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Transport Studies of Dimensionally-Similar Low-Energy-Density Plasmas in CHS Heliotron/Torsatron

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1. Introduction

Understanding of turbulent transport in a toroidal plasma is a very important and challenging task in magnetic confinement fusion research. Correlation measurements among plasma fluctuations are crucial to clarify underlying physics mechanisms in turbulent particle and heat transport of a toroidal plasma. In the case that electrostatic fluctuations are dominant the turbulent particle and electron heat fluxes are respectively expressed as $\Gamma_{turb} = \langle \tilde{n}_e \tilde{E}_\theta \rangle / B_t$ and $Q_e = \frac{3}{2}(T_e \langle \tilde{n}_e \tilde{E}_\theta \rangle + n_e \langle \tilde{T}_e \tilde{E}_\theta \rangle) / B_t$, where $\tilde{n}_e$, $\tilde{T}_e$ and $\tilde{E}_\theta$ are fluctuations of electron density, electron temperature and poloidal electric field, and B_t is the toroidal magnetic field strength. However, the correlation measurement is extremely difficult in high temperature plasmas, except for the measurements with Langmuir probes in the plasma edge region. If the transport behaviours in a high temperature plasma is simulated by those in a cold and low density plasma, detailed studies of turbulent transport are possible in such low energy density plasma with aid of Langmuir probes and may provide a knob to clarify unknown transport mechanisms. When the relevant dimensionless plasma parameters such as ν_* (effective collision frequency), β_t (toroidal beta) and relative scale length of density and temperature profiles except for ρ^* (normalized gyroradius) are the same in two kinds of plasmas, these two plasmas are “dimensionally similar” each other and their plasma transport is expected to be similar[1,2]. Based on this hypothesis, we have started a new simulation experiment on high temperature plasma transport using low energy density plasma obtained at low toroidal field (B_t <0.1 T) in CHS heliotron/torsatron. Main objectives of this new experimental campaign are as follows, (1) to compare fluctuation characteristics of both plasmas, (2) to obtain improved confinement regimes observed in hot plasmas and clarify physics mechanisms of turbulence suppression, and (3) to establish realistic transport model in a toroidal plasma through detailed comparison between experimental data and numerical simulations. In CHS, we intend to produce low energy density plasmas at low toroidal field (B_t ~0.09T) with 2.45GHz microwaves (up to 20 kW) and/or 9 MHz helicon waves(up to 100kW). The electron density from10^{16} m^{-3} to 10^{19} m^{-3} and the electron temperature from 5 eV to 100 eV are expected in low energy density plasma, where the expected effective collision frequency ν_*(=0.01-1) and toroidal beta

β_t (= 0.01 – 1 %) are comparable to those in high temperature plasmas at $B_t \geq 0.9$T.

2. Plasma parameters in an initial experiment

An initial experiment presented here was performed in so-called outward-shifted plasmas produced with up to 1 kW ECH. In these plasmas the toroidal beta value is still very low (β_t =0.002%), but $\nu*$ and ρ^* are comparable to those in CHS plasmas at $B_t \geq 0.9$T. This plasma is not dimensionally similar to that at high magnetic field. Nevertheless, it is interesting and important for this new experimental project to investigate characteristics of electrostatic fluctuations in the plasma. Plasma parameters and their fluctuations were measured with a triple probe [3]. Radial profiles of electron density n_e, electron temperature T_e and plasma potential V_s in a plasma produced by 0.4 kW ECH are shown in Fig.1(a). The density profile is slightly hollow and electron temperature has a very flat profile, where ECR layer is located at the magnetic axis. This hollow ne-profile is very similar to the ECH plasma obtained at high magnetic field ($B_t \geq 0.9$T). In Fig.1(b), the radial profiles of the radial electric field *Er* and its shear *Er'* are also shown.

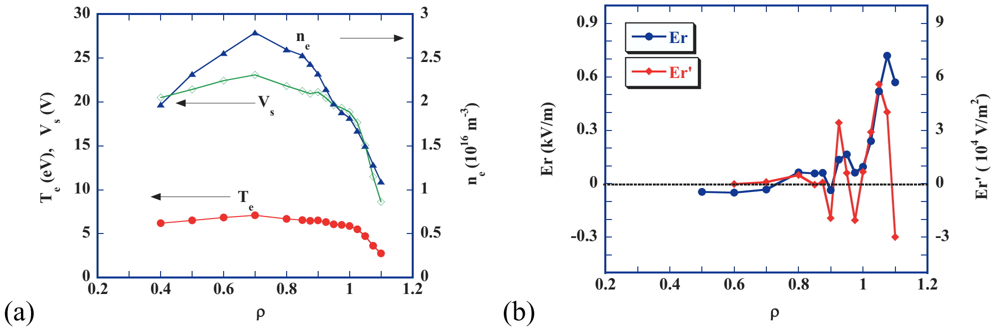

Fig.1(a) Radial profiles of electron temperature, density and plasma potential in a plasma produced by 0.4 kW ECH at Bt=0.0875T. (b) Er and Er' profiles derived from Vs.

3. Characteristics of electrostatic fluctuations

In Fig.2, we compare power spectra of ion saturation current and floating potential in the plasma edge (ρ~1) of a low energy density plasma produced by 2.45 GHz ECH at B_t~0.09 T and NBI heated plasma at B_t~0.9T, where ECH and NBI powers are respectively to be 0.4 kW and 500 kW. Although

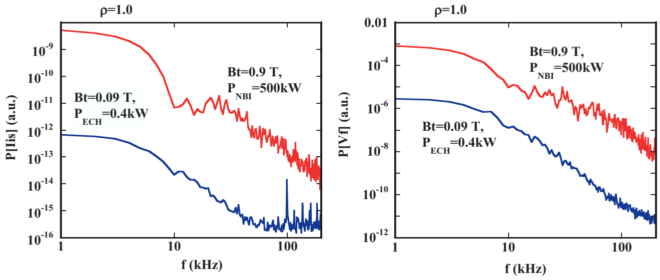

Fig.2 Comparison of frequency spectra of edge fluctuations measured at ρ ~1 for 0.4 kW ECH plasma and 500 kW NBI plasma, where P[Iis] of the ECH plasma is in the noise level in the range of f>70 kHz.

the magnitude of the spectral power of the NBI plasma is by three or four orders magnitude larger than that of ECH plasma, both spectra have a very similar turbulent character without clear coherent modes.

In this low energy density plasma, fluctuations can be measured even in the plasma core region with LP, as shown in Fig.3. All fluctuations of n_e, T_e and V_s are increased rapidly from ρ~0.7 toward the edge. That is, the relative amplitudes of n_e, T_e and V_s fluctuations are respectively ~5%, ~5% and ~1% at ρ~0.6, and ~13%, ~7% and ~23% at ρ~0.9. That is, the n_e-fluctuation level is two time larger than that of T_e. These features are very similar to that of edge turbulence in tokamak and helical plasmas[3-5]. Note that a reduction in these fluctuations is seen just inside the last closed flux surface. In this edge region, the radial electric field shear is fairly small (Er'~2-3.5 x10^4V/m^2) as shown in Fig.1(b), but the poloidal velocity shear is fairly large ~2.3-4x10^5 1/s) because of low magnetic field(B~0.09T). This reduction is also similar to that in the edge region of the TEXT ohmic plasma [6].

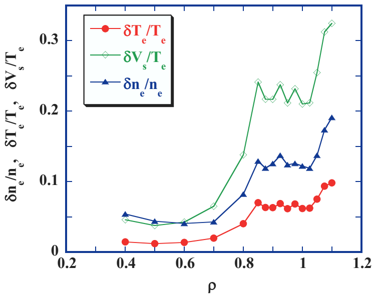

Fig.3 Radial profiles of the relative amplitude of Te, ne and Vs fluctuations.

Frequency spectra of these fluctuations in the scrape-off layer(ρ~1.1), edge (ρ~0.9) and core (ρ~0.6) are shown in Fig.4. Spectral power of n_e-fluctuations is concentrated less than ~50 kHz in the edge region and less than 30 kHz in the core region. On the other hand, the spectra of T_e and V_s fluctuations extend to relatively high frequency range more than 100 kHz in the core region as well as the edge. The turbulent particle flux Γ_{turb} is obtained from the correlation between n_e-fluctuations and poloidal electric field (E_θ) fluctuations which are derived from the difference of the floating potential signals at two points separated poloidaly by 6 mm. That is, the effect of T_e-fluctuations was neglected in the present analysis. The frequency spectrum of Γ_{turb} is concentrated in the low

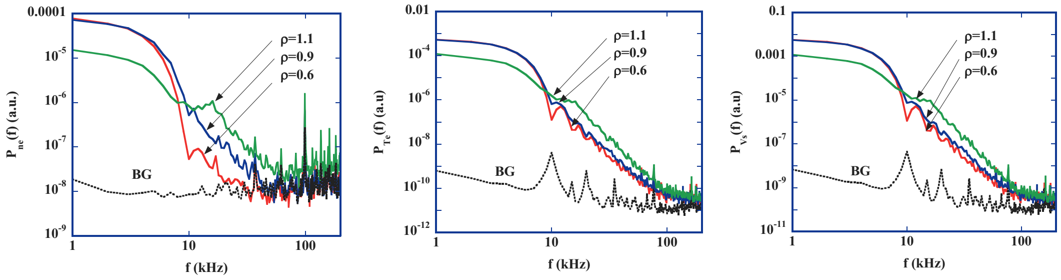

Fig.4 Frequency spectra of ne-, Te- and Vs-fluctuations for different radial locations at ρ=0.6(red), ρ=0.9(blue) and ρ=1.1(green). The black dotted curve denotes the noise level(BG).

frequency range less than ~20kHz. Note that the phase difference between ne- and E_θ- fluctuations is nearly 0 degree over the range of 100 kHz in the region of 0.4≤ρ≤.1.1. The radial profile of the particle flux integrated in the frequency region Γ_{turb} is shown in Fig.5. The turbulent particle flux is localized in the edge region from ρ~0.8 to ρ~1.1.

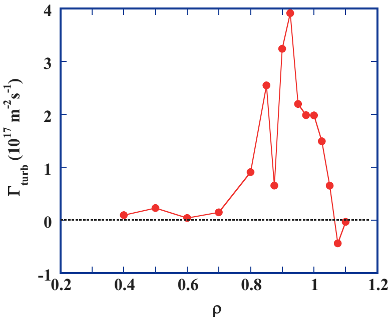

Fig.5 Radial profile of turbulent particle flux.

4. Summary

Characteristics of plasma profiles and fluctuations in a low density and low temperature plasma produced with ≤1 kW ECH at B_t~0.09T were investigated in CHS. Although the beta value of this plasma is very low as β_t ~0.002%, the other two parameters ρ^* (~0.07) and ν^* (~0.9) are similar to those in a high temperature plasma obtained at high magnetic field (B_t≥0.9T). Radial profiles of relative amplitude of n_e-, T_e-, and V_s fluctuations, power spectra of the ion saturation current and floating potential also exhibit similarity to those in high temperature plasmas. Even this preliminary experiment suggests a potentiality that transport characteristics might be simulated with those in a low energy density plasma obtained at low magnetic field condition (B_t≤ 0.1T). Experiments with 2.45GHz ECH of ~20 kW and/or helicon wave heating of ~100kW are required in order to adjust similar values of relevant dimensionless plasma parameters such as ν^*, β_t, ρ^* and the relative scale length of density and temperature profiles, and to proceed detailed comparison of transport characteristics with those of high temperature plasmas.

References

[1] B.B. Kadomtsev, Sov. J. Plasma Phys.**1**, 295(1975).

[2] R.E. Waltz et al., Phys. Rev. Lett. **65**, 2390(1990).

[3] K. Ohkuni, K. Toi et al., Phys. Plasmas **8**, 4035 (2001).

[4] Ch.P. Ritz et al., Phys. Rev. Lett. **62**, 1844(1989).

[5] B.A. Carreras, IEEE Trans. Plasma Sci. **25**, 1281 (1997).

[6] Ch.P. Ritz et al., in Proc.13th IAEA Conf. On Plasma Phys. Contr. Fusion Res. (Washington D.C., 1990), Vol.**2**, IAEA, Vienna 589.