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Radial electric field dynamic in the edge during ergodic magnetic limiter setting up in tokamak TF-2

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1.Introduction

There is a need for improvement in producing uniform power load and particle flux to the wall and in the avoidance of locked modes in tokamaks. It may be assisted by producing an ergodic magnetic divertor and an ergodic magnetic limiter (EML) in the edge that was tested in Hybtok-II, TEXT and TORE SUPRA[1-3]. In a tokamak the external radial magnetic perturbation (stochastic boundary) is generated by a specific set of helical coils located outside the vacuum vessel. The volume of open field lines connected to the wall is referred to as the divertor volume. At the moment the issue is whether the features of transport result from the properties of the magnetic perturbation or from a change in radial electric fields and turbulence? In a stochastic boundary the large mobility of the electrons along the flux lines induces an electron loss which can be compensated only by a parallel electric field to ensure an ambipolar flow of particles. The radial electric field is expected to adjust to the stochastic boundary in order to increase the confinement of the electrons. Poloidal shear flow [4,5] and radial gradients in the turbulent Reynolds stress [6] remain the best explanations of the fluctuation suppression at the naturally occurring velocity shear layer and at L-H transition.

The goal of the presented experiments is to investigate the radial electric field and turbulence dynamic in the edge plasma during setting up EML in a small-scale tokamak TF-2.

2.Experimental Results

In TF-2 tokamak (R=0.23 m, r=0.04 m, $B_{(r=0)}$=0.7 T, q=3.6, I_{pl}=5-6 kA, n_e=2-$3\times10^{19}m^{-3}$, T_{e0}=0.2-0.3 keV, poloidal ring limiter a=0.035 m) the helical coil is a complete poloidal ring (outside of the vacuum vessel). It is characterized by periods of opposite currents (I_{eml}<1.2 kA), i.e. the perturbation is multipolar. The coils have a small toroidal extent ~7^o. The main low poloidal mode is determined by the geometry of the helical coil with m/n=7/2. As the poloidal coil is a complete ring the poloidal spectra are narrow, Δm=$\pm$1. The perturbation current is resonant to the magnetic field near the q=3 surface at r/a=0.95. The characteristic Chiricov parameter (island width/island separation) is about 1 for the central plasma position. Plasma density, electric fields, turbulence driven flux, turbulence spectra at the edge in TF-2 are studied using movable Langmuir probe array. Standard techniques are used to calculate plasma parameters.

The ergodic magnetic limiter results in the change in the edge plasma profiles. The EML effects on the formation of a layer in the shear region with less correlative properties. Relatively low temperature and a high density are observed at 0.9<r/a<0.95 with the EML whereas at r/a>0.95 the density is dropped by ~30-50 %. A growth in the radial electric field value measured in the shear region (r/a=0.95) is ~0.2 msec earlier than the changes in the turbulence and the edge density profile steeping (fig. 1). Probability density function of density fluctuations in the shear layer is changed with the EML (fig. 2) nevertheless it remains nongaussian indicating multimode structure of the turbulence. The EML modifies the turbulence dispersion relation in the region of destroyed magnetic surfaces. The width of poloidal k-spectra in the shear region (r/*a*=0.95) becames broader (fig. 3) and the frequency spectra becames narrower with the EML (fig. 4). The EML affects quasi-coherent mode. Coherency between density and poloidal electric field decreases with the EML accompanied by a change in a phase shift between the fluctuations (fig. 5). Fluctuation-induced particle flux is reduced ~2 times in the shear region. The reduction is resulted mainly from the decreasing of the coherency. Comparing the probe measurements with a theory we find that the ratio of the turbulent decorrelation rate to hybrid shear decorrelation rate $\Delta\omega_t /(2\omega_s^2\Delta\omega_t)^{1/3}$~2-2.5 without the EML. With the EML the ratio $\Delta\omega_t /(2\omega_s^2\Delta\omega_t)^{1/3}$ ~2.5-3.5.

Radial profiles of density fluctuation level, radial electric field, poloidal phase velocity of fluctuations are changed with the EML (fig. 6). We observe the cases where density fluctuation level is not changed or decreased with the EML.

In the shear layer radial electric field is increased with the EML (fig. 6). The change in the radial electric field can be associated with a change in the ion poloidal rotation. The rotation can be estimated from the phase shift of ion saturation current fluctuations of two probes separated poloidally. A poloidal phase velocity direction in the SOL remains an ion diamagnetic one with the EML. The velocity shear is increased near the naturally occurring shear region at r/a=0.97. An inversion point of the phase velocity is shifted toward plasma center with the EML.

The radial profiles of the cross-correlation between fluctuating poloidal E_θ and radial E_r electric fields are investigated at the edge to analyze the importance of the poloidal flow driven by electrostatic Reynolds stress. Fig. 6 shows the radial profiles $\langle E_\theta E_r \rangle$ obtained from the measurements of tips placed 2 mm apart in the poloidal and radial direction. With the EML a radial derivative of $\langle E_\theta E_r \rangle$ evolves in the proximity of the velocity shear layer. The Reynolds stress and the poloidal shear flow result in the radial flux reduction.

In a conclusion, stochastic boundary is a configuration to control the edge plasma. In the region of destroyed magnetic surfaces the radial electric field and the poloidal velocity shear are increased with the EML leading to the response in plasma profiles and turbulence.

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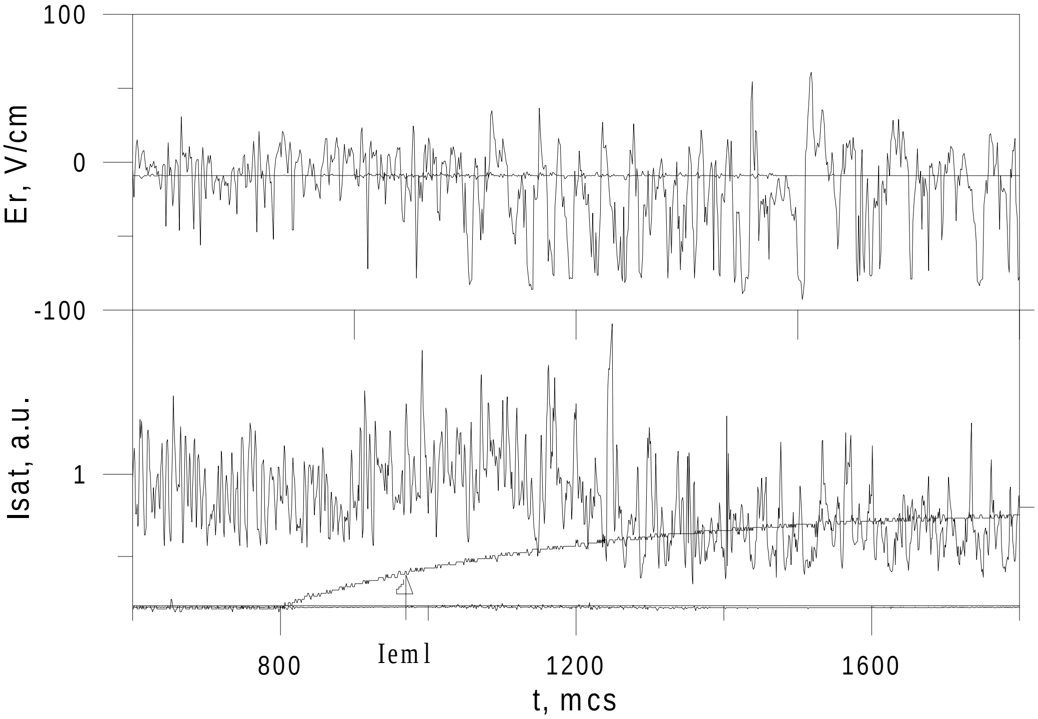

Fig. 1. Time traces of ion saturation current I_{sat} and radial electric field E_r (estimated from a difference of floating potentials measured by radially separated probe) in the shear region r/a=0.95 where magnetic surfaces are destroyed by the ergodic limiter configuration. The ergodic limiter coil current I_{eml}. starts at 0.8 msec.A growth in radial E_r value is ~0.2 msec earlier than a change in I_{sat}., I_{eml}/I_{pl} =0.2.

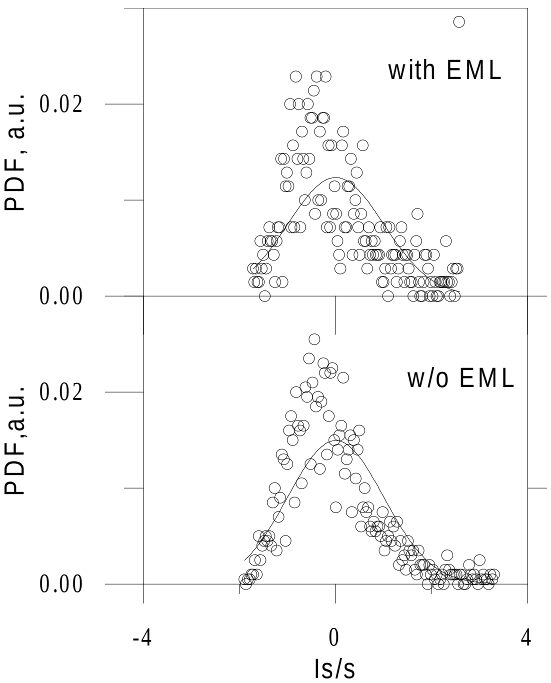

Fig. 2. Probability density function of density fluctuations in the shear layer r/a=0.95 without and with the EML. A Gaussian (solid lines) is plotted for reference.

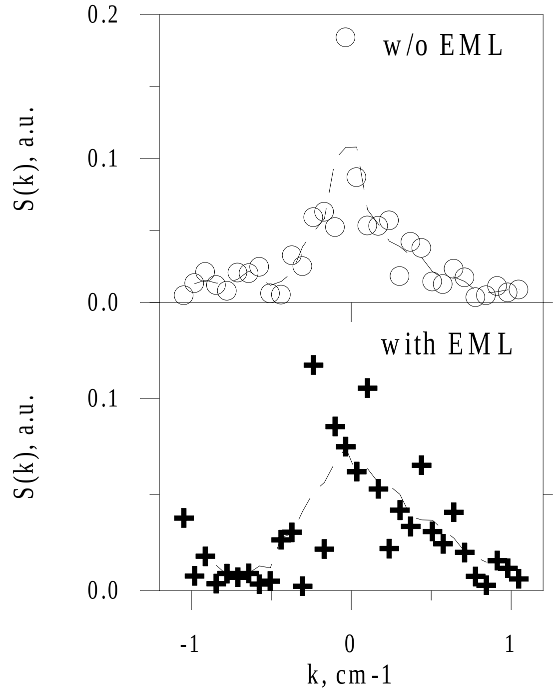

Fig.3. Poloidal wavenumber spectra in the shear region (outerboard) without and with the EML.

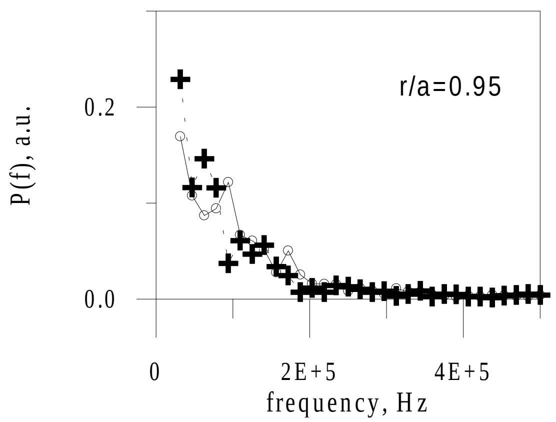

Fig. 4 . Power spectra of turbulence for density fluctuatiobns at r/a=0.95. Oouter board. Circles - without, crosses - with the EML. The EML affects quasi-coherent mode.

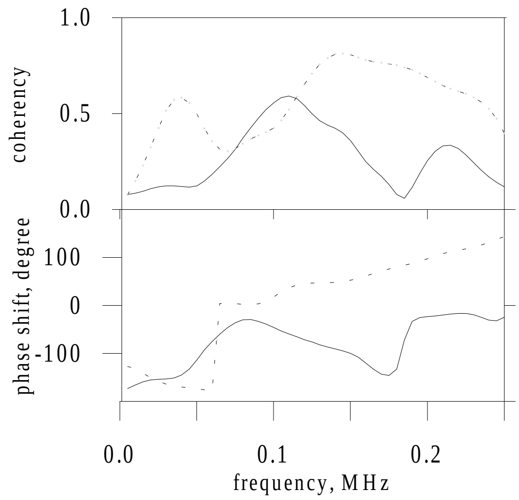

Fig.5. Phase shift and coherency between density and electric field fluctuations in the shear region, r/a=0.95 .Dashed lines - without the EML, solid - with the EML.

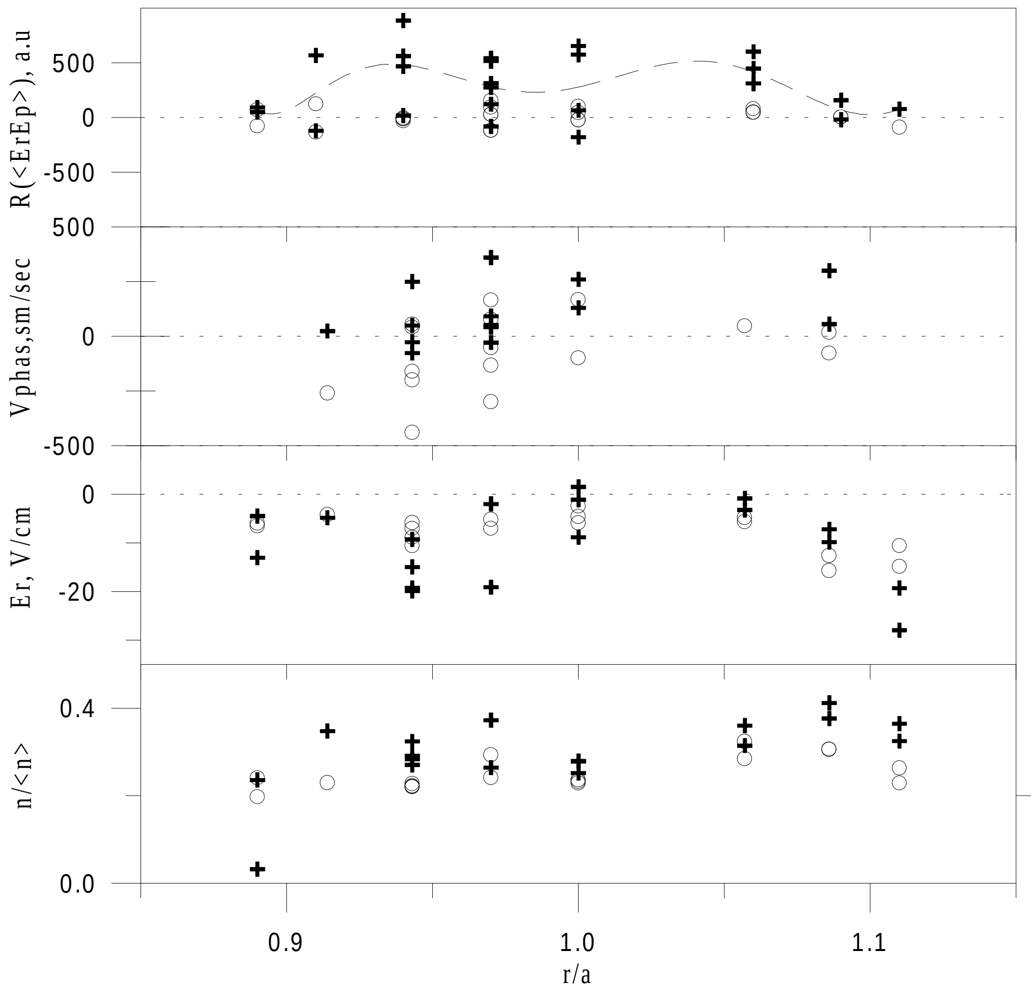

Fig.6. Radial profiles of density fluctuation level n/<n>, radial electric field E_r, poloidal phase velocity of fluctuations V_{phas} and Reynolds stress $R(<E_rE_p>)$ without the EML (circles) and with the EML (crosses). Outer board.