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# Poloidal flow generation via Reynolds stress in T-10 tokamak.

G.S. Kirnev, V.P. Budaev, S.A. Grashin, L.N. Khimchenko

*Nuclear Fusion Institute, RRC "Kurchatov Institute", Moscow 123182, Russia*

## Introduction.

Spontaneous shear flow generation in magnetized fusion plasmas is thought to occur by the turbulent Reynolds stress [1]. This can be viewed as a transfer of turbulent energy to the shear flow scales via a three-wave coupling process. Therefore investigations of bispectral quantities of the plasma fluctuations may be of interest.

Investigation of nonlinear interactions of plasma fluctuations in the plasma periphery in the T-10 tokamak is presented in this paper. Study of the nonlinear interactions has been performed on basis of the bispectral analysis of Langmuir probe signals. Main tasks of the study are:

- investigation of three-wave coupling process in the plasma edge on basis of bispectral analysis;
- measurements of radial profile of the electrostatic Reynolds stress;
- measurements of radial profile of the poloidal velocity;
- revelation of the interconnection between plasma fluctuations and poloidal flows.

## Experimental set-up and plasma parameters.

Experiments were performed on the T-10 tokamak having a major radius of $R_0$=1.5 m, a full poloidal graphite limiter at a minor radius of $a_0$=0.33 m and a graphite rail limiter defining a minor plasma radius $a_L$=0.30 m. The experiments were performed in deuterium ohmic plasma. The average electron density $\bar{n}_e$ measured along a central chord was in the range $5 \cdot 10^{19}$ $m^{-3}$, the toroidal magnetic field induction $B_t$ = 2.4 T, the plasma current $I_p$ = 0.3 MA.

Measurements of the edge plasma parameters were performed using movable Langmuir probe array with radial and poloidal separated tips. Distance between the tips is about 0.3 cm. Probe is located at the LFS $30^0$ below the outer mid-plane.

## Experimental results.

Regimes investigated are described in [2,3]. These regimes are characterized by enhanced intermittent transport in the scrape-off layer (SOL). Power spectrum of the floating potential measured at the last closed flux surface (LCFS) contains a great peak near frequency $f_0$ of about 20 kHz (Fig. 1a). Application of the bispectral analysis shows that strong nonlinear interaction of the plasma oscillations in continuous spectrum (20-150 kHz) near the LCFS leads to power transfer from the broadband small-scale turbulence to the large-scale mode fluctuating with a frequency $f_0 \approx 20$ kHz (Fig. 1b). This mode is assumed to be poloidally symmetrical with a poloidal wave number $k_\theta \approx 0$. Nonlinear interaction seems to be the result of the reverse energy cascading process. The mode "20 kHz" reveals features peculiar to the zonal flows predicted theoretically [4] and observed experimentally [5,6,7]. Maximum of the poloidal velocity of the potential fluctuations is located in the vicinity of the LCFS (Fig. 2).

Measurements of the electrostatic Reynolds stress component R ($R = \langle \tilde{v}_r \tilde{v}_\theta \rangle$, where $\tilde{v}_r$ and $\tilde{v}_\theta$ are the radial and poloidal components of the fluctuating velocity) show that maximum of R is located near the maximum of the bispectrum (Fig. 3 and 4), i.e. at the LCFS. This is in agreement with [1,8], where generation of low-frequency fluctuations in the plasma potential via nonlinear energy transfer from high-frequency fluctuations is considered.

**Conclusions.**

Investigation of nonlinear interactions of plasma fluctuations was performed on basis of bispectral analysis of Langmuir probe signals.

Application of the bispectral analysis for electrical probe data shows that:

- Strong nonlinear interaction of plasma oscillations in the continuous spectrum (20-150 kHz) was observed near the LCFS. This interaction is assumed to lead to energy transfer from the broadband small-scale turbulence to the large-scale mode "20 kHz".
- Nonlinear interaction seems to be the result of the reverse energy cascading process. The mode "20 kHz" reveals features inherent in so called zonal flows predicted theoretically and observed experimentally.
- In the scrape-off layer, only low-frequency component of the decomposing mode "20 kHz" is observed. A frequency of the component corresponds to the frequency of appearance of the high density plasma structures (blobs) observed in the SOL only.
- Measurements of the electrostatic Reynolds stress show that maximum of the Reynolds stress is located near the maximum of the three-wave coupling process intensity and poloidal velocity of the fluctuations, i.e. at the LCFS. This result is in

agreement with ideas considering the poloidal flow generation via nonlinear energy transfer from high-frequency fluctuations.

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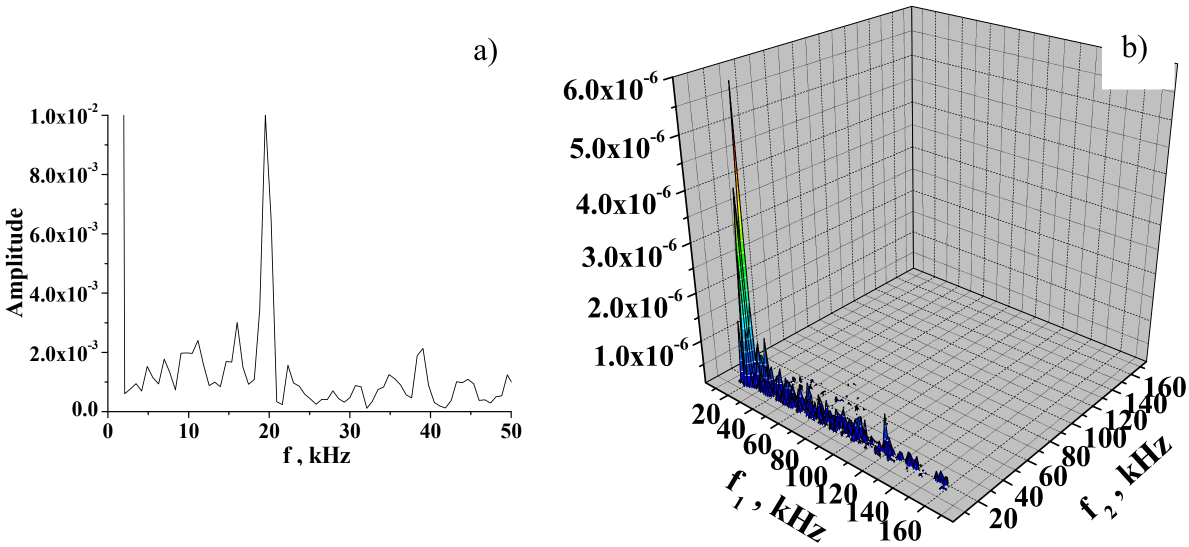


*Fig. 1. Power spectrum (a) and bispectrum (b) of the floating potential fluctuations at the LCFS.*

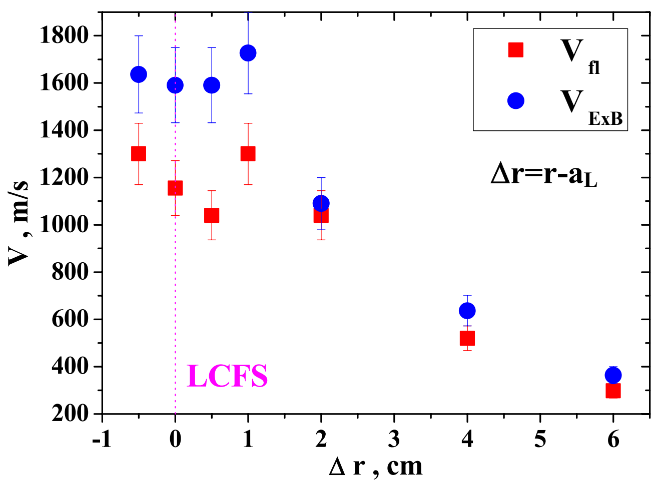


*Fig. 2. Radial profiles of poloidal phase velocity ($V_{fl}$) and poloidal electrical drift velocity ($V_{ExB}$).*

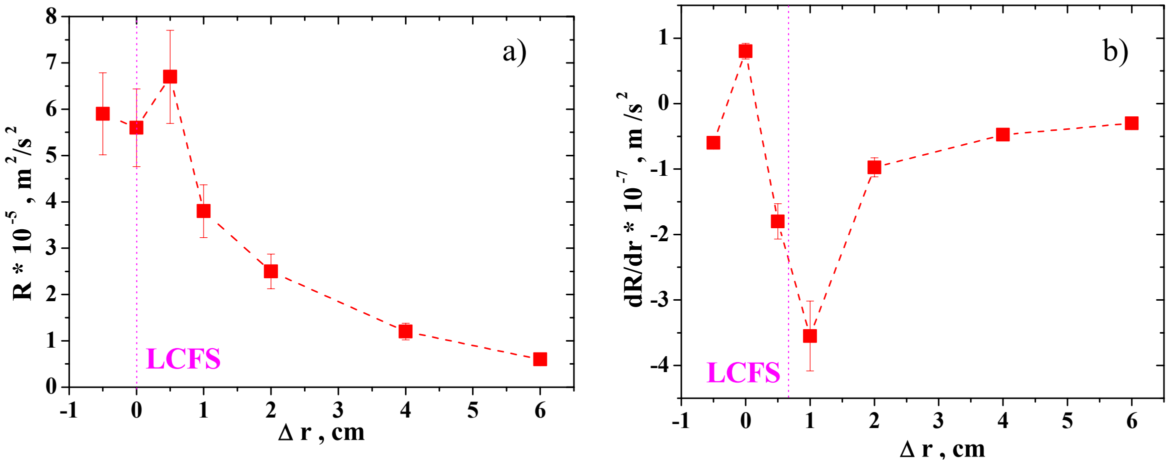


*Fig. 3. Radial profiles of Reynolds stress component R (a) and dR/dr (b).*

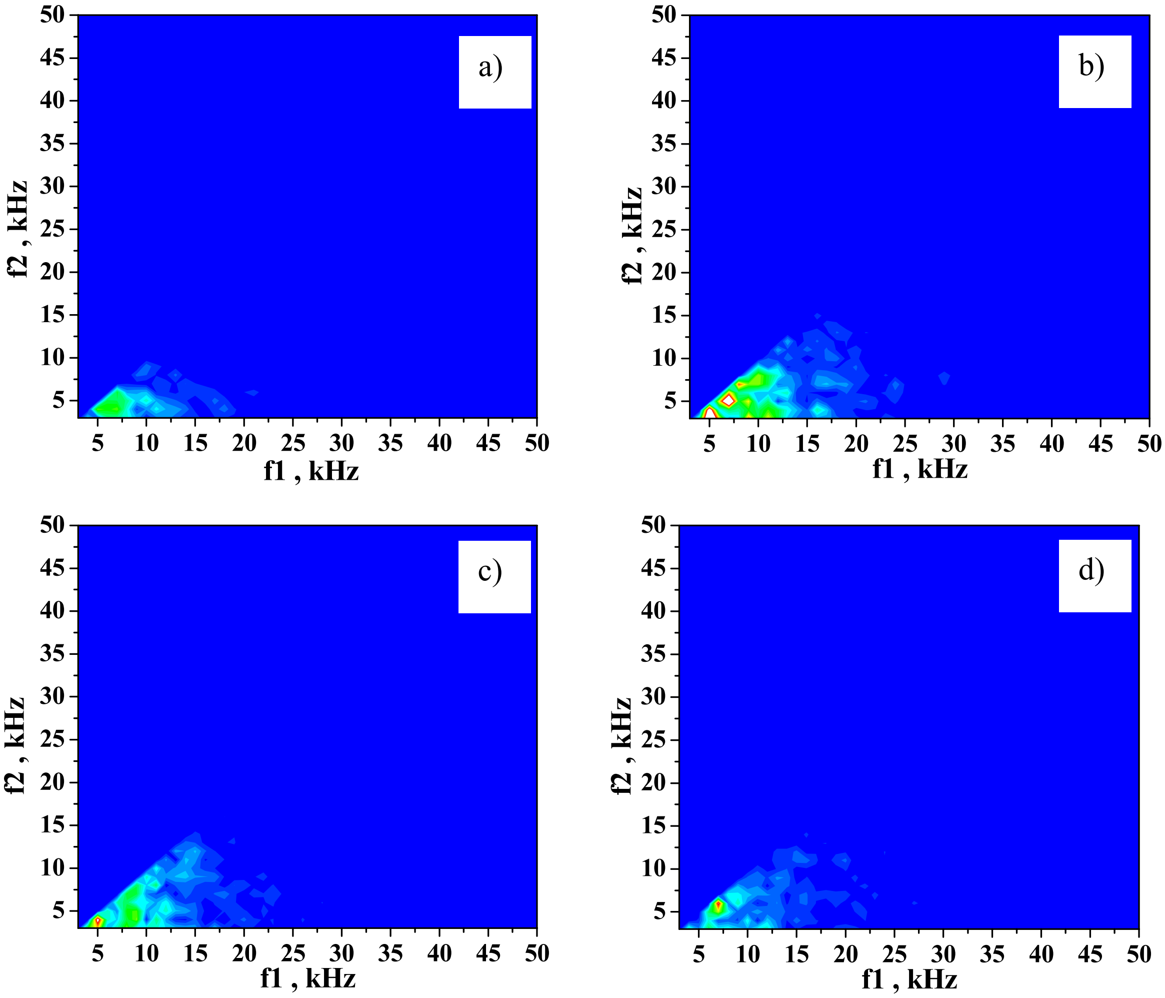


*Fig. 4. Modification of the nonlinear interaction intensity with radius: a) - Δ r=3 cm; b) - Δ r=0.5 cm; c) - Δ r=0 cm; d) - Δ r= -0.5 cm.*