Demonstration of 122-nm VUV laser by means of a transient collisional excitation scheme

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In fast breeder nuclear reactor, liquid sodium is employed because of less interaction with neutron and high-thermal conductivity. The accident of sodium leakage from the tube occurred in the fast breeder plant "Monjyu" in 1995. The reason for this was explained by an intense vortices created around a thermocouple installed inside the sodium coolant tube. Thus, it is essential to monitor the sodium flow in tubes. However, since the liquid sodium is opaque to visible and ultraviolet wavelengths, it is hard to observe the sodium flow. Recently, it was found that the liquid sodium is transparent $\lambda \leq 216$ nm ultraviolet (UV) regions, whereas below 40.5 nm the absorption processes (ionization and plasmon excitation) decrease the transparency gradually [1,2]. This transparent wavelength is determined by the extinction coefficient κ of the substance [1]. On the other hand, considering that the radiation above 115 nm can pass through MgF_2 glass, bright vacuum UV (VUV) laser (115 nm$\leq \lambda \leq$216 nm) makes it possible to observe the liquid flow through the MgF_2 windows installed on the sodium coolant pipe. In particular, conventional particle imaging velocimetry (PIV) method by means of the Mie scattering of tracer particles is applicable.

In this study, we have tried to develop a plasma excited VUV laser (lasing wavelength: ~122 nm, pulse width: 10 ps, output energy: >10 μJ) by a Ne-like ion transient collisional excitation (TCE) scheme, which was one of the methods to realize the plasma X-ray lasers. In the experiment, first a nanosecond laser pulse (wavelength: 532 nm or 1064 nm, 7 ns, ~500 mJ) was line focused onto an aluminum slab target, creating significant Al^{3+} ground state ion. Subsequently, a picosecond laser pulse (1064 nm, 10 ps, >300 mJ) further heated the plasma by a grazing incidence pumping geometry (GRIP) [2]. For line focusing, we employed five segmented prism lens arrays [3], by which the line shaped plasma having a hat-top intensity distribution was created. The Al target was mounted on 4 motorized stages, and the laser beam was completely overlapped temporally and spatially. Consequently, the population inversion was generated between Ne-like Al 3s-3p states (wavelength: ~122 nm). Al spectra were measured by a 20-cm VUV spectrometer.

In order to examine optimum plasma conditions for the lasing, first we calculated the spatiotemporal laser plasma behaviors by a radiation hydrodynamic simulation, Star2d code [5]. Next, with use of a population kinetics code, a General-purpose Relativistic Atomic Structure Program (GRASP) [6] was used to calculate atomic level energies and oscillator strengths. With the code, the population densities of Ne-like Al ion relevant to the population inversion were calculated and evaluated the gain coefficient of a 3s-3p transition (~122 nm).

In the presentation, we will describe the details on the results of 122-nm plasma VUV laser oscillation and application to flow analysis by using PIV-LIF (laser induced fluorescence) method.

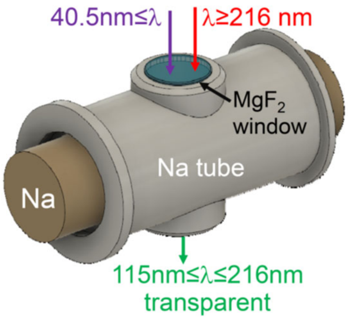

FIG.1 A schematic diagram of the sodium tube installed MgF_2 windows for direct Na observation.

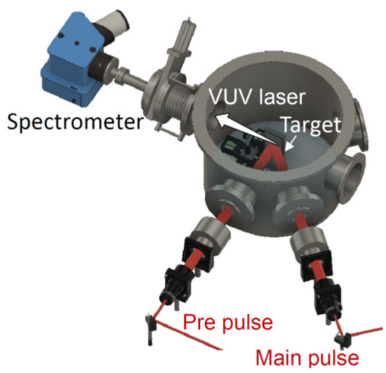

FIG.2 Experimental setup for the VUV laser generated by the TCE plasma scheme (λ~122 nm)

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