§7. Measurements of Rotational Transform Due to Non-inductive Toroidal Current Using Motional Stark Effect Spectroscopy in Large Helical Device

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The change of rotational transform due to the non-inductive plasma current driven by negative neutral beam, which is typically less than 10 % of rotational transform determined by the external current in the helical coils, are measured in the Large Helical Device with Motional Stark Effect (MSE) spectroscopy. Radial profiles of rotational transform are derived from the radial profiles of the polarization angle of the σ component in the H_α line emitted from the high energy hydrogen atom of the beam with four sets of linear polarizers, spectrometers and CCD detectors. The radial profile of the change in rotational transform due to the non-inductive toroidal current driven by the neutral beam is measured[1].

Figure 1 shows the CCD image for the H_α emission emitted from the neutral beam measured with different polarization angle. Each group has four spectra with 0, 45, 90 and 135 degree linear polarizers starting from the top. Clear peaks corresponding to the σ components (which is parallel to the magnetic field) are observed for the spectra with a 0 degree linear polarizer at the top of each group. Two peaks with a separation of 40 –50 pixel are observed for the spectra with the 90 degree linear polarizer at the second line from the top of each group, which correspond to the π component (perpendicular to the magnetic field). The third line and forth line correspond to the spectra with 45 and 135 degree, respectively. These spectra are contributed by both σ components and π component and the contribution depends on the direction of the magnetic field. The spectra with a 45 degree linear polarizer (third line) has a larger contribution from σ components for groups 7 - 13, which indicates that the magnetic field is tilted upward. On the other hand, the spectra with a 135 degree (= -45 degree) linear polarizer (fourth line) has a larger contribution from σ components for groups 17 - 20, which indicates that the magnetic field is tilted to downward.

In order to derive the rotational transform, the equilibrium code VMEC is used. The radial profile of the polarization angle measured is compared with that calculated with a VMEC database with various pressure profile and current profiles. The VMEC data consists of a few hundred equilibria with various total pressure, total toroidal current, and current density profile. Figure 2(a)(b) show the radial profile of the rotational transform in the equilibrium magnetic field which gives the best fit to the polarization angle measured. The total toroidal current measured with a coil is used in this best fit process. Then the central rotational transform depends on the current profile for a given total toroidal current. When the current profile is peaked at the plasma center, the central rotational transform becomes large (small) for the positive (negative) toroidal current.

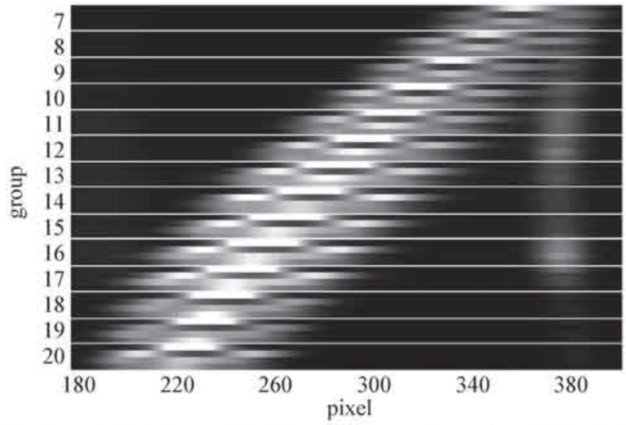

Fig. 1. CCD image for the spectra of Doppler shifted H_α emission from beam hydrogen atom.

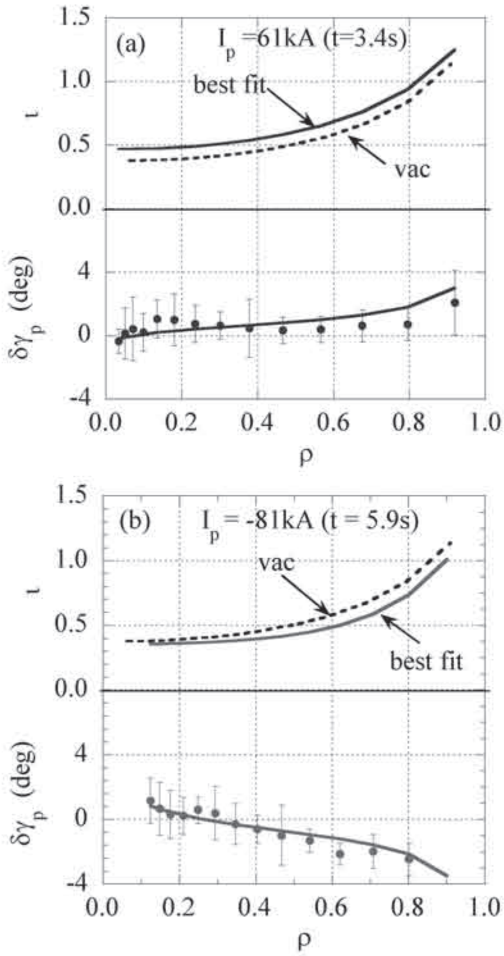

Fig. 2. The radial profile of the shift of polarization angle due to plasma and rotational transform for the best fit to the measured polarization angle and vacuum rotational transform in the plasma with (b) a positive toroidal current of 61kA (co-injection) and (b) a negative totoidal current of -81kA (counter-injection.

Reference

1) Ida, K., et.al., Rev. Sci. Instrum. **76**, (2005) 053505