34th EPS Conference on Plasma Phys. Warsaw, 2 - 6 July 2007 ECA Vol.**31F**, P-2.110 (2007)

Multi-Electrode Measurement of Electrostatic Fluctuations in High-Density Helicon Linear Device

K. Terasaka[1], S. Shinohara[1], Y. Nagashima[2], T. Yamada[2], M. Kawaguchi[1], T. Maruta[1], S. Inagaki[2], Y. Kawai[2], M. Yagi[2], A. Fujisawa[3], K. Itoh[3], and S. -I. Itoh[2]

[1] *Interdisciplinary Graduate School of Engineering Sciences, Kyushu Univ., Fukuoka, Japan*

[2] *Research Institute for Applied Mechanics, Kyushu Univ., Japan*

[3] *National Institute for Fusion Science, Gifu, Japan*

Recent works indicate that the mutual interaction between fluctuations, which have different temporal and spatial scales, plays an important role in plasma turbulence dynamics. Many studies to understand the structural formation of the drift wave turbulence, have been performed in torus and linear devices (e.g., [1,2]). Since multiple electrostatic probe arrays (e.g., [3]) can directly measure the turbulence structure with high spatial resolution, the arrays have been used in linear devices and torus. However, the conventional arrays are fixed in space and could not cover the wide measuring region. We have developed a probe array having the 48 electrodes (48ch.-probe). This array can measure the turbulence structure in the radial-poloidal plane, since it is movable in the radial direction. The 48ch.-probe, as shown in Fig. 1, had 16 radially movable modules, and each module had three tungsten tips (its diameter and length were 0.8 mm and 4.0 mm, respectively). When all modules are at radius r = 40 mm, the distance between adjacent two tips is 5.2 mm in the poloidal direction. Furthermore, we could also measure plasma parameters in a wide r-θ region by moving the modules in radial direction. Here, θ is the poloidal angle.

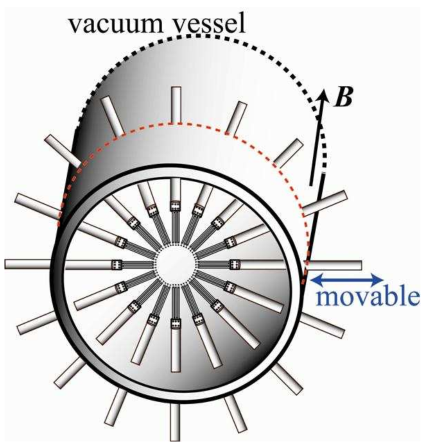

Figure 1: The schematic of 48ch.-probe aligned at r = 40 mm.

The drift wave measurements with the probe array have been performed in Large Mirror Device-Upgrade (LMD-U), modifying the previous device [4]. LMD-U has a vacuum vessel, 3740 mm long and 445 mm inner diameter. The high-density helicon plasma was produced by a double-loop antenna (excited mode number was $m = 0$), and the magnetic field up to 1500 G was generated by 23 coils around the vacuum vessel. In order to make steeper radial density gradient, here, we had a configuration of the convergent magnetic field. In this experiment, argon gas was used with the pressure of 2 mTorr, and the RF power was 3 kW. The typical electron density was $< 10^{19}\mathrm{m}^{-3}$

with electron temperature of ~ 3 eV.

Figure 2(a) shows the B-dependence of the normalized ion saturation current (I_{is}) fluctuation level (f = 1-10 kHz components), and Fig. 2(b) shows the frequency power spectrum (B = 200-1000 G) when all tips were aligned at r = 40 mm. In the case of B = 200-340 G), a coherent mode (f = 3.8 kHz), close to the linear drift wave eigen frequency [5], was observed. The relative fluctuation level was less than 10 %. The observed frequency of the dominant mode changed gradually with the increase in the magnetic field. Another coherent mode with f = 1.2 kHz was excited at B = 350 G, which showed the coexistence of the two modes. The spectrum clearly changed at $B \sim 400$ G: the amplitude of the coherent mode of f = 3.8 kHz decreased and some peaks were excited. Then, the spectrum was broadened up to f = 5 kHz region at B = 440 G. The valley levels between the peaks increased, and the band-width of the ~ 3 kHz mode became wider. The broad-band range expanded with increasing the magnetic field ($|\nabla_r n_0/n_0|$ became steeper with the field), and reached up to $f \sim 10$ kHz region at B = 1000 G. Here, the spectrum had some peaks in a broad-band state and the fluctuation level ($\sim$ 30 %) was very large. When $B > 1200$ G, the spectrum became coherent ($f \sim 2.8$ kHz), and the relative density fluctuation level gradually decreased with increasing the field.

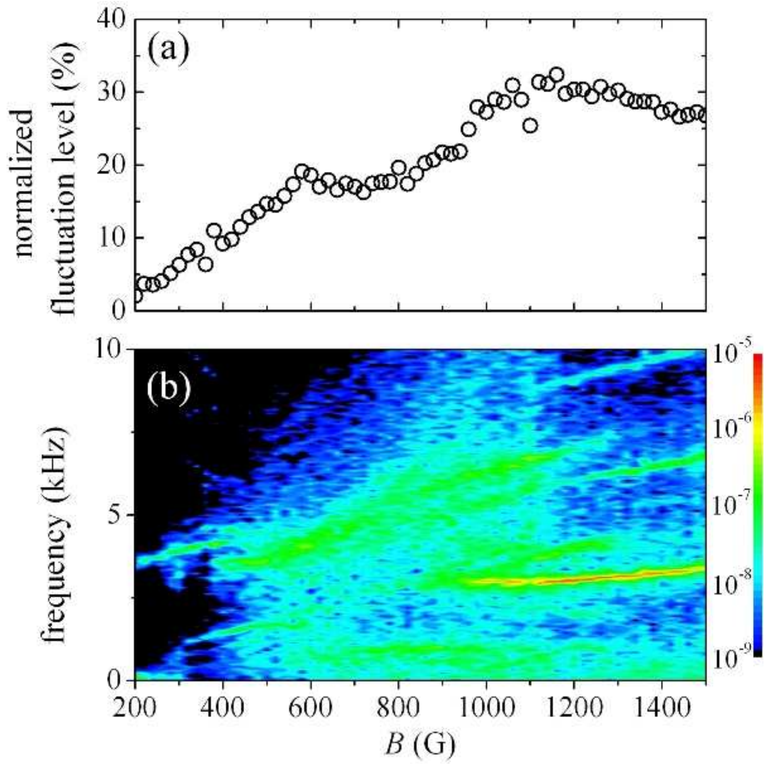

Figure 2: Dependence of (a) the normalized fluctuation level and (b) frequency spectrum of I_{is} on B.

Figrure 3(a) shows the time development of the poloidal structure of the normalized I_{is} fluctuations, $\tilde{I}_{is}(\theta)/I_{is}(\theta)$, at B = 900 G. There were some modes propagating to the electron diamagnetic direction (from upper left to down right in this figure), and their typical relative fluctuation amplitudes were $\sim$ 0.6. Note that the large positive amplitude [$\tilde{I}_{is}(\theta)/I_{is}(\theta) \sim$ 1.0-1.2] was observed when their modes overlapped. Temporal behavior of the power spectrum of the poloidal mode number m at 900 G in Fig 3(b) shows that the low m modes (m = 1-6) grew and decayed temporally. Here, from the power spectrum with 8 ms data, three excited modes satisfied the matching conditions of frequency and mode number [6]. From these results, it indicated that large positive amplitude, shown in Fig. 3(a), was produced when the some modes synchronized each other.

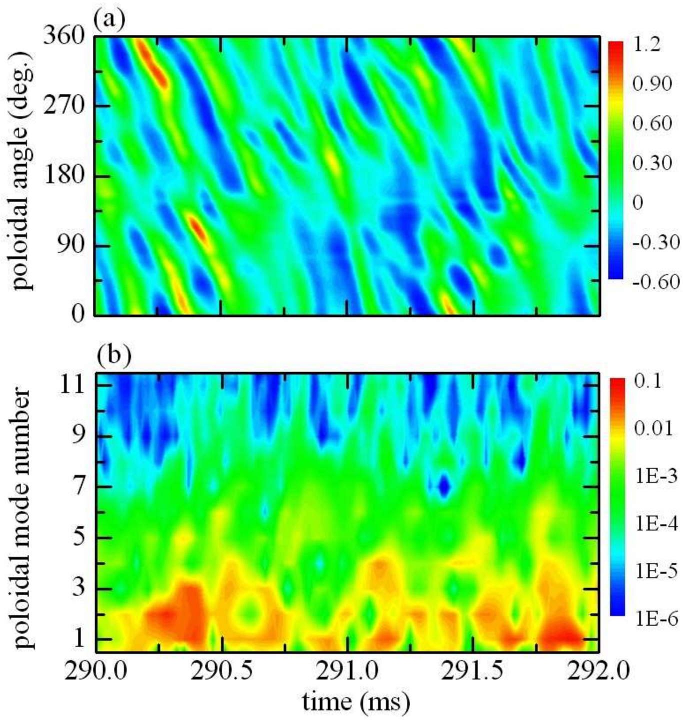

Figure 3: Contour map of (a) the spatiotemporal behaviour of the relative I_{is} fluctuations (linear scale) and of (b) the time development of the ploidal mode number (logarithmic scale) at B = 900 G.

Figure 4 shows the radial profile of the normalized probability density function (PDF), I_{is}/I_{is0}. Here, I_{is0} mean the value which has the maximum probability. At r = 20-30 mm, the PDF had a tail in the negative side: negative amplitudes were observed more often than the positive ones. On the other hand, there were more positive amplitudes at r = 35-40 mm. The positive and negative amplitudes were temporally / intermittently localized around the steep density gradient region (i.e., $r = 30 \pm 5$ mm), and it indicated that the localized structural change occurred in the narrow width.

In summary, we have developed a new azimuthal probe array to measure the turbulence structure. The frequency power spectrum became coherent or broad-band with changing the magnetic field. When the spectrum was broad-band, the density relative fluctuation level was very large (∼ 30 %). In this case, the ploidal structure of the fluctuation included some modes, and intermittent positive amplitude excited at r = 40 mm. These ploidal modes were temporally changed, and had the synchronized characteristics.

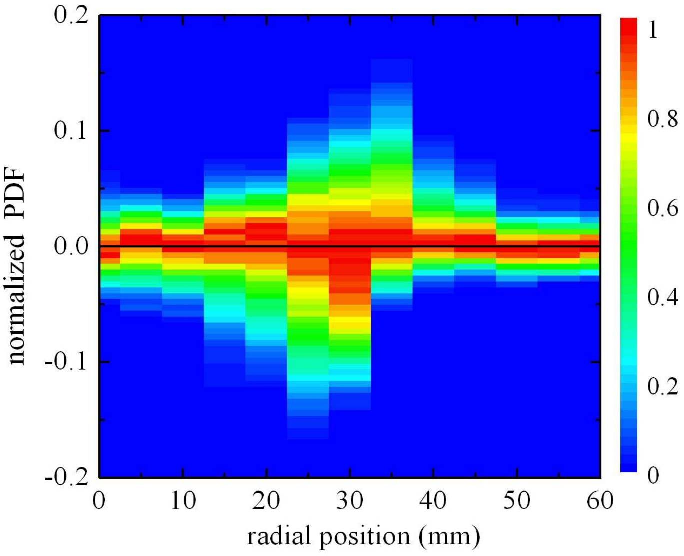

Figure 4: The contour map of the dependence of the PDF of I_{is} at 900 G.

This work was partially supported by the Grant-in-Aid for Specially-promoted Research (16002005)., Mext, Japan, and by the collaboration programs of NIFS (NIFS07KOAP017) and of the Research Institute of Applied Mechanics of Kyushu University. Authors would like to thank Prof. A. Fukuyama, Prof. M. Fukao, Dr. M. Ignatenko, Dr. M. Azumi, Prof. G. Tynan, Prof. U. Stroth, Dr. O. Grulke, Dr. F. Greiner, Prof. T. Ohkawa and Prof. F. Wagner for their useful discussions and comments.

References

[1] K. Itoh, S. -I. Itoh and A. Fukuyama, *Transport and Structural Formation in Plasmas* (IOP, Bristol, 1999).

[2] P. H. Diamond *et al.*, Plasma Phys. Control. Fusion **47**, R35 (2005).

[3] C. Schröder *et al.*, Phys. Plasmas **12**, 042103 (2005).

[4] S. Shinohara *et al.*, Plasma Phys. Control. Fusion **39**, 1479 (1997).

[5] N. Kasuya *et al.*, J. Phys. Soc. Jpn. **76**, 044501 (2007).

[6] K. Terasaka *et al.*, Plasma Fusion Research, in press.