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One of causes of the edge ballooning deformation may be the nonuniformity of the magnetic surface which is produced by the shell cut.

5. Relaxation oscillation

The actual profile does not remain at a purely steady relaxed state, because the depositions of the ohmic input and the energy loss are different in space. The configuration of the dissipative plasma might be different from the energy minimum state. It may transfer to that of the dissipation minimum state in given magnetic energy /5/. It has rather peaked profiles and a higher free energy than the relaxed state. The real q profile has a step near the rational number of the plasma edge, while $q(0)$ is more than 1. The current profile deviates from uniform profile to a double peaked one. This strained q profile lasts for 100~500 μsec and relaxes to the inherent state in a few μsec, which is similar to that in **Fig.1**. As the phenomenon repeats and appears to be a small sawtooth, we call it a relaxation oscillation. The period of it decreases with decreasing q_l and is 50~200 μsec in low q plasma or more than 1 msec in high q plasma. Usually, the change occurs over the whole torus simultaneously. The rapid macroscopic plasma motion, accompanied by the energy and particle losses to the outward edge of the torus, is observed at the relaxation. The relaxed profile is reconstructed by releasing the excess energy. These phenomena may be recognized to be a kind of ELMs. In the case that q profile is carefully controlled to be the relaxed state, the relaxation oscillation disappears, and consequently, the plasma without particle loss and with a slight energy loss is obtained and then good confinement is established, in spite of fact that the rotating ballooning mode still exists and the density fluctuations appear near the edge region.

At first, the q relaxation, that is, the magnetic flux reconnection, occurs at a certain point of the toroidal direction and the flux change propagates along the magnetic field line in Alfven transit time (~1μsec). The relaxation occurs over the 1/3 of full torus. When the deviation is not so large, the magnetic flux change may not be necessary to occur over the full torus. In the short time of the transition, the plasma returns to the relaxed state.

6. Conclusion

The experimental results are summarized as follows: The relaxation and self-organization of q profile have been observed. The configuration with the self-organized q and density profiles might be in a minimum energy state of a high β and very low q plasma. The necessary condition for relaxation to the high β low q stable state is that β_p before and after the relaxation is high. The ballooning like deformation (m=2/n=2) occurs outside the torus in the relaxed plasma and rotates with the rotation of the plasma nearly to the magnetic line. The plasma rotation may have a stabilization effect on the mode and the deformation may not degrade the confinement. As the profile is deviated by the electron thermal transport loss and the deposition of ohmic input, it has a step near the rational number of q and the plasma current has a tendency of flowing on near the rational surface. The strained state relaxes to the inherent profile. This might cause the release of excess energy and make the particle and energy flows, which then degrades the confinement. These phenomena may be recognized to be a kind of ELMs and might be understood as the relaxation oscillation which might be the repetitive transition from the dissipation minimum state to the energy minimum state.

REFERENCE

/1/ KIYAMA, S., et al., Bull. Electrotech. Laboratory 50 (1986) 95. Electrotechnical Laboratory Report 937, March 1992.

/2/ KIYAMA, H., et al., in Plasma Physics and Controlled Nuclear Fusion Research (Proc.of 12th Int.Conference Nice, 1988) Vol.1, IAEA, Vienna (1989) p.437.

/3/ KIYAMA, H., et al., Proc. of 1992 International Conference on Plasma Physics (Innsburg, 1992) Vol.2, p.799.

/4/ KIYAMA, S., Proc. of 1992 International Conference on Plasma Physics (Innsburg, 1992) Vol.3, p.1781.

/5/ Chen, T.k., Princeton Plasma Physics Laboratory Report PPPL-2822, February 1992.

Analysis of edge fluctuations on the CASTOR tokamak

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Introduction

Edge fluctuations play a dominant role in the anomalous particle losses from tokamak plasma. In particular, recent lower hybrid current drive (LHCD) experiments in low density plasmas on ASDEX [1] and CASTOR [2] tokamaks demonstrated an improvement of the particle confinement at moderate lower hybrid powers, which is linked closedly to a reduction of edge electrostatic fluctuations. The mechanism of the fluctuation reduction is discussed elsewhere [3]. This contribution is devoted to a more detail characterization of electrostatic and magnetic fluctuations in this regime.

CASTOR tokamak

Experiments were carried out on the CASTOR tokamak ($R = 0.4\ m, a = 0.085\ m$) at $B_t = 1\ T$, $I_p = 12\ kA$ and densities $\bar{n}_e = 2\text{–}6\cdot 10^{18}\ m^{-3}$. For LHCD, the lower hybrid wave ($f = 1.25\ GHz, P_{LH} \leq 40\ kW$) was launched into the plasma via the three-waveguide multijunction grill [2] during the quasistationary phase of discharge. A brief survey of fluctuation measurements follows:

A) Oscillatory technique for T_e – measurements (OH)

A sinusoidal voltage $V = V_0 \sin\omega t$ is applied to a Langmuir probe as shown in Fig. 1. The floating potential of the probe drops due to the rectification of electron current as [4]:

$$\Delta V_{fl} = T_e \ln \mathcal{J}(V_0/T_e) \qquad (\simeq V_0^2/4T_e \quad \text{for} \quad T_e > V_0)$$

where $\mathcal{J}(V_0/T_e)$ is the modified Bessel function and $T_e \equiv kT_e/e$.

Results of measurements are shown in Fig. 2. The frequency of sinusoidal modulation is 0.5 MHz, the amplitude V_0 is gated to determine the drop ΔV_{fl} by means of a single tip (the top trace). The middle trace shows the raw signal. The marks indicate the interpolated values of the signal with and without modulation. The resulting temperature (the bottom trace) is compared with evolution of T_e measured by a triple probe located in the vicinity of the oscillatory tip. The satisfactory agreement suggests that the oscillatory technique can be used if strictly local measurements of the electron temperature are needed.

Further, we test this technique to determine the T_e- fluctuations. For this, three tips spaced poloidally by 2.5 mm were used, the sinusoidal voltage being applied to the central one. The floating potential in this spatial point, necessary for determination of ΔV_{fl}, was estimated by the interpolation of data from the neighbouring floating tips. The relative level of temperature fluctuations $\tilde{T}_e/T_e \doteq 0.12$ obtained seems to be quite reasonable.

B) Mapping of the floating potential (OH)

The linear array of tips spaced poloidally by 2.5mm was used to investigate poloidal asymmetries in the plasma edge and to determine the correlation length of electrostatic fluctuations. The probe array was movable on a shot to shot basis.

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n=4 only), see Fig. 6b. It is interesting to note that their form is linked to the radial profile of autocorrelation time, see Fig. 6c. When the dimensionality in LHCD is higher than in the OH regime, the autocorrelation time is lower and *vice versa*. Therefore, we investigated the relation between these two quantities in more detail. Fig. 6d is a plot of the dimensionality of data from a shot versus the time delay d. Note that the typical autocorrelation time for our data is $2-7\mu s$ (d = 10-35 samples). In this range of d, the dimensionality is practically independent on the delay and the difference between LHCD and OH regimes remains nearly constant. It seems, therefore, that the observed effects are not caused by an improper choice of the delay.

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References

[1] Stöckel J, Söldner F.X et al.: Rep. IPP 1/268, Garching, 1992
[2] Stöckel J. et al.: IAEA TCM on Research Using Small Tokamaks, Würzburg, 1992
[3] Voitsekhovich I.A et al.: this Conference
[4] Ivanov R.S. et al.: Textor Rep. Jul-2432, January 1991
[7] Grassberger P., Procaccia I.: Phys. Rev. Lett.,50, 1983, 346

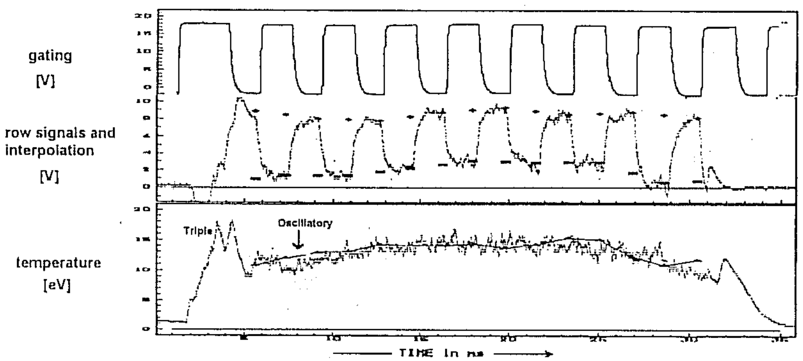

Fig.2. Temporal evolution of signals of the oscillatory probe

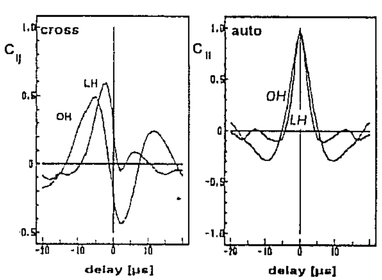

Fig.7 Correlations of magnetic fluctuations

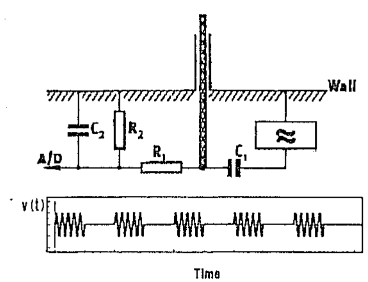

Fig.1. Arrangement of the oscillatory probe

Fig. 3 depicts evolution of the raw signals of floating potential (sampled by $1\mu s$) from eight adjacent tips in a 2D plot for two radial positions of the array. It is evident that the perturbations propagate mostly from the tip No. 8 to the tip No.1 (which coresponds to the direction of electron diamagnetic drift) when the probe is within the limiter radius ($a > r = 83mm$), while a reverse tendency is apparent for a more outward position of the array.

The propagation velocity in poloidal direction was deduced by the correlation analysis. Fig. 4 manifests the variation of the form of crosscorrelation function with the radial position of the probe (2D plot, two tips are spaced by 5 mm). The direction of poloidal velocity corresponds to the cross-field drift velocity $(\vec{E}_r \times \vec{B}_t)/B_t^2$. The velocity shear layer is located close to the region with $E_r \sim -\partial V_{fl}/\partial r = 0$ (see Fig. 5).

C) Correlation analysis of magnetic fluctuations (OH + LHCD)

Poloidal magnetic fluctuations are monitored by two magnetic probes fixed inside the liner, their poloidal distance is 37 mm. The correlation functions of the probe signals are shown in Fig. 7. Typically, the cross-correlation function has two maxima. The maximum with a higher correlation ($C_{ij} > 0.5$) characterizes magnetic fluctuations propagating in the electron diamagnetic drift direction. We suppose, in concordance with Langmuir probe measurements, that these fluctuations have the origin within the plasma ($r < a$). The fluctuations related to the positive time delay of cross-correlation function are interpreted as a consequence of perturbations located within the scrape-off layer and propagating in the ion dimagnetic drift direction.

The time delay of both the maxima decreases with LHCD, which indicates an enhancement of the poloidal velocity of magnetic fluctuations which is also manifested by narrowing of the autocorrelation function. The similar effects are observed for the electrostatic fluctuations as well [6].

D) Dimensional and correlation analysis of density fluctuations (OH+LHCD)

To characterize whether the fluctuations are stochastic or chaotic (with less degrees of freedom than a noise), we calculated the correlation dimension of density fluctuations using the Grassberger-Procaccia algorithm [5]. The ion saturation current of a Langmuir probe is sampled by $0.2\mu s$ and 4096 samples (denoted as x_i) can be stored per a shot.

The dimensional analysis consists in construction of n-dimensional vectors from the data, n is the embedding dimension:

$$\vec{r}_i = (x_i + x_{i+d} + x_{i+2d} + ... + x_{i+(n-1)d}) \qquad i = 1, 2, ..., 4096 - (n-1)d$$

The correlation between the individual vector components should be negligible, therefore, we take the delay d as the autocorrelation time τ, defined as a halfwidth of autocorrelation function. Result for OH and LHCD regimes are summarized in Fig. 6.

Fig. 6a compares the dimensionality in LHCD and OH regimes for the probe position close to the limiter radius. The dimensionality in both the regimes seems to be lower than the same quantity for the computer-generated Gaussian noise in the all embedding dimensions. Further, the LHCD data are closer to the noise than the OH ones. This suggests that the density fluctuations in the LHCD regime (with reduced fluctuations and improved confinement [2]) are more stochastic. Our limited set of data do not allow to reach the saturation of dimensionality (even if exists).

Further, we compute the radial profiles of dimensionality (in the embedding dimension

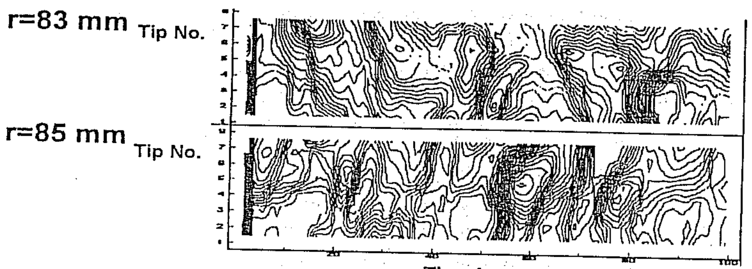

Fig.3. Evolution of floating potential monitored by 8 tips (2D plot)

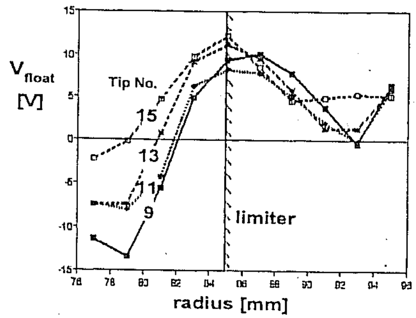

Fig.4. Radial profile of V_{float}

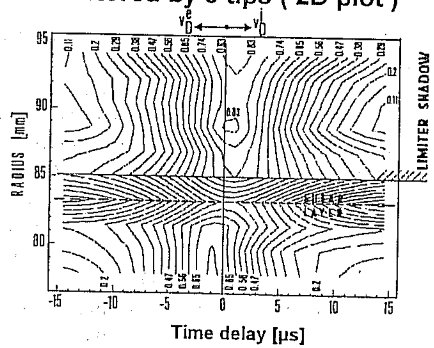

Fig.5. Crosscorrelation of tips 1-3

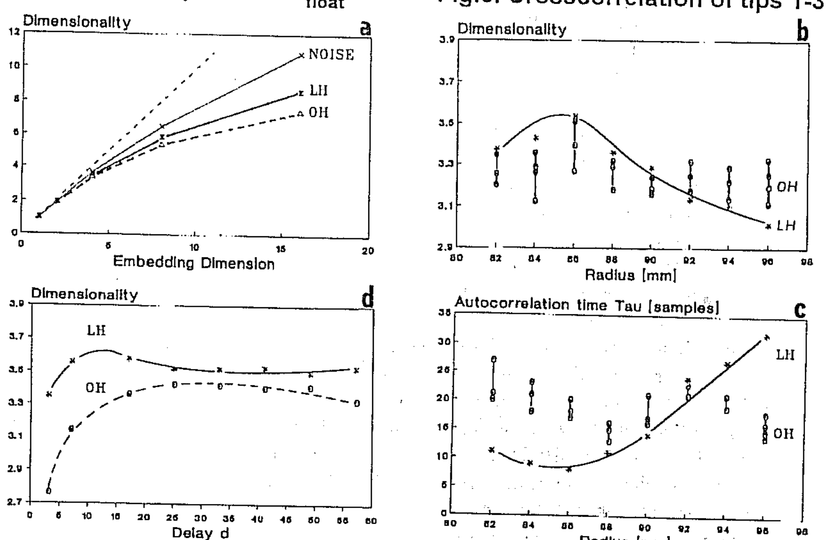

Fig.6. Dimensional and correlation analysis of density fluctuations

CHARACTERIZATION OF THE RFX EDGE PLASMA

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Introduction The edge region of the Reversed Field Pinch (RFP) experiment RFX ($R = 2$ m, $a = 0.457$ m at the inner wall) /1/ has been investigated by an array of 6 Langmuir probes and 6 heat sensors mounted on a graphite limiter. The limiter is mushroom shaped and the probes are flush with the limiter surface. Each probe consists of a 3 mm diameter cylindrical graphite tip insulated by a machinable ceramic mount /2/. In this campaign two Langmuir probes, 4 mm beyond the tip of the limiter, have been operated in single probe configuration (50÷200 Hz, ±150 V sinusoidal voltage sweep) and the other 4 were floating. The limiter has been protruded into the plasma up to 4 mm without any significant change in main plasma parameters. At the deepest insertion the surface temperature of the graphite rose up to 2000 degrees, with an incident energy flux of the order of 100 MW/m^2 as derived by the energy sensors 1 mm beyond the tip of the limiter. Taking into account the surface exposed to the plasma, the power collected by the limiter results <<1% of the input ohmic power during the current flat-top. Typical waveforms of the plasma current and line averaged density compared with the limiter floating potential are shown in fig.1.

Measurements The data refer to a range of toroidal current I and line averaged electron density n_e of $500 < I < 700$ kA and $2.5 < n_e < 5 \cdot 10^{19}$ m^{-3} respectively. As previously found in other RFP experiments /3/ the energy flux in the outer region of the plasma is strongly directional and exhibits a maximum when the collecting surface is exposed with the normal parallel