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Comprehensive study of detached recombining plasmas by using a high density linear plasma device

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Reducing the heat load on the divertor plate is one of the most important issues in magnetically confined fusion plasmas. The formation of detached recombining plasma（DRP）in the divertor region is considered to be the most effective method to reduce the heat load. The underlying physics and atomic/molecular processes associated with the detached recombining plasma has been intensively investigated by using a linear plasma device[1].

We used the linear divertor plasma simulator NAGDIS-II (NAGoya university DIverter simulator II) shown in Fig. 1[2]. Typical plasma parameters are an electron density n_e < 10^{20} m^{-3} and an electron temperature T_e < 10 eV. The device is equipped with sophisticated diagnostics including laser Thomson scattering system (LTS), laser absorption spectroscopy (LAS), and axially and radially movable Langmuir probe system (2D probe). The neutral gas pressure in the plasma test region can be controlled by feeding neutral gas, and DRP can be generated at a steady state. Figure 2 shows the photo of the DRP produced in NAGDIS-II. At the upstream near the discharge region, the plasma is in a state of ionizing phase (attached plasma). As the plasma is transported toward the target plate along the magnetic field, the plasma is cooled down due to collision with neutrals, High density and low temperature plasma leads to strong volume recombination in the recombination front region at the downstream, and the plasma disappears in front of the target plate.

The spatial structure and its decay length of the DRP near the recombination front region has been revealed depending on the neutral gas pressure P. Figure 3 shows the distribution of n_e (top) and T_e (bottom) in the direction of the magnetic field line at the plasma center. T_e becomes less than 1 eV downstream, indicating the DRP formation. As P is increased, the region where n_e decreases rapidly (recombination front) is shifted upstream. T_e monotonically decreases from the upstream, and a sharp decrease in n_e starts at the position below T_e ~ 1 eV. This can be explained by the fact that the rate coefficients of radiative and three-body recombination exceed those of ionization at T_e below 1 eV, and the recombination process becomes dominant.

On the other hand, 2D probe measurements indicated that the n_e radial distribution was flattened near the recombination front This is because convective plasma transport across the magnetic field was enhanced near the recombination front, which leads to broadening plasma profile and reversal plasma flow at the peripheral region of plasma column[3-6].

LTS measurements with high temporal resolution have been realized near the recombination front region using the conditional averaging method. The fluctuation phenomenon of n_e and T_e in the DRP has been also clarified[8-9].

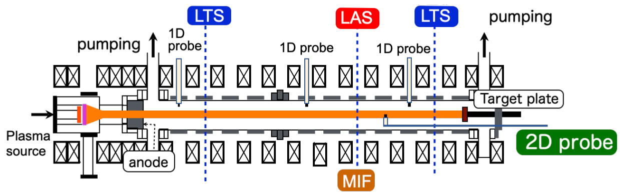

Fig. 1 Schematics of the linear divertor plasma simulator, NAGDIS-II.

Fig. 2 Photo of detached recombining plasma

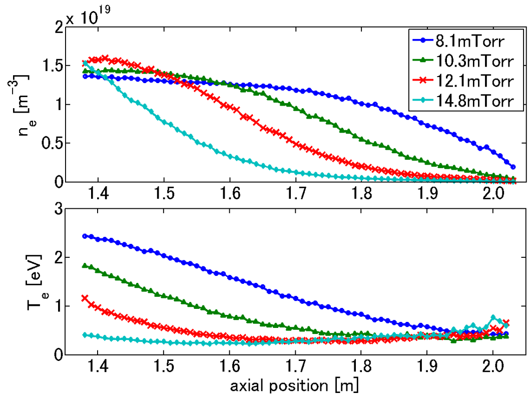

Fig. 3 Axial profiles of electron density and temperature in detached recombining plasma

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