§6. Laser-aided Spectroscopic Diagnostics in a Negative Hydrogen Ion Source

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The investigations on the production processes and extraction mechanisms of negative hydrogen ions are still insufficient in cesium-assisted negative hydrogen ion source for NBI heating. We started this research activity from the last academic year with the intention of investigating the behaviors of atomic hydrogen and cesium vapor in the large-scale, arc-discharge negative hydrogen ion source in NIFS. In this academic year, we evaluated the kinetic temperature of atomic hydrogen at the $n = 2$ state by laser absorption spectroscopy at the Balmer-α line.

The light source for absorption spectroscopy was a diode laser (New Focus, Vortex II), which emitted tunable single-mode laser radiation in the wavelength range of the Balmer-α line of atomic hydrogen. The laser beam passed through the plasma in the region close to the grid electrode (the plasma grid) for extracting negative ions. The transmitted laser beam was detected using a photodiode.

Since the magnitude of absorption was too small to be detected by simple absorption geometry because of the low density of the $n = 2$ state, we employed frequency-modulated absorption spectroscopy. In this method, the frequency of the laser beam was modulated in two manners. One was the wide ($\sim$ 100 GHz), slow (1 s) scan with a triangle waveform to measure the absorption spectrum in the entire wavelength range of the Doppler-broadened Balmer-α line. The other frequency modulation had a sinusoidal waveform at a frequency of 600 Hz. The second frequency modulation was superposed on the first modulation. The signal from the photodiode was connected to a lock-in amplifier which amplified the signal component at the second harmonic of the sinusoidal frequency modulation. This method can yield a signal which is similar to the second-order derivative of the absorption line profile with a much higher sensitivity than simple absorption spectroscopy. The kinetic temperature of atomic hydrogen at the $n = 2$ state was derived from the width (Doppler broadening) of the spectrum.

Figure 1 shows the relationship between the kinetic temperature of atomic hydrogen and discharge parameters. The temperature ranged between 2000 and 4000 K. It increased with the discharge power as shown in Figs. 1(a) and 1(c). On the other hand, the temperature of atomic hydrogen decreased with the pressure in the range below $\sim$ 0.8 Pa, and it was roughly constant at pressures higher than $\sim$ 0.8 Pa. The electron density in the observation region decreased significantly by introducing cesium ($n_e/n_- \simeq 0.1$). This resulted in the weaker absorption signal or the lower density of atomic hydrogen at the $n = 2$ state. However, as shown in Fig. 1, the temperature of atomic hydrogen in the observation region was roughly unaffected by the cesium introduction.

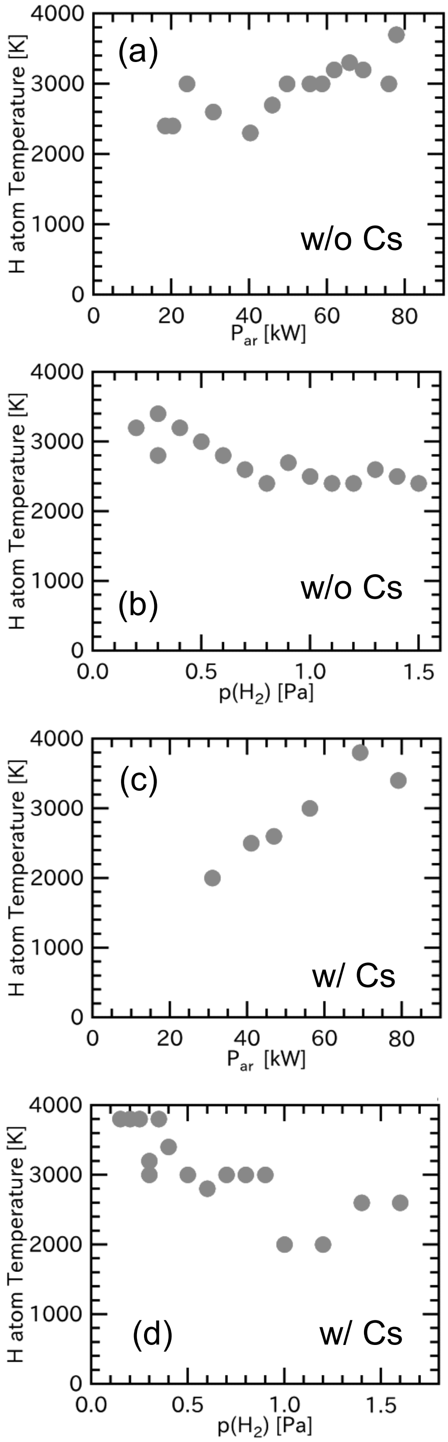

Fig. 1: Relationship between the kinetic temperature of atomic hydrogen at the $n = 2$ state and discharge parameters. Cesium is not introduced in (a) and (b), while plasmas in (c) and (d) include cesium.