§8. Research of Plasma Turbulence, Turbulent Transport and Experimental Methods

Itoh, S.-I., Yagi, M., Inagaki, S. (Kyushu Univ.),
Yamada, T., Nagashima, Y. (Tokyo Univ.),
Kasuya, N., Fujisawa, A., Itoh, K., Yamada, H.

To control and to predict the properties of the magnetically confined plasmas, the worldwide researches have been vitally carried out. However, transport phenomena that are difficult to understand under the existing paradigm for turbulent transport have been observed (e.g. non-local edge-core coupling and internal diffusion barrier formation in LHD). According to the recent theoretical achievement, the new concept is being established that the meso-scale fluctuating structure such as zonal flows and streamers coexist with microscale fluctuations, so as to regulate the turbulent transport. The new concept makes it enable to explain the changes in structure and transport occurring in much faster time scale than diffusive one.

This research aims at establishing a basis of turbulence transport study by improving a linkage between theory and experiment in the Linear Mirror Device Upgrade (LMD-U) at Kyushu University. Development of advanced methods for experimental data analysis is also in scope of our research.

Progress in Theory: A statistical theory of plasmas turbulence for the assessment for meso-scale fluctuation has been developed. In particular, not only like-scale (LS) interactions, which induce diffusive transport, but also disparate-scale (DS) interactions are analyzed. The results are applied to the study of global and transit response in turbulent transport by theoretically formulating space and time dynamics for LS and DS interactions on equal footing. A preliminary theory indicates, new phenomena such as "seesaw mechanism" appear in transport[1]. For identifying the mechanism of transit transport, a non-local picture based on the disparate-scale interactions is adopted. The new analysis method is applied to dynamic transport data from LHD[2].

A variation of geodesic acoustic mode (GAM) spectroscopy is proposed in order to measure the safety factor q in toroidal plasmas[3]. The dispersion relation of GAM has previously been studied and the eigenfrequency obtained[4]. Measuring GAM frequency at the peak of the radial eigenmode gives us the value of $\omega_{\mathrm{GAM}} \sim C_{\mathrm{s}}/R$, where C_{s} is the ion sound velocity and R is the major radius of the torus. It has previously been proposed to deduce the ion species from this measurement[5]. The lowest frequency of the ion acoustic mode (IAM), on the other hand, is given as $\omega_{\mathrm{GAM}} \sim C_{\mathrm{s}}/qR$. The ratio between the lowest frequency of the co-existing IAM and the frequency of GAM enables us to identify the q value in toroidal plasmas. The IAM is stable in high temperature toroidal plasmas. Low frequency IAM, however, can be excited by microscopic instabilities such as GAM and zonal flows. The nonlinear interaction associated with GAM has been studied experimentally by means of a novel method of bi-spectrum analysis. When both GAM and IAM are excited, the lowest frequency can be also detected by bi-spectrum analysis with high frequency resolution.

Experiment in LMD-U: Bi-spectral analysis and multi-channel measurement are becoming attractive investigating tools in plasma fluctuation studies. Drift wave excitation experiments were performed in the LMD-U and fluctuation of the ion saturation current was measured with a 64-channel poloidal Langmuir probe array. The two-dimensional (2D) (poloidal wave number and frequency) power spectrum showed a number of fluctuation peaks and broadband fluctuation in the poloidal wave numberfrequency space. In previous studies[6], the nonlinear mode couplings among the fluctuation peaks and broadband fluctuation were confirmed by bi-spectral analysis with considering the matching condition of frequency only. In turbulence, multi-scale phenomena coevolve in space and time, and thus the 2D bi-spectral analysis, which considers both the matching conditions of poloidal wave number and frequency, is required for understanding true character of plasma turbulence. The 2D bi-spectrum analysis revealed that more than ten fluctuation peaks have origins to only three original parent modes generated in the plasma.

Streamer, which is believed to enhance plasma transport to degrade the property of magnetically connement plasmas for fusion, is identified using massive data processing systems and advanced diagnostic tools, such as multi-channel probes and a 2-D movable probe, in the LMD-U[7]. The streamer is a poloidally localized, radially elongated global structure that lives longer than characteristic turbulence correlation time.

1) Itoh K., Itoh S.-I., et. al., International Congress on Plasma Physics 2008, Fukuoka, Japan

2) Inagaki S., et. al., Plasma Fusion Res. **3**, S1006 (2008)

3) Itoh S.-I., et. al., Plasma Fusion Res. **4**, 014 (2009)

4) Itoh K., et. al., Plasma Fusion Res. **1**, 36 (2006)

5) Itoh S.-I., et. al., Plasma Phys. Control. Fusion **49**, L7 (2007)

6) Yamada T., Itoh S.-I., et. al., Plasma Fusion Res. **3**, 044 (2008)

7) Yamada T., Itoh S.-I., et. al., Nature Phys. **15**, 072511 (2008)