§4. Precise Toroidal Flow Measurements with Bi-directional Line of Sight

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There is great interest in the driving mechanism of the spontaneous toroidal flow and the momentum transport physics to control the toroidal flow profiles. It has been observed that there are both NBI driven toroidal flow and spontaneously driven toroidal flow due to the steep gradient of T_i in the high T_i discharges on large helical device (LHD). An accuracy of absolute values of the measured toroidal flows should be improved to study the toroidal flow in details.

New system of charge exchange spectroscopy installed for measurement with BL5 as a diagnostic beams. Lines of sight for the system is arranged to acquire the charge exchange signal from BL5 at 9O port with a camera lens and two optical mirrors as show in Fig.1. The toroidal flow component of the plasma flows can be measured with the lines of sight like as the toroidal lines of sight for BL4 which has been used on LHD (7T port in Fig.1). Importance of the new lines of sight for BL5 on the toroidal flow measurement is that the sign of the Doppler-shift by the toroidal flow velocity measured with the new lines of sight is negative to that measured with the toroidal lines of sight for BL4. We can check up the wave-length (λ_0) of charge exchange line of carbon (CVI) without the Doppler-shift by comparing the two values of the toroidal flow velocity is same or not with assuming the toroidal symmetry of the toroidal flow (Fig.2).

Both the channels in the lines of sight for BL5 and for BL4 are acquired with a CCD camera. The CCD detector has 128 x 128 pixels with pixel-pitch of 0.048mm. Although the size of the detector is small but the readout time is fast as the exposure time can be 0.5 msec (2kHz). Because only 12 channels with 400μm core-diameter of a fiber can be used for measurement on the single detector, the new spectrometer system has three detectors to gain the number of channels.

Figure 3 shows the toroidal flow velocity measured with the new CXS system for BL5. The BL4 and BL5 are injected from 5.3sec to 7.3sec. The beams are modulated with frequency of 10Hz (80 msec on / 20 msec off). Signals acquired during the beam off are used for background signal on the CXS analysis. The plasmas are produced with magnetic strength of -2.75T and magnetic axis of 3.6m.

Circles in the Fig.3 show the profiles of the toroidal flow velocity with co-directed tangential beam injection (BL1). The increase of toroidal flow toward the core due to the tangential beam injection can be observed with both lines of sight for BL5(9O) and BL4(7T). Squares in the Fig.3 show the profiles of the toroidal flow velocity without tangential beam injection. Flat profiles of the toroidal flow are observed with both the lines of sights. Scatter of the data measured with BL4 is larger than that with BL5 because the intensity of signals measured with BL4 is weaker than that with BL5 due to smaller aperture of fiber (200μm core-diameter) and transmittance of optics.

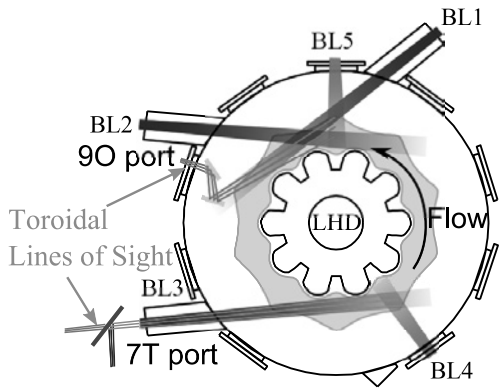

Fig. 1: Toroidal lines of sight for BL5 (9O port) and for BL4 (7T port).

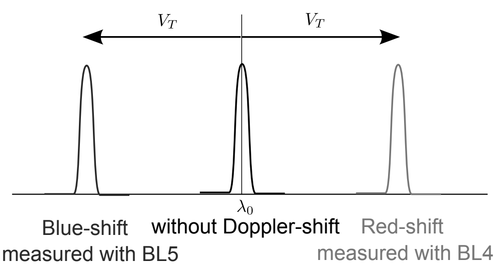

Fig. 2: Value of Doppler-shift is identical with same measured toroidal flow. The direction of the Doppler shift measured with 9O lines of sight for BL5 is opposite to that measured with 7T for BL4.

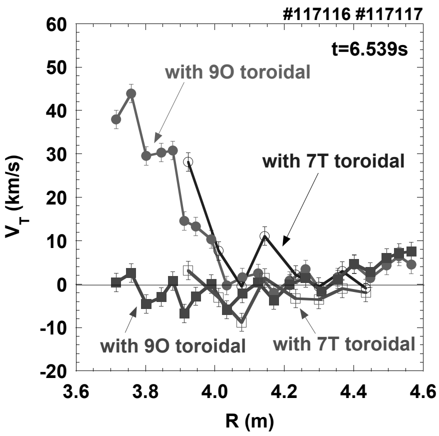

Fig. 3: Profiles of toroidal flow velocity measured with the 9O and 7T lines of sight in the case with (circle) and without (square) tangential beam injection.