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Experimental analysis on the multi-ion-source effect on motional Stark effect diagnostic in KSTAR

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1. Introduction

The motional Stark effect (MSE) diagnostic is used to obtain the magnetic pitch angle by measuring the direction of the Lorentz electric field induced by the energetic neutral beam injection (NBI) into the plasma. The MSE diagnostic has been operated successfully since 2015 in Korea Superconducting Tokamak Advanced Research (KSTAR) [1]. The KSTAR MSE diagnostic was designed to be operated at NBI-A of 100 keV and NBI-B of less than 70keV to guarantee the clean MSE spectra where the MSE spectra of NBI-A is not overlapped by those of NBI-B. Recently, however, the limitation on the allowable NBI-A energy due to the safety issue makes the measured MSE spectra more affected by those of NBI-B, (called the spectra overlap) [2]. Therefore, quantifying the effect of the spectra overlap is necessary. Herein is the experimental analysis on the spectra overlap effect on the polarization angle measurement.

2. Analysis

2.1 Experimental approach

To see the spectra overlap effect on the measured polarization angle, NBI-B is temporarily turned off several times during the discharge. Since the power of NBI-B is turned off in very short time (< 2 ms), it allows to observe polarization angle change dominantly due to the elimination of the spectra overlap effect. Figure 1 shows that averaged MSE intensities are changing promptly right after the NBI-B off at 4.89 s. It implies the spectra overlap. Considering systematic oscillation in the MSE diagnostic, the data points of about 10 ms before and after the NBI-B off are selected. It is noteworthy that the MSE intensities can be decreased by the spectra overlap because more counterphase components of the MSE spectra of NBI-B can overlap with those of NBI-A. 8 discharges operated with 8 different energy combinations of NBI-A and B are analyzed. In each discharge, plasma current is also changed from 600 kA to 500 kA to see how the magnetic pitch angle affect the spectra overlap effect.

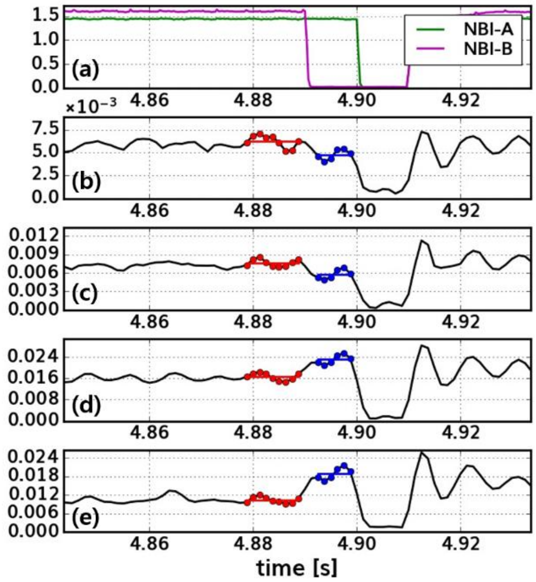

Fig. 1. (a) Power of NBI-A (green) and NBI-B (magenta) in #28095. (b) – (e) the MSE intensity averaged over 5 channels; (b) is for the 5 innermost channels and (e) for the 5 outer channels. The red and blue dots indicate the data points to be analyzed to quantify the spectra overlap effect.

Figure 2 shows the example of the tangent value of the polarization angle, $\tan(\gamma)$, measured before and after NBI-B off at two different plasma current in a single discharge, #28095. In figure 2(a), the measured $\tan(\gamma)$ tends to be biased upward by the spectra overlap. In the outer channels located at the larger R, the spectra overlap effect is shown exceptionally strong in some channels. On the other hand, figure 2(b) shows the downward-biased $\tan(\gamma)$ in the inner channels. In the outer channels, it is still biased upward but the bias is more reduced. This is probably because the MSE spectra of NBI-A and B respond differently to the changes in the magnetic pitch angle due to the geometric difference between them [2] which is maximized in the inner channels.

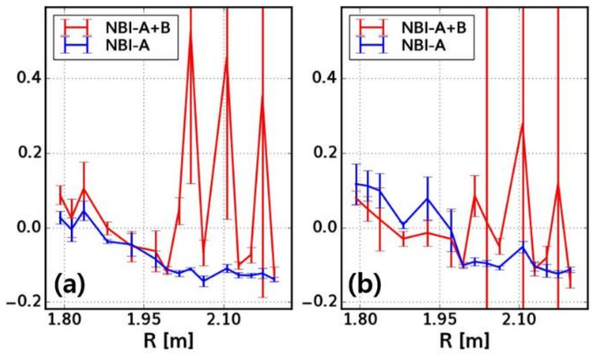

Fig. 2. The tangent value of the polarization angle, $\tan(\gamma)$, at the plasma current of 600 kA (a) and 500 kA (b) in #28095 with NBI-A and B of 80 and 85 keV, respectively.

2.2 Results

Figure 3 and 4 are summary plots for the bias of $\tan(\gamma)$ analyzed for 8 energy combinations of NBI-A and B and two different plasma currents, 600 kA and 500kA. First, the exceptionally large bias in the outer channels is found when the energy of NBI-B is larger than or equal to that of NBI-A. Second, the overall bias tends to be reduced as the energy of NBI-B decreases, but there are some exceptions such as the core channels in figure 3(b). Note that the cases with 10 keV larger energy of NBI-A than that of B where the spectra overlap effect seems to be minimized in the data set still have nonzero bias. Lastly, there is no linear tendency such as the direction and the size of the bias according to the energy combinations or plasma current.

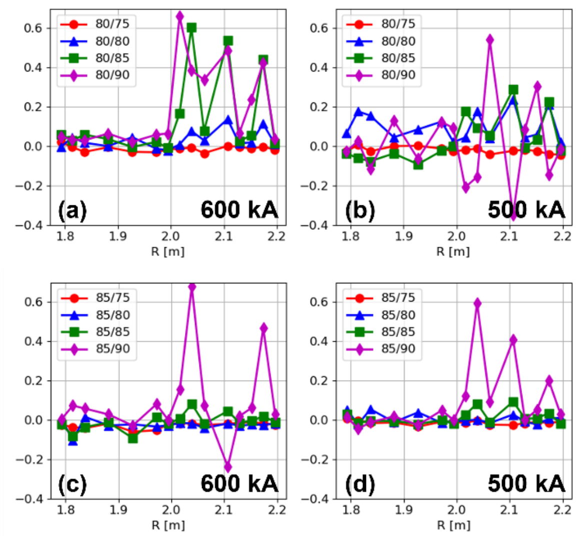

Fig. 3. The bias of the tangent value of the polarization angle for 8 energy combinations of NBI-A and B at two different plasma current. The legend in each plot indicate the energy combination of NBI-A and B in keV unit.

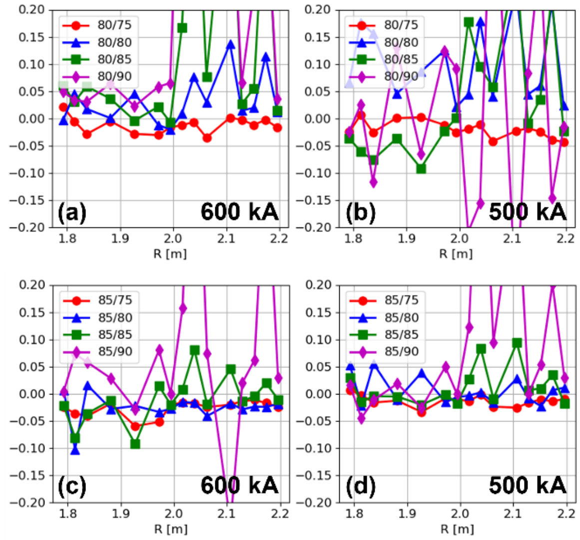

Fig. 4. The zoomed-in version for y-axis of figure 3.

3. Conclusion

To see the multi-ion-source effect on motional Stark effect diagnostic in KSTAR, experimental approach has been made. The bias in the tangent value of the polarization angle, $\tan(\gamma)$, due to the inclusion of the additional neutral beam injection (NBI-B) has been analyzed for 8 energy combinations at two different plasma current. The overall bias, as expected, tends to be reduced as the energy of NBI-B decreases, but some exceptions are also observed. Therefore, considering dynamically evolving magnetic pitch angle during a plasma discharge, the magnitude and the direction of the bias cannot be simply determined by the energy combinations of NBI-A and B. It requires more intensive analysis on the evaluation of the bias.

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