# §6. Development of Gundestrup-type Directional Langmuir Probe: Ion Flow Measurement in a Hyper-I Plasma

Yoshimura, S., Nakano, H.

Gundestrup probes are used to measure ion flows in edge/divertor plasmas of fusion devices because of the advantage to perform local measurements. We have designed and constructed a Gundestrup-type directional Langmuir probe (GDLP) for the fast scanning probe system of LHD. The head of the GDLP is constructed from boron nitride (BN) and the electrodes are made of isotropic graphite. It has eight openings equally spaced at 45-degree intervals around its circumference, and in each of the openings the negatively-biased electrode collects ion saturation current ($I_{is}$).

We performed a test experiment to measure ion flow velocity in a magnetized helium plasma using the HYPER-I device, where the neutral pressure and the microwave power were 2.5 mTorr and 10 kW, respectively. Figure 1 shows the end-view CCD image of the HYPER-I plasma with the GDLP. An example of the polar diagram of $I_{is}$ measured at the position of $r = 8$ cm from the center is shown in Fig. 2 with the direction of the magnetic field. Here we employed the analyzing method for directional Langmuir probe developed by Nagaoka et al[1] to determine the ion flow velocity. The following equation gives the Mach number ($M$) of the ion flow directing to the angle $\theta_d$,

$$M = \frac{\upsilon \cos(\theta - \theta_d)}{C_s} = \frac{1}{\alpha} \frac{I_{is}(\theta + \pi) - I_{is}(\theta)}{I_{is}(\theta + \pi) + I_{is}(\theta)} \qquad (1)$$

, where $C_s$ is the ion sound speed, $\theta$ the angle of normal of ion collection surface and $\alpha$ the calibration coefficient. Figure 3 shows the result obtained by applying eq. (1) to the data shown in Fig. 2. Downstream ion flow ($M$~0.4) can be seen in this figure. The ion flow perpendicular to the magnetic field ($\theta$= 270 deg.) is also evident, the direction of which corresponded to that of the $E \times B$ drift driven by the convex potential profile presented in the HYPER-I plasma. The total vector of the ion flow in this case is approximately directed to 225 degrees.

Note that there is still an ambiguity which arises from the calibration coefficient $\alpha$ in the eq. (1). In order to calibrate the GDLP, an alternative measurement is needed and the laser induced fluorescence (LIF) spectroscopy system for absolute ion flow velocity measurement is being developed by collaborative research with Kyushu University, Nagoya University and Tohoku University.

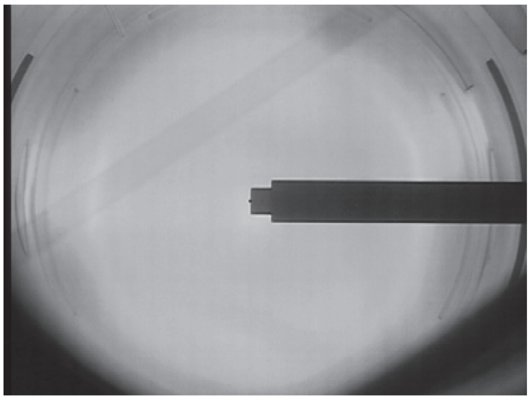

Fig.1 End-view CCD image of the HYPER-I plasma with the GDLP.

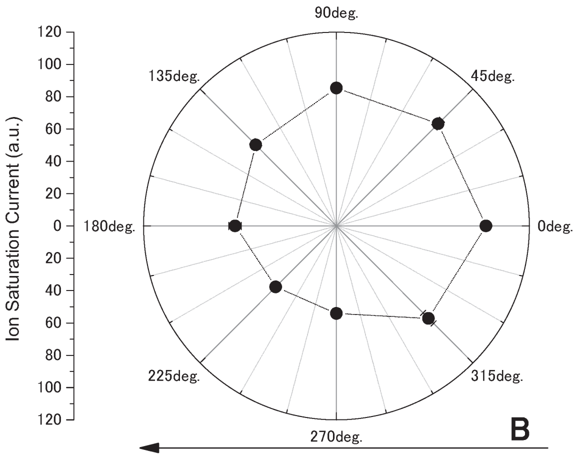


Fig.2 Polar diagram of the ion saturation current measured by the GDLP.

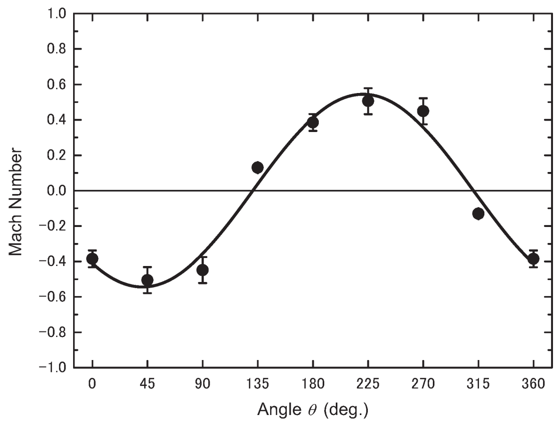


Fig.3 Mach numbers of the ion flow determined by eq. (1), where the calibration coefficient $\alpha$ is 0.5 (conventionally used for HYPER-I plasmas). Downstream ion flow, the Mach number of which is approximately 0.4, can be seen at 180 degrees in the horizontal axis.

1) K. Nagaoka *et al*., J. Phys. Soc. Jpn. **70** (2001) .131.