§13. Development of Plasma Diagnostics in Detached Plasmas

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To improve the core plasma performance, it is inevitable to understand the physics in divertor region as well as core plasmas. Plasma detachment is thought of as a method to control particle/heat loads on divertor materials; the measurement of the low temperature recombining plasmas is not so simple. Anomaly is identified in the current voltage characteristics of electrostatic probes, and a special care is required for Thomson scattering, since the temperature is much lower than 1 eV. In this study, based on developments of measurements systems in linear divertor simulators, we progress the understand of the physics of plasma detachment. A laser absorption spectroscopy and a laser Thomson scattering system have been developed to measure the atomic temperature and the electron density and temperature in the divertor simulator NAGDIS-II [1], and a fast framing camera observation was conducted in the TPD-SheetIV device [2].

The wavelength of the ECDL (External Cavity Diode Laser) was tuned at ~1083 nm (HeI: $2^3S \rightarrow 3^3P$). The wavelength was monitored using a wavemeter, and single-mode operation was confirmed using a Fabry-Perot interferometer. Two photo detectors were used to measure the laser beam power with and without the pass through the plasma. Doppler absorption spectra were obtained using the difference between the laser power measured with the two beam paths. First, the absorption spectrum was obtained using a inductively-coupled plasma. The neutral temperature was obtained to be ~330 K from the width of absorption profile. Then, the system was installed to the NAGDIS-II device. Figure1 shows typical absorption spectra in the detached plasma in NAGDIS-II. The atomic temperature was obtained to be 1410 ± 300 K from the width of absorption profile by considering the influence of Zeeman split.

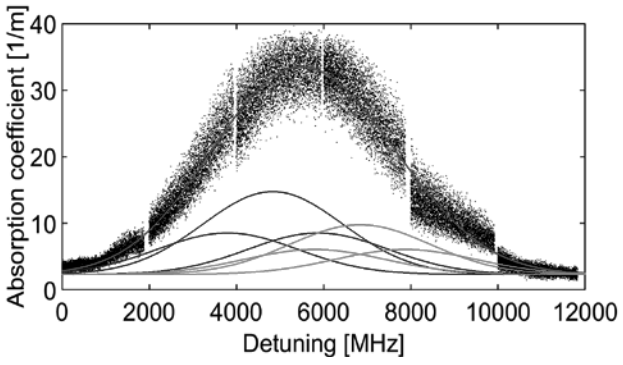

Figure 1: Typical absorption spectra in NAGDIS-II.

We have observed dynamic behaviors of a sheet plasma in TPD-SheetIV with a high-speed camera. A high-speed camera (ULTRA CAM HS-106E : NAC Image Technology, Inc.) was used at a frame rate of 100000 fps. A heat-resistant glass was installed at the end of TPD Sheet-IV to observe the plasma in parallel to the magnetic field.

Figure 2 (a) and (b) shows fast framing camera images of He and Ar mixture plasma and pure He plasma, respectively, observed with the high-speed camera. It is seen in Fig.2(a) that the plasma column moves back and forth horizontally at a frequency of about 4 kHz in He/Ar mixture plasma. However, in case of pure He plasma, the plasma column did not exhibit such a dynamic behavior. In addition, intermittent transport which is similar to plasma blob was observed. The temporal evolution of I_{sat} in the peripheral plasma supported the fact that blob like plasma was released at the same frequency of ~4 kHz.

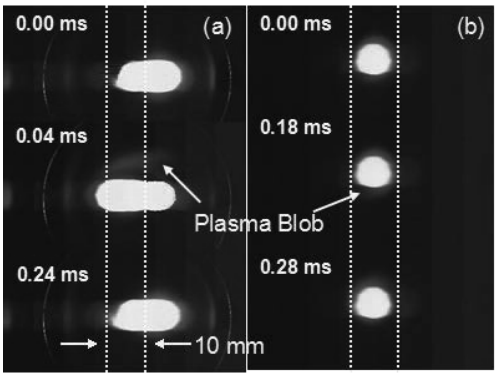

Figure 2: A snapshot of image captured by the high-speed camera:(a)He and Ar plasma (b)He plasma.

Moreover, the laser Thomson scattering system was installed in the divertor simulator NAGDIS-II. A Nd:YAG laser at the wavelength of 532 nm was used for the laser, and an image intensified charge coupled device (ICCD) (Princeton instruments, PIMAX-IV) was used. We obtained the laser Thomson scattering signal in the ionizing plasmas in NAGDIS-II. The temperatures were in the range of 3-4 eV, which was consistent with the electrostatic probe measurement. Also, it was confirmed that the density increased with the discharge current. We plan to apply the developed method in the recombining plasmas.

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1) T. Onda, S. Kajita, A. Tonegawa, T. Iijima, and N. Ohno, "Observation of plasma dynamics in TPD-sheet IV", 25th International Toki Conference (2015)
2) T. Tsujihara, T. Aramaki, S. Kajita, N. Ohno, "Measurement of neutral temperature in detached recombining plasma in NAGDIS-II by laser absorption spectroscopy", ISPlasma2016 (2016).