§13. Comparison of OES and CRDS in Large-Scaled Hydrogen Negative-Ion Source for NBI

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Optical emission spectroscopy (OES) and cavity ring-down spectroscopy (CRDS)[1] systems are installed in a 1/3-scaled negative hydrogen-ion source at the National Institute for Fusion Science testbed to investigate the dynamics of H^- ions in the extraction region near the plasma grid. OES is a useful diagnostic method[2] for measuring hydrogen dynamics, Cs consumption, and impurity trend can be simultaneously observed with simple optical components such as an optical ber and spectrometer. The analysis of OES is quite complex because the excited state of the hydrogen population involves numerous processes. With the present plasma parameters near the PG ($T_e < 1$eV), it is di cult to obtain the H^- density from the ratios of Balmer-line intensities solely using OES analysis because dissociative recombination of molecular hydrogen ions signi cantly contributes to the Balmer-line radiation. Therefore the calibration approach is employed in the OES measurement for H^- estimation used in CRDS.

Hydrogen spectra and H^- density in the extraction region were observed during arc discharge with a beam extraction of 1 s. At the extraction region in the arc chamber, the H^- density measured by CRDS grew to 1.6×10^{17}m^{-3} with an applied bias voltage of 0.1 V as shown in Fig 1. The signal of the H^- ion density rapidly drops after beam extraction 1.1×10^{17}m^{-3}. The H^- densities of di erent bias voltages somewhat increased in the same manner as the increasing arc discharge during beam extraction, and the values were nearly the same. The time evolution of H_α emission intensity measured by OES is also shown in Fig. 1. The H_α intensity also increased in the same manner as H^- density by increasing the arc discharge power before beam extraction. Similar signal drops appeared in the low-bias voltage condition during beam extraction. It is caused by decreasing atomic hydrogen produced by mutual neutralization effects between H^- and H^+.

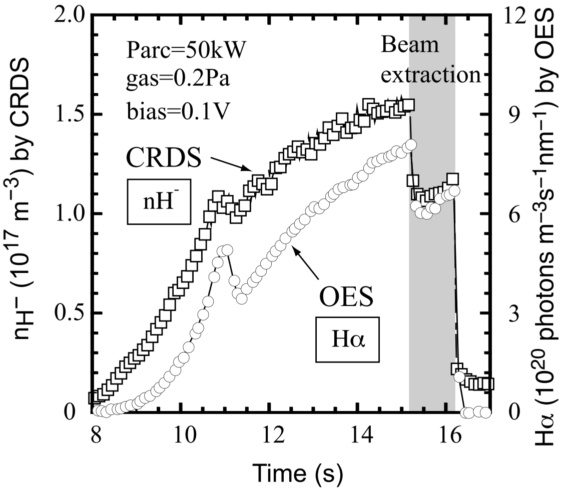

Fig. 1: Time evolution of H^- density measured by CRDS (squares) and H_α emission intensity measured by OES (circles) in arc discharge. Both of which dropped during beam extraction (gray area).

Shot trend of the beam currents are similar to the H^- density and H_α/H_β in the extraction region, which increases twice as large immediately after Cs seeding with an oven temperature of 160 °C. The H^- density doubled in size without beam extraction, and a similar increase was observed in the H_α/H_β line ratio. The beam currents and H^- density gradually increased after raising the oven temperature to 185 °C. According to this experiment with constant discharge conditions (arc power, bias voltage, and gas pressure), we observed a linear correlation between the inclination of H_α/H_β by OES and H^- density by CRDS, as shown in Fig. 2. A linear correlation also existed between the H^- beam current and the source H^- density near the PG surface. Thus, H_α/H_β measurement by OES with CRDS calibration can be applied for the estimation of H^- density in the negative-ion source under severe conditions such as a high-energy NBI system in a fusion reactor.

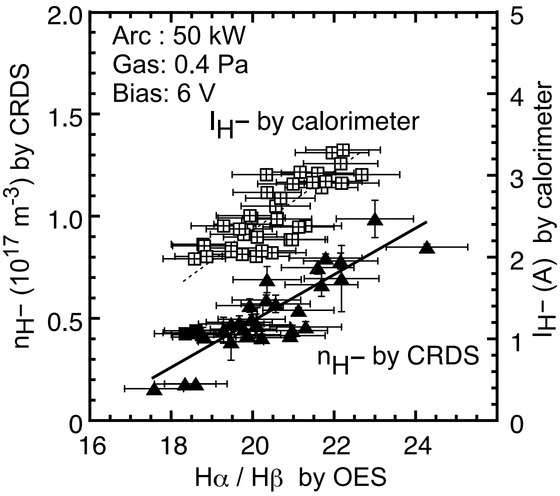

Fig. 2: Correlations of H_α/H_β measured by OES with H^- ion density measured by CRDS in the extraction region and with the H^- beam current measured by the beam calorimeter. The condition of arc discharge is constant with di erent Cs conditions.

1) G. Berden and R. Engeln eds., Cavity Ring-Down Spectroscopy: Techniques and Applications, John Wiley and Sons Ltd., 2009.

2) U. Fantz, et al., Nucl. Fusion, **46**, S297-S306 (2006).