TEMPORAL EVOLUTION OF TEMPERATURE PROFILES INSIDE THE MAGNETIC ISLANDS IN TEXTOR-94 PLASMAS

V. S. Udintsev, A. Krämer-Flecken[1], J.W.Oosterbeek[1], B.H. Deng[2], C. Domier[2], A.J.H. Donné, E. Graffmann[1], M.J. van de Pol, and F.C. Schüller

*FOM-Instituut voor Plasmafysica "Rijnhuizen", Association EURATOM-FOM, P.O. Box 1207, 3430 BE Nieuwegein, The Netherlands**

*[1]Institut für Plasmaphysik, Forschungszentrum Jülich GmbH, EURATOM Association, D-52425 Jülich, Germany**

[2]Department of Applied Science, University of California at Davis, USA

**Partners in the Trilateral Euregio Cluster*

1. Introduction.

To gain a better understanding of the development of large by magnetohydrodynamic (MHD) modes, the evolution of the temperature profile inside m/n = 2/1 magnetic islands is being studied at TEXTOR-94 tokamak by means of fast Electron Cyclotron Emission (ECE) diagnostics. To study transport properties of the plasma perturbed by MHD modes, the island width and temperature gradients are evaluated out of the evolution of temperature profiles throughout the island and background plasma. Spectral analysis of the dynamic frequency behavior of the mode has shown a frequency change during current and density ramp-up and ramp-down phases. Possible mechanisms responsible for such kind of behavior are discussed in this paper.

2. Evolution of temperature profiles and gradients throughout the island.

Large MHD modes at TEXTOR-94 tokamak (R_0 = 1.75 m, a = 0.46 m, B < 2.9 T) are usually created by a fast density ramp up (~ $3 \cdot 10^{19}$ $m^{-3}s^{-1}$) with a slower current ramp up (~ 200 kA/s) in the early phase of the discharge [1]. In standard discharges, these values are typically equal to 1.5-2.5$\cdot 10^{19}$ $m^{-3}s^{-1}$ and 300-350 kA/s. Co-Neutral Beam (NB) injection (P_{NB1}= 0.3-0.4 MW) is applied during the ramp up phase to decrease the mode rotation frequency and to make it stationary for a certain time interval. As an alternative to early NB injection, an intensive Ne puff is being used to get modes prior to radiation limit disruption.

The present ECE diagnostic configuration on TEXTOR-94 covers the frequency range of 96 – 180 GHz. A new 16-channel heterodyne radiometer is being routinely used to obtain radial temperature profiles within the magnetic islands with a high temporal resolution (up to 2 MHz) [2]. To study the island rotation in poloidal direction, the unique feature of the ECE-Imaging system to observe a vertical line of sight in the vicinity of the q=2 surface at the Low Field Side (LFS) (114 GHz, B $\geq$ 2.14 T) is being used [3].

A large rotating m=2 island is shown in Fig. 1. For this shot, the magnetic field has been set to 2.4 T, so the ECE-imaging is monitoring the q=2 surface in poloidal direction at R = 2.06 m. Due to the co-NB injection, the mode inverts its toroidal rotation at ~ 0.565 s, yielding a change in its frequency from 2500 Hz down to 300 Hz. From the contour plot out of 14 available channels of the ECE-Imaging system (see Fig. 2a and 2b), the island's poloidal connection length is found to be 0.45 – 0.55 m. The island rotation velocity projected on the poloidal direction is calculated to be 1100-1200 m/s and 300-400 m/s before and after the rotation inversion, respectively (Fig. 2a, b, c). A secondary temperature peaking inside the island up to 25-30 %, with respect to the temperature at the separatrix, is very pronounced.

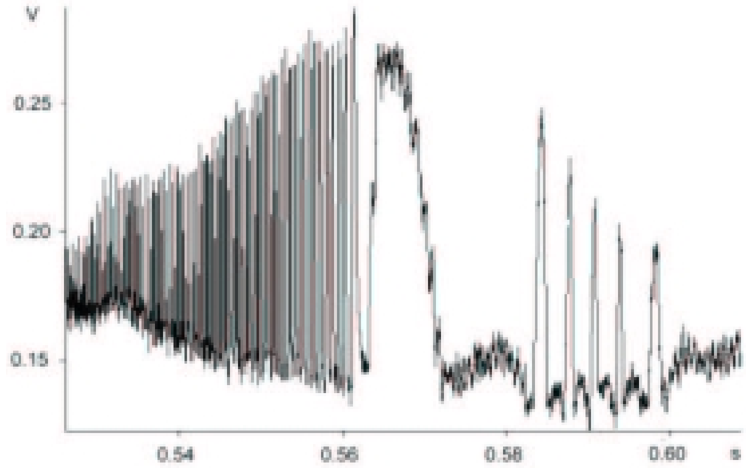
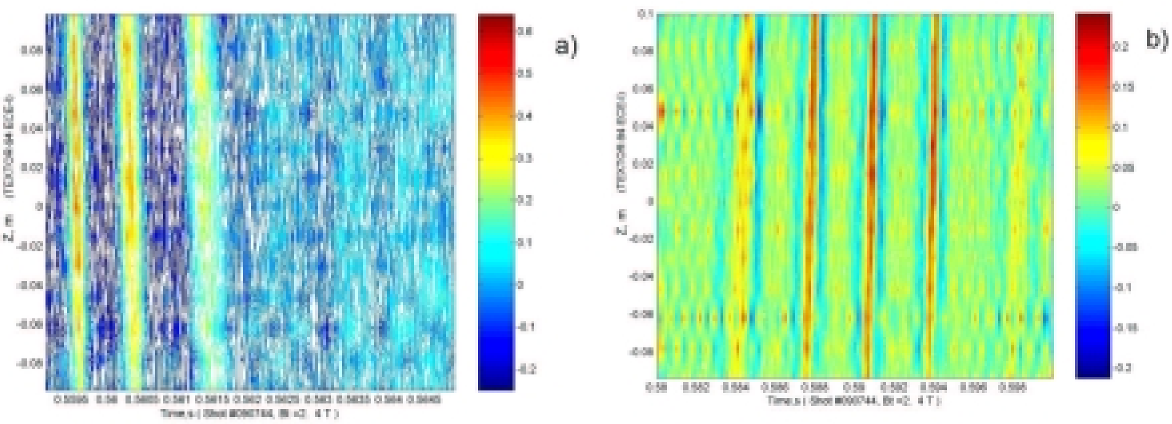


FIG. 1. A large m=2 mode monitored by the ECE-Imaging system (raw data). The toroidal rotation inversion due to co-NB injection occurred at ~0.565 s. X-point of the island is clearly seen as series of voltage peaks. Magnetic field B = 2.4 T.

Figure 2c shows a complicated structure of the X-point of the island. This can be attributed to the temperature fluctuations due to presence of modes with high m number; although, detailed analysis is required.



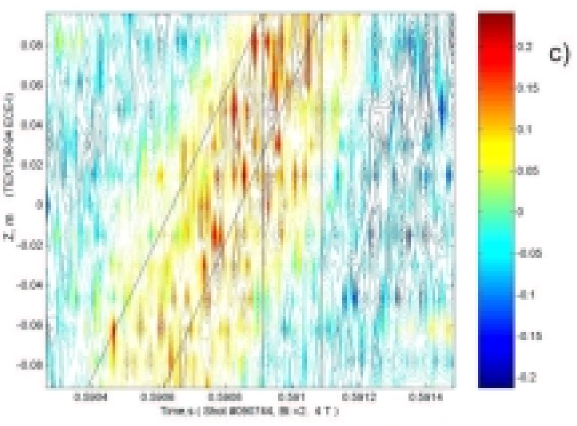


FIG. 2. Contour plots of the normalised temperature fluctuations measured by the ECE-Imaging for the times before (a) and after (b, c) the rotation inversion (the same shot as in Fig. 1). Lines in Fig. 2c shows the rotation of the island in poloidal direction, as it moves from bottom to upper channels. A complicated structure in the temperature distribution in the X-point of the island is seen in Fig. 2c.

To study radial heat transport properties of plasma in presence of the m/n=2/1 magnetic islands, analysis of the evolution of the radial temperature profiles has been made for a set of experiments with different heating methods. As an example, Fig. 3 shows the evolution of the radial temperature profile for the same shot as in Fig. 1 and 2. For the X-point, the temperature gradients are found to be 4 – 6 keV/m at the time of 0.5607 s. In the vicinity of the O-point, outside the separatrix and facing the core,

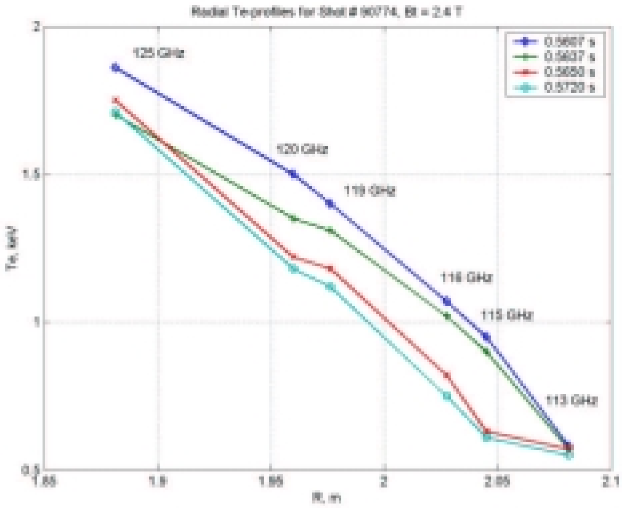


FIG. 3. Radial temperature evolution throughout the m/n=2/1 island. The profile at 0.5607 s shows the temperature distribution at the X-point, and profiles at 0.565 s and 0.572 s in the vicinity of the O-point. Temperature flattening (compare to the X-point) inside the island is clearly seen at R = 2.04–2.07 m. Absolute values for temperature gradients are calculated to be 4-6 keV/m at the X-point.

the temperature gradients are about 5 – 7 keV/m. From this temperature evolution, the island's width can be estimated as $d_{isl} = 2 \cdot \Delta T_e/(dT_e/dr)$, where dT_e/dr is a gradient defined for the X-point, ΔT_e – difference in temperatures between the X and O-points at the same radial location. For R = 2.04 m, the island width is about 6 cm. This is in a good agreement with previous measurement [4].

3. Dynamic frequency behaviour during current and density ramps.

As has been reported in [4], the mode's dynamic frequency behaviour during density and current ramp down has been observed. For a set of recent experiments, the same sort of behaviour has been detected also during the ramp up phase of the discharge. As can be seen from Fig. 4a, the frequency of a large m=2 mode is jumping from 100 to 800 Hz in less than 100 ms. Low power (~ 0.3 MW) co-NB injection is applied at 0.5 s and remains constant for 1.5 s. No additional gas puff has been used for these shots. Since the diamagnetic frequency for electrons is proportional to the pressure gradient, one could possibly think about the formation of steep temperature and density gradient in the q = 2 vicinity during a very short time. Although, these gradients remain almost unchangeable for the time interval from 0.7 to 0.9 s, and, thus, cannot explain the jump in frequency.

Another observation shows an enhancement of the H_α signal measured at the limiter (see Fig. 4b). It is in phase with the mode oscillation on the ECE LFS channel. Possibly, the neutral particles from the wall influence the mode rotation momentum due to charge exchange induced viscosity. As the mode spins down, a plateau in the density ramp up has occurred at 0.84 – 0.98 s. This explanation does not hold for the ramp down, as no enhancement of H_α has been observed. Moreover, this anomalous viscosity can not explain a jump upward in frequency.

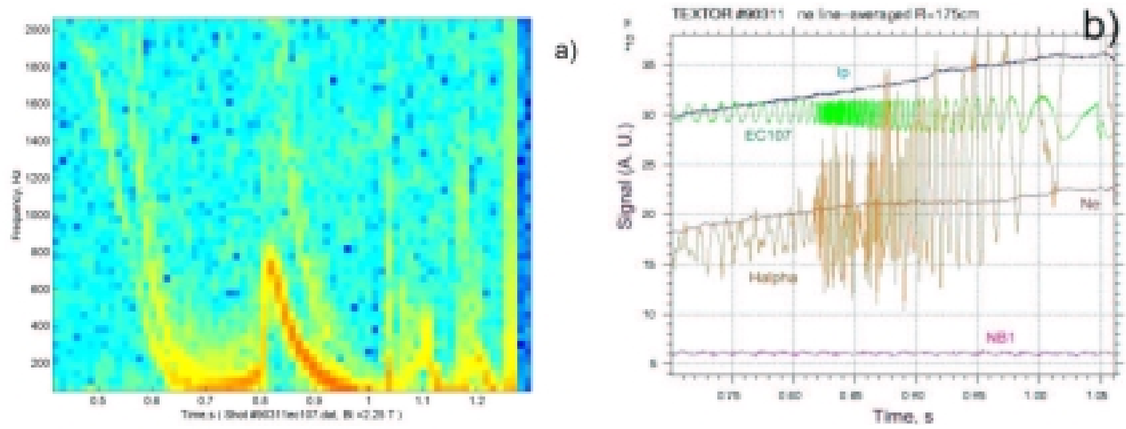


FIG. 4. Mode dynamic frequency behaviour during a ramp up phase of the discharge around 0.82 s (I=320 kA, n_e=2.1·10^{19} m^{-3}). The mode frequency is jumping from 100 to 800 Hz in less than 100 ms (Fig. 4a). Figure 4b shows an enhancement of H_α signal during the frequency change. For this shot, the m=2 mode is coupled to the m=1 mode.

4. Conclusion.

The evolution of temperature profiles throughout the large magnetic islands has been investigated by means of fast radial and vertical ECE. The m/n=2/1 mode rotation in poloidal direction has been obtained from the contour plot out of ECE-Imaging data. The typical width of the island from different observations is found to be 5–7 cm. Temperature gradients throughout the island are evaluated from radial ECE. The dynamic frequency behaviour of the m=2 mode during the ramp up phase of the discharge can be explained by a change in the diamagnetic frequency of electrons, or are caused by viscosity due to neutral particles released from the wall. Although, the models do not work well to explain the mode's frequency behavior during the ramp down phase.

Acknowledgments.

The work described in this paper was performed as part of a research programme of the 'Stichting voor Fundamenteel Onderzoek der Materie' (FOM) and 'Institut für Plasmaphysik, Forschungszentrum Jülich GmbH' with financial support from the 'Nederlandse Organisatie voor Wetenschappelijk Onderzoek' (NWO), EURATOM and Forschungszentrum Jülich, and was carried out at the TEXTOR-94 tokamak, Institut für Plasmaphysik, Forschungszentrum Jülich GmbH, Germany.

5. References.

[1] G. Mank, A.Krämer-Flecken *et al*., These Proceedings.
[2] V.S. Udintsev *et al*., Rev. Sci. Instrum. **72** (2001) 359.
[3] B.H Deng *et al*., Rev. Sci. Instrum **72** (2001) 368.
[4] V.S. Udintsev *et al*., in Proc. of the 27th EPS Conf., Budapest (2000)