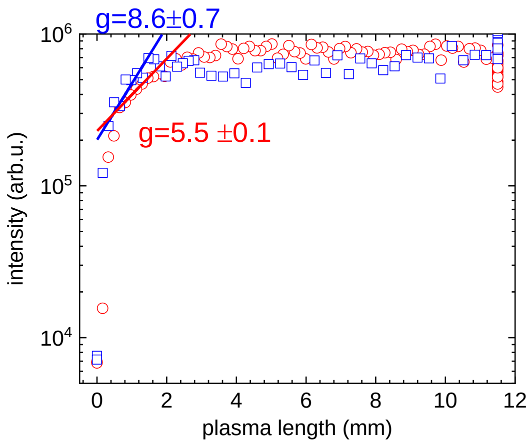

Figure 1: Gain coefficients by using 100 ps seed pulse. Total energy (16-pulse train) was ~3 J.

Also, we measured the gain coefficient for 10-ps laser pulse train. The optimal laser pulse duration will be discussed in detail.

References

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