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Impact of the DED on ion transport and poloidal rotation at TEXTOR

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Introduction

Sheared plasma rotation is one of the favored means to improve plasma confinement by tearing apart convective cells at the plasma edge [1]. The dynamic ergodic divertor (DED) at the tokamak TEXTOR has the potential to drive the plasma rotation through a static and a rotating magnetic perturbation, which opens up the opportunity to study and possibly control the formation of transport barriers. The external force on the plasma may simply be evoked by the build up of radial electric fields via ergodization. This can happen in both the static and the dynamic operation. Moreover, the dynamic operation of up to 10 kHz has the unique possibility to directly exert a torque on the plasma through the creation of a Lorentz force or shielding currents [2]. The findings presented here point to the first mechanism being the dominant one.

Measurement

The 16 helical coils of the DED can be operated in different configurations with respect to resonant toroidal and poloidal m and n mode numbers. The rotation measurements were conducted in the 3/1 and 12/4 configuration, where the first one creates a stronger and deeper penetrating field, whereas the second one acts more moderate and distinct at the plasma edge [3]. The poloidal rotation of C^{6+} is measured at the edge observation system of the diagnostic hydrogen beam [4], fig. 1, designed for active CXRS on CVI ($\lambda = 5290.5$ Å). The optical set-up has the special feature of opposing lines of sight, put through the same high resolution spectrometer and projected onto the same detector together with the actual 20 radial channels. This technique provides an absolute calibration of the doppler shifted rotation measurement. At the beginning of the experiments and prior to completion of the aforementioned set-up we used *passive* CIII emission ($\lambda = 4647.4$ Å) which is much stronger and allows for a better time resolution. These measurements provide the poloidal rotation of C^{2+} at only one radial position just inside the last closed flux surface.

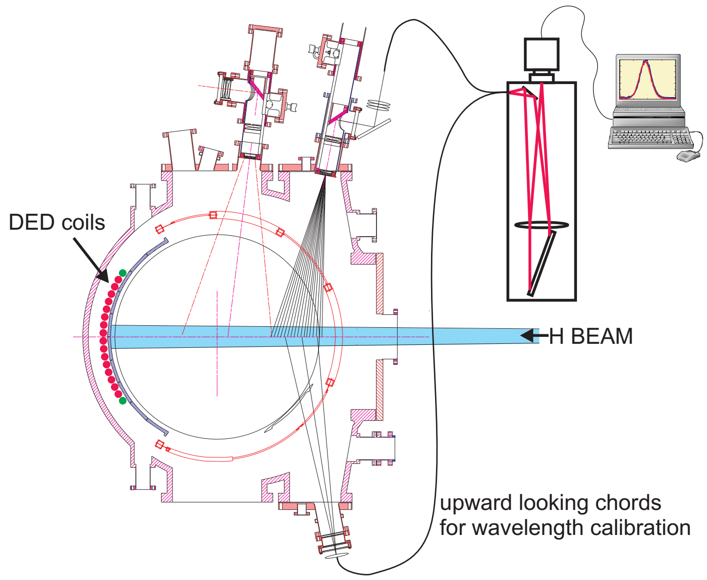

Figure 1: Set-up of the poloidal rotation measurement at the diagnostic hydrogen beam.

Results

Fig. 2 shows time traces of a typical TEXTOR discharge with static DED from the 3/1 campaign. The DED is switched on as soon as the main plasma parameters are reached ($I_p = 300$ kA, $B_t = 2.25$ T, $n_e = 2 \cdot 10^{19}$ m^{-3}, $P(NBI) = 0.3$ MW, $R_0 = 1.75$ m, $a = 0.45$ m, $q_a = 4.7$). When the DED current ramps up the rotation starts to increase into ion diamagnetic direction (fig. 2, d)-e)), synchronous and directly proportional to the DED amplitude. For the poloidal rotation this becomes even more apparent in the *change* of the rotation versus the perturbation current (fig. 3). The same has been observed for the toroidal rotation [5] and the rotation of edge turbulence at the $q = 3$ surface [6]. There seems to be a small difference in the rise of the poloidal rotation between dynamic co and counter rotating DED field. This is however still within the scatter of the DC data and should be clarified by extending the data set.

While in 12/4 configuration we observe a similar increase of the poloidal C^{2+} rotation, we have for the first time measured a C^{6+} rotation profile (fig. 4). Both profiles could be integrated over 0.6 seconds during the constant DED phase ($I_p = 400$ kA, $B_t = 1.9$ T, $n_e = 2.5 \cdot 10^{19}$ m^{-3}, $R_0 = 1.68$ m, $a = 0.4$ m, $q_a = 3.1$). The neutral beam heating power however was different between the DED-shot (1.3 MW) and the reference (0.8 MW) and we will have to see later wether this influences our results. Between 2.05 m and the last closed flux surface at 2.09 m we measure the same change of rotation from electron to ion diamagnetic drift direction, as with the C^{2+} rotation before. Independent calculations of the Chirikov parameter σ by field line mapping give a value greater than one in the same radial region, meaning that here the plasma is completely ergodized.

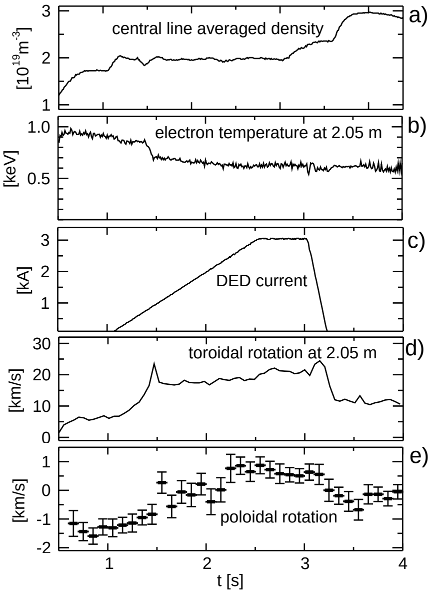

Figure 2: Time traces during a slow DED ramp. The poloidal C^{2+} rotation rises with the DED current. (The drop in T_e and toroidal rotation at 1.9 s is due to the onset of a 2/1 tearing mode)

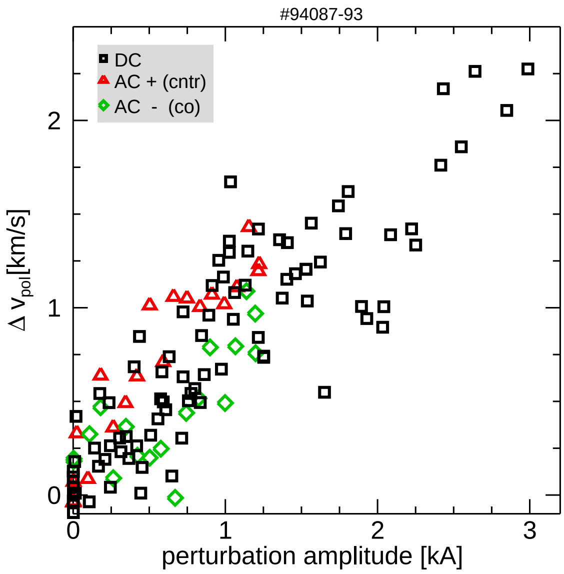

Figure 3: Change of poloidal rotation with increasing ergodization strength, represented by the DED current

Finally we have calculated the radial electric field from the radial force balance for C^{6+}:

$$E_r = \frac{1}{Z_{C^{6+}} e n_{C^{6+}}} \frac{\partial p_{C^{6+}}}{\partial r} - v_{\theta, C^{6+}} B_\phi + v_{\phi, C^{6+}} B_\theta \tag{1}$$

Pressure, intensity and rotation profiles are input from the measurements, whereas the magnetic field profiles have been calculated from a toroidal model for the q-profile. The diamagnetic and the toroidal rotation term give practically no change in E_r, so that the reversal of the poloidal rotation is directly linked to a reversal from a negative to a positive radial electric field. When the DED ergodizes and thus breaks up initially closed flux surfaces, there is an enhanced flow of electrons to the wall. This flow gets then balanced by the build up of a positive electric field. In this respect our measurements are in line with the prediction of $\sigma > 1$ (compare fig. 4), and the idea of a reversal of the radial electric field is further more supported by measurements of the floating potential in a different plasma discharge together with the DED. Nevertheless fig. 3 implies that the rotation is already affected earlier, probably by the near field of the DED. In any case this result can be interpreted of a shift of the last closed flux surface from the position initially defined by the limiter to a new position given by the extend of the ergodized zone.

Summary

We have shown measurements of poloidal carbon rotation under the action of the dynamic ergodic divertor. In any of the applied scenarios the rotation increases in ion diamagnetic drift

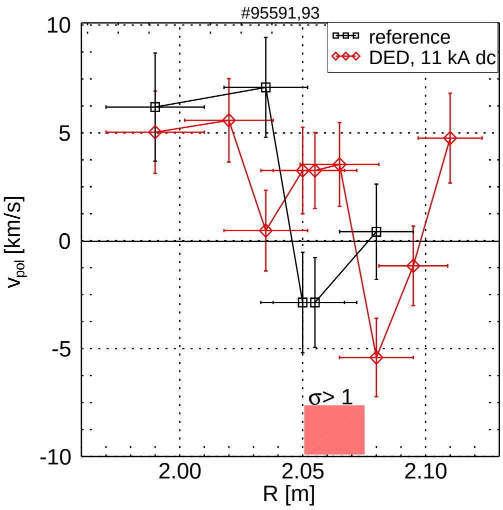

Figure 4: Poloidal rotation profiles during DED phase and a reference. The location of $\sigma > 1$ is calculated by field line mapping.

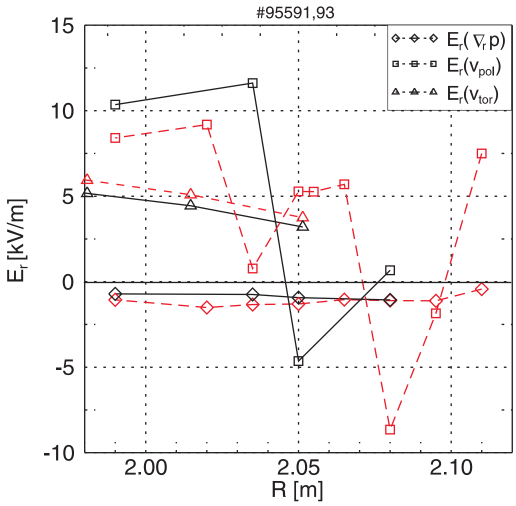

Figure 5: Contributions to the radial electric field according to equ. 1; - - DED shot; — reference shot

direction, even for opposite directions of the rotation of the perturbation field. The evaluation of the radial force balance implies that the reaction of the rotation is directly linked to the reversal of the electric field at the plasma edge, which is supported by floating potential measurements. Our results suggest that it is the mere perturbation of the edge which plays the major role in changing the plasma rotation.

The results presented in this contribution are part of an ongoing PhD thesis at the "Heinrich-Heine-Universität Düsseldorf".

References

[1] K. H. Burell. Effects of ExB velocity shear and magnetic shear on turbulence and transport in magnetic confinement devices. *Physics of Plasmas*, 4(5):1499, 1997.

[2] K. H. Finken et al. Modelling of the field line penetration and force transfer by the dynamic ergodic divertor of TEXTOR. *Nuclear Fusion*, 44:S55–S63, 2004.

[3] K. H. Finken et al. Operating space of the Dynamic Ergodic Divertor for TEXTOR-94. *Nuclear Fusion*, 39:637–662, 1999.

[4] Donné et al. Overview of core diagnostics for TEXTOR. *Fusion Science and Technology*, 47:220, February 2005.

[5] M. de Bock et al. P2.042. this conference.

[6] A. Krämer-Flecken et al. P2.031. this conference.