Characterization of toroidal intrinsic rotation with MHD activity in the TCABR tokamak

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Introduction

Plasma rotation has an important play in stabilization of MHD modes and reducing turbulent transport of particles and energy. Because in fusion reactors it is expected the torque provided by external sources will be small, the intrinsic (or spontaneous) rotation is of great interest[1, 2, 3]. Furthermore, the origin and physics of plasma rotation is also an important issue by itself.

The behavior of the intrinsic toroidal rotation during the growth and saturation of m/n = 2/1 magnetic islands, triggered by programmed density ramp up, has been investigated in L-mode ohmic discharges in the TCABR tokamak. In those discharges $R = 0.61$ m, $a = 0.18$ m, $I_p \approx 80$ kA, $B_t = 1.07$ T, $q(a) \approx 3.5$ and the toroidal spontaneous rotation of the plasma core is in the counter-current direction. The results show that the plasma is accelerated as the island starts to grow, while the island frequency slows down. And, as the island saturates, the toroidal rotation decreases quite rapidly (faster than the island), and the discharge is followed by a major disruption. In some discharges, where the density decreases after the island saturation (and thus, avoiding the plasma disruption), the MHD instability becomes smaller until it vanishes, and the toroidal rotation slows down to its original value before the gas injection.

Diagnostic system

The plasma rotation in the TCABR is measured with 2 photomultiplier (PMT), per optical chord, at the axial and lateral output of a single monochromator, as shown in figure 1. They are adjusted to measure slightly different wavelengths by means of a beam splitter inside the monochromator output. Thus, in this scheme, the plasma rotation v can be estimated by the Doppler shift of an impurity emission line with central wavelength λ_0: $v = c\frac{\Delta\lambda}{\lambda_0} = R(\Delta\lambda)$ where $\Delta\lambda$ is the Doppler shift of the spectral line due to the rotation, c is the speed of light and $R(\Delta\lambda)$ is the ratio of the signal from the two slits as a function of the Doppler shift. The $R(\Delta\lambda)$ is obtained from calibration, where all optical ports are set to view the central chord of the plasma poloidal cross section (where the rotation is negligible), and the ratio of the impurity emission signal is recorded as a function of wavelength.

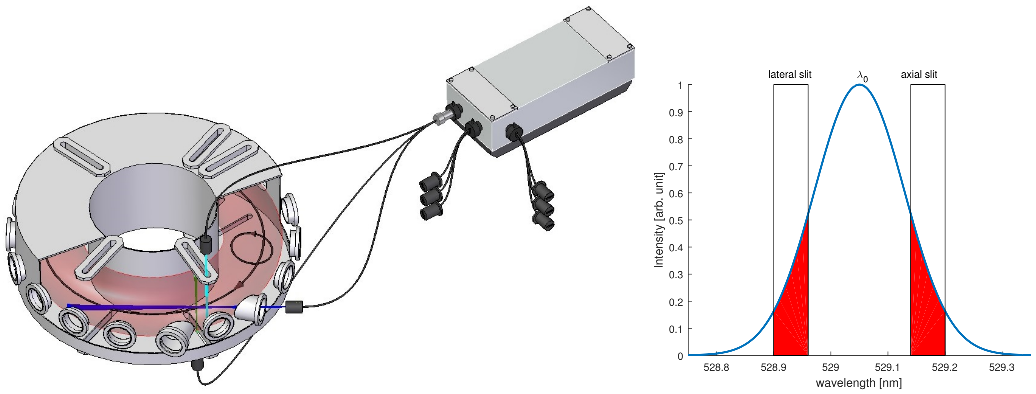

Figure 1: *Experimental setup: the light from the poloidal chords and toroidal chord arrive in the entrance slit of the monochromator, and each signal is measured in the PMT at the axial and lateral output slit. Currently, there are 3 optical ports, one for toroidal rotation, and 2 for poloidal rotation.*

Results

In those discharges, the carbon line CVI (529.05 nm) was employed to measure plasma rotation velocity. In the figure 2 are shown the main signals from discharges with and without disruption where, in both cases, the density was ramped up to induce the MHD activity. The mode m/n = 2/1 is the dominant one, as estimated from spatial FFT from the Mirnov coils (figure 3).

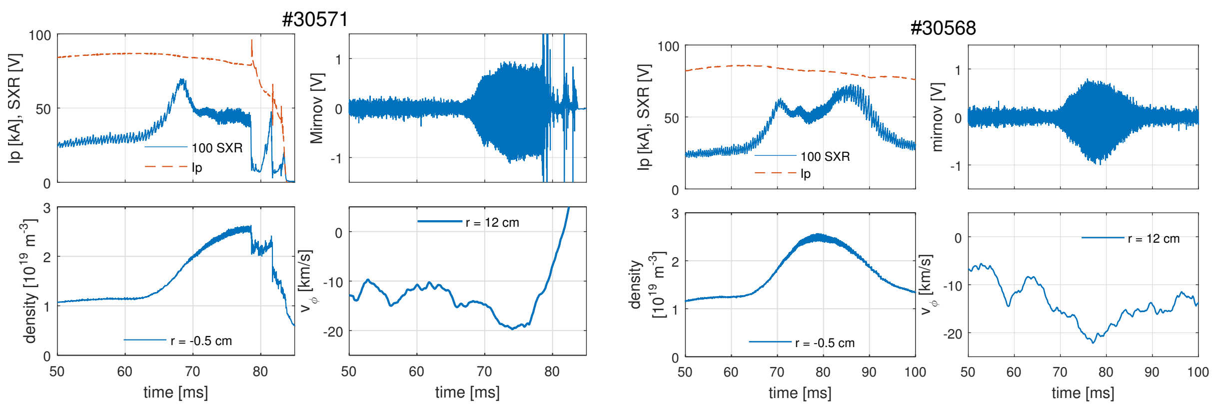

Figure 2: *Plasma current, soft X-rays (SXR), line-average electron density, Mirnov signal and toroidal velocity for discharges with (#30571) and without disruption (#30568)*

In these discharges the line-averaged electron density is slowly increased from 1×10^{19} m^{-3} to 2.8×10^{19} m^{-3}. In this process, the sawtooth instability, as seen in the SXR diagnostic, fades out just before a 2/1 magnetic island is destabilized, indicating an internal change of the safety factor profile.

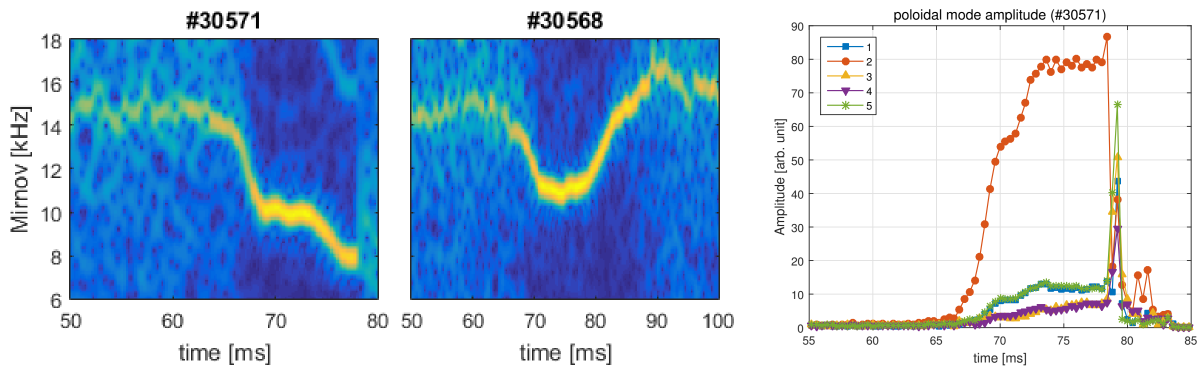

Figure 3: *Spectrogram of the Mirnov oscillations for discharges with (#30571) and without disruption (#30568), and the poloidal amplitude for the discharge #30571.*

At this point, the plasma core velocity increases and, a few milliseconds later, the mode amplitude saturates, while the toroidal velocity continues to increase. If density continues to increase, the strong interaction between the magnetic island and the mirror currents in the plasma wall reduces the MHD frequency, and in a few milliseconds later, the toroidal velocity starts to decrease rapidly and before it changes its sign, a major disruption occurs.

The radial profile of the line-integrated toroidal rotation velocity for plasmas both with and without MHD is shown in figure 4: the average velocities during approximately 50 ms to 65 ms (without MHD), and the maximum velocity in the presence of MHD (usually at $\sim$ 77 ms, just after the mode m/n = 2/1 saturation). The rotation in the plasma core is in the counter current direction, while at the edge, usually it is in co-current direction.

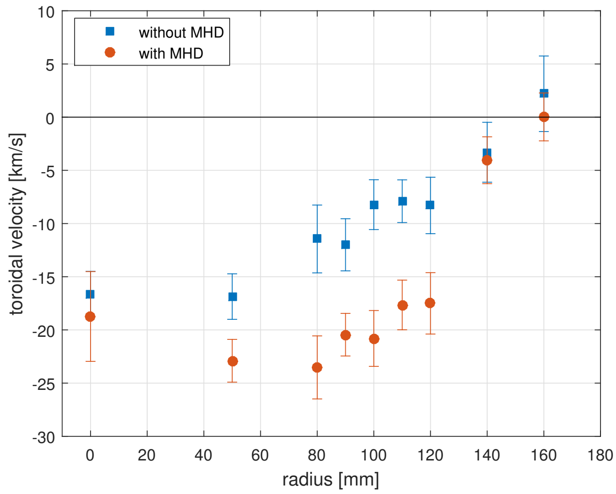

Figure 4: *The radial rotation profile with and without m/n=2/1 activity.*

Discussion

Even in the absence of MHD activity, there is a natural breaking of axisymetry due to toroidal field ripple and magnetic error fields, leading to a spontaneous rotation as it has been extensively investigated [4, 5]. The increase in toroidal velocity may be explained due to enhanced transport (from breaking axisymmetry), leading to an internal rearrangement of toroidal momentum [6].

Further investigation must be done with electrostatic probes at the scrape-of-layer to determine the radial flux change in the presence of 2/1 tearing mode. Also, a proper inversion of this signal is still necessary to estimate the actual rotation value, particularly, in the plasma core.

A similar behaviour, although not presented here, is also observed in during mode coupling (n=2, 3) in discharges with small plasma vertical displacement ($\sim$ 1 cm), but in this case the interpretation is not straightforward.

Acknowledgements

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