§16. Development of Electric Field Measurement with Saturated-Absorption Spectroscopy for Negative-Hydrogen Ion Source

Sasaki, K., Nishiyama, S. (Hokkaido Univ.),
Nakano, H., Goto, M., Tsumori, K., Kisaki, K.

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. In particular, the optimization of the extraction efficiency of negative ions needs the understanding on the structure of the sheath electric field in front of the extraction electrode. It is predicted that the sheath electric field has a unique structure since negative ions are produced from the surface of the cesium layer on the extraction electrode. The objective of the present work is to develop a method for measuring the sheath electric field in the cesium-assisted negative hydrogen ion source.

The principle of the electric field measurement is Stark spectroscopy in the Balmer-α line of atomic hydrogen. Although the Stark effect of the Balmer-α line is insensitive to the electric field in comparison with transitions to Rydberg states, we expect that the Stark spectrum can be measured by saturation spectroscopy with an ultrahigh wavelength resolution. In this year, we examined the Stark spectrum of the Balmer-α line of atomic hydrogen in the sheath region of an inductively-coupled hydrogen plasma.

The light source for saturation spectroscopy was an oscillator-amplifier system of diode lasers. The laser beam was divided into the pump and probe beams, and they were injected into the region close to a planar electrode from the counter directions. The electrode was immersed in the inductively-coupled hydrogen plasma which was produced by an rf power of 1 kW at 13.56 MHz. The electrode was biased at -50 V with respect to the ground potential. The weak absorption was detected with the help of a lock-in amplifier and the pulse-modulation of the rf power. The saturated absorption spectrum was obtained from the difference between the absorption spectra observed with and without the pump beam. The electrode was movable, and we examined the saturated absorption spectra at various distances from the electrode.

Figure 1(a) shows the saturation spectra observed at various distances from the electrode, and Fig. 1(b) shows theoretical spectra of the Balmer-α line of atomic hydrogen in various electric fields. The peaks in the spectrum observed at a distance of 5 mm from the electrode coincide with the peaks in the theoretical spectra in the field-free condition. The additional peaks in the experimental spectrum are explained by the cross-over components. We observed the splits and the shifts of the peaks when we observed the spectra in the closer region to the electrode. The shifts of the peaks illustrated by dotted lines in the experimental spectra (Fig. 1(a)) coincide with those illustrated in the theoretical spectra (Fig. 1(b)). Therefore, it has been shown that the developed system of saturated spectroscopy has a sufficient wavelength resolution for measuring Stark spectra of the Balmer-α line of atomic hydrogen. By comparing the experimental and theoretical spectra, the electron fields at distances of 0.1 and 0.5 mm from the electrode are estimated to be approximately 1 and 0.1 kV/cm, respectively.

Although the developed system has a sufficient wavelength resolution, its sensitivity is insufficient to detect absorption in the negative hydrogen ion source. In the next year, we will develop a method for enhancing the sensitivity of the measurement system.

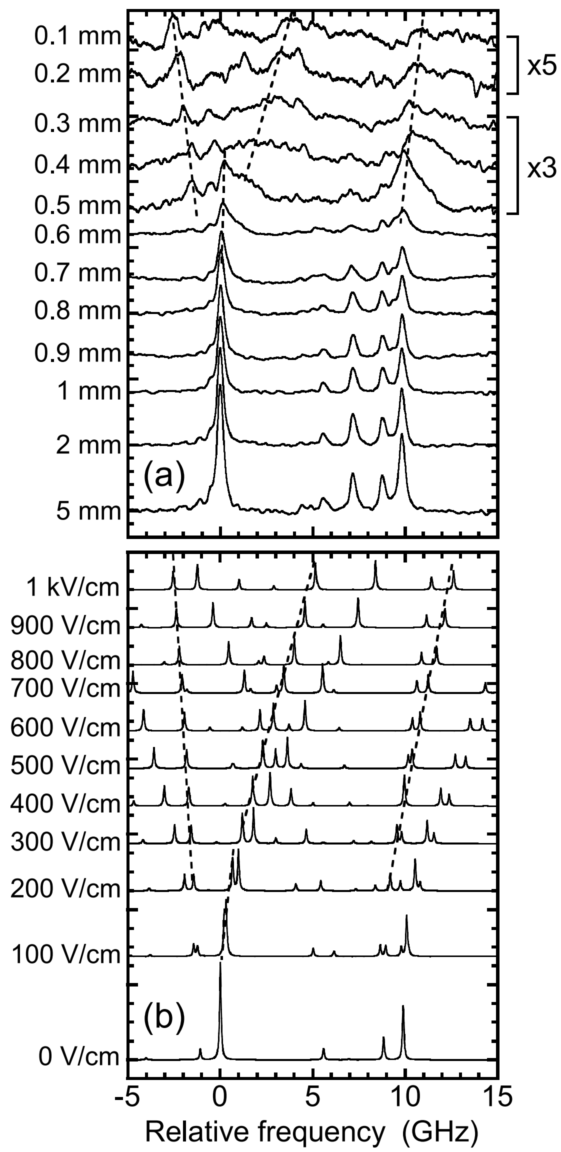

Fig. 1: (a) Experimental saturation spectra observed at various distances from the electrode. (b) Theoretical spectra of the Balmer-α line of atomic hydrogen in various electric fields.