*34th EPS Conference on Plasma Phys. Warsaw, 2 - 6 July 2007 ECA Vol.**31F**, P-1.124 (2007)*

High-k density fluctuation experiment in HT-7 tokamak

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Understanding transport in magnetized plasmas is a subject of utmost importance for the design of future reactor. There is no satisfactory model for explaining the anomalous large particle and energy transport of electrons. It is up to two orders of magnitude larger than that predicted by neoclassical theory. It is believed that the turbulent fluctuations in the plasma are responsible for this anomalous transport[1] .it deserve attention since the alpha particles will heat mainly electrons in burning plasmas. The density fluctuation study has become an important feature of fusion research. A large variety of modes can become unstable, and they differ in particular by their typical scale. The most commonly invoked[2,3] are the ion temperature gradient mode(ITG) with a typical scale longer than the ion Larmor radius ρ_i ($k_\perp\rho_i \leq 1$),the trapped electron mode (TEM) also the order of ρ_i and the smaller scale electron temperature gradient mode (ETG),with $k_\perp\rho_i >> 1$.Determining how the turbulence scales with plasma typical length is important to identify the driving mechanism[3].Collective light scattering measurement is a powerful tool for investigating fluctuations and their relation with anomalous transport since it allows a direct, discriminating analysis of the turbulent scales. In HT-7 tokamak, A new three k-wavevector CO_2 laser collective scattering diagnostics is dedicated to turbulence and transport studies. In this letter, The k spectrum, a new density fluctuation component and the unstable erupt are observed in electron transport channel.

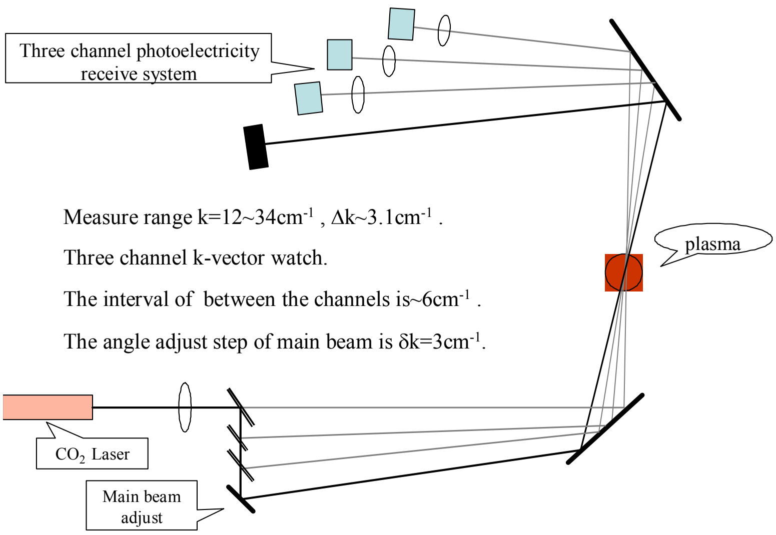

Fig.1. CO2 laser collective scattering system

HT-7 is a medium sized superconducting tokamak with circular limiter (major radius R=1.22m, minor radius a=0.27m) .The three k-wavevector CO_2 laser collective scattering diagnostics shown in Fig.1. The CO_2 laser beam power is about 10 watt which is separated into four beams by the beam splitters. These beams (three beams local oscillator LO and one main beam) pass along vertical chord through the plasma and cross in one point at core plasma .The

LO beams go to three photovoltaic detectors. The anger of LO beams is fix. The angles of main beam cross with the local beams defining the moduli (k_1,k_2 and k_3)of the observation wavevectors. The angles can be changed by adjust the main beam and allowing selection of three wavenumbers between 12 and 34 cm^{-1}. The wavenumber resolution of system is Δk=3.1cm^{-1}. the local beam power is about $5*10^{-4}$ times the main beam power. Therefore, there is no significant scattering light from the local beams.the three observed wavevectors, perpendicular to the beams. the local oscillator beams mixed with the scattered light are sent to three HgCdTe detectors(it is a homodyne measure system). After 40 dB gain preamplification. The detector signals are filtered with band-pass from10kHz to 2MHz.then, through IF amplifiers with 40 dB gain to go to a date acquisition system. This is a four channel date acquisition system and each channel with a sampling rate of 4MHz .

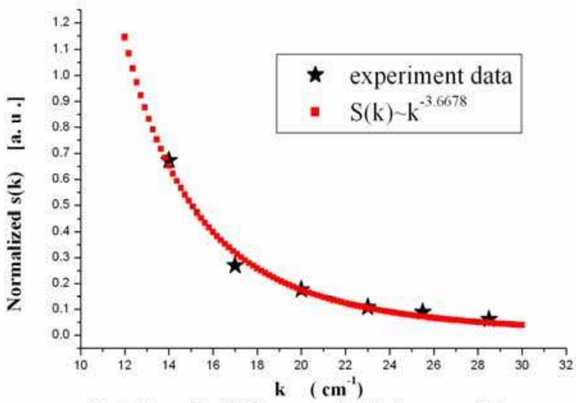

Fig.2. Normalized S(k) spectra for discharge condition I_p=100kA,B_t=1.68T,n_e=2.0*$10^{19}m^{-3}$

In a first set experiments, several identical ohmic shots were applied in deuterium plasmas ,with Bt=1.68T, Ip=100kA, and the plasma density $<n_e>$ = $2.0*10^{19}m^{-3}$. the ion Larmor radius at T_e is evaluated around $\rho_s \sim 0.9\pm0.2$mm in r/a=0.6 during the ohmic discharges the k-spectrum and the fitting line is shown in fig.2 .the power spectra obtained with the acquisition system were integrated over the frequency to obtain the fluctuation power for each k value. the line obtained by fitting k=14cm^{-1} up to k=28.5cm^{-1}.it is observed decreasing as $k^{-3.67}$and similar to the accustomed results decreasing as $k^{-3.5\pm0.5}$ most experiments[4,5,6].

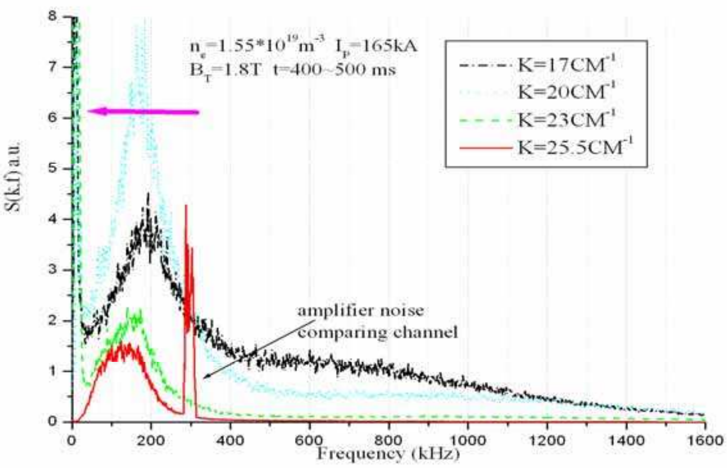

Fig.3. the frequency spectrum variety with k-wavenumber changing at the first probing channel

The second set experiments are three identical ohmic discharges with deuterium .The discharge conditions is B_t=1.8 T, I_p =165kA and plasma density $<n_e>=1.5*10^{19}m^{-3}$. The ion Larmor radius at T_e is evaluated around $\rho_s \sim$ 1.3mm in r/a=0.6 during the ohmic discharge. Fig.3 shows frequency spectrum variety with k-wavenumner changed at the plasma flat region. it is the first probing channel and the comparing channel (the second probing channel). Fig.4 shows the frequency spectrum variety with k-wavenumber increasing at the third probing channel. In the fig.3, the normal broad frequency component strength decrease and the narrow frequency peaking go to a lower frequency when k-wavenumber increase from 17 cm^{-1} to 23 cm^{-1}. in the fig 4 , the narrow frequency component peaking go to the high frequency when k-wavenumber increase from 28.5 cm^{-1} to 34 cm^{-1}. The measure district is sameness during k scan experiment. $\omega=k_\theta v_p$, the v_p cannot be changed with k-wavenumber increasing . So the frequency spectrum profile change cann't be explained by plasma poloidal rotation effect. We changed plasma density to $<n_e>=2.0*10^{19}m^{-3}$ and found the same narrow frequency fluctuation component change.

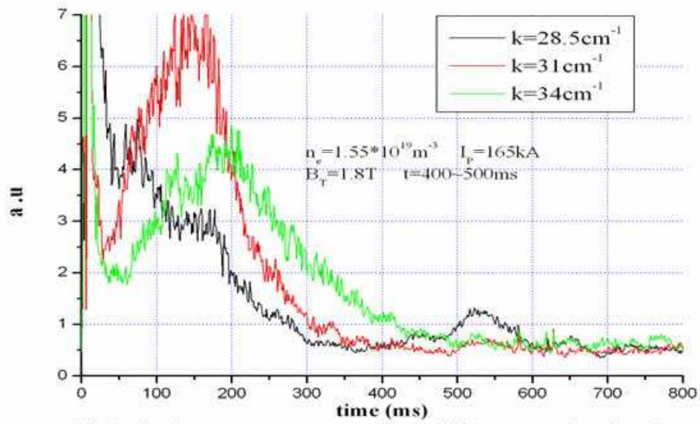

Fig.4. the frequency spectrum variety with k-wavenumber changing at the third probing channel

The $v_p \approx -130$ ms^{-1} in k_θ=17~23cm^{-1} and $v_p \approx$ 100ms^{-1} in k_θ=28.5~34cm^{-1}. We changed plasma discharge condition, B_t=1.92T, I_P=160kA and plasma density ramp down from $<n_e>=3.5*10^{19}m^{-3}$ to $<n_e>=1.0*10^{19}m^{-3}$ in 0.53s. We found a broad frequency component transform into a narrow frequency component.(fig.5.)

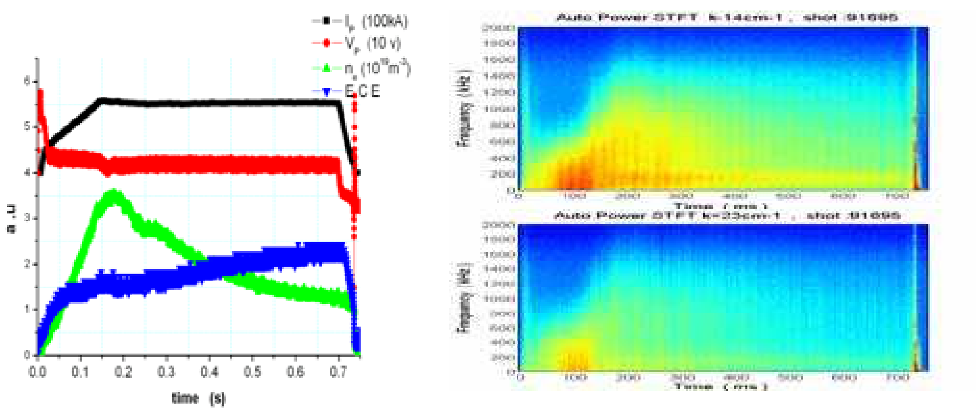

Fig.5 the broad frequency density fluctuation component transform into the narrow frequency density fluctuation component

The third set experiment is low hybrid wave current drive experiment in HT=7 tokamak. (fig.6.). We changed experiment condition in low hybrid wave power and plasma density. We watched a violent instability erupted in medium and high k density fluctuation (k_θ=14cm^{-1} k_θ=23cm^{-1}). We found it has critical value that correlation with LHCD power and plasma density. We found no correlation with high energy particle.

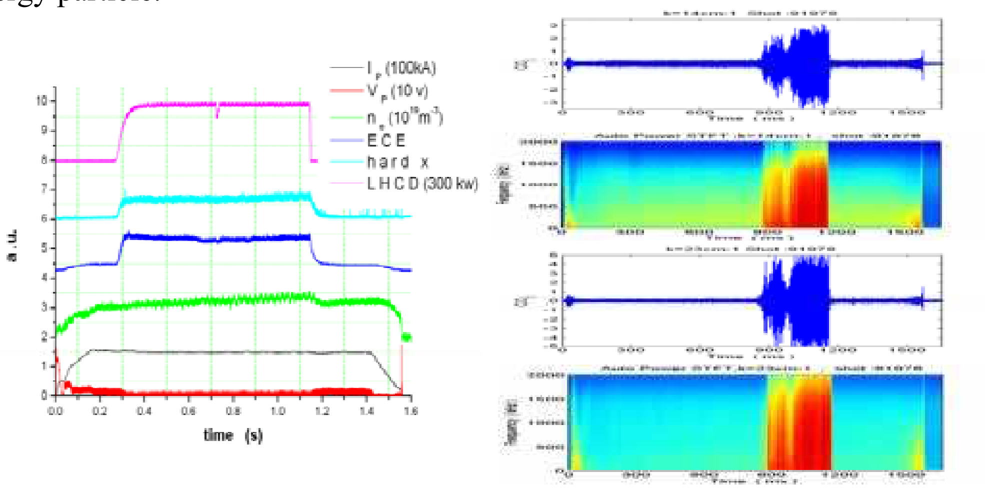

Fig.6.a violent instability erupted in low hybrid current drive experiment

In conclusion, high k density fluctuation is measured by the new CO_2 laser collective scattering diagnosis in HT-7 tokamak. In a low plasma current discharge condition, Ip=100kA,Bt=1.68T and the plasma density $<n_e>$ = 2.0*10^{19}m^{-3}. The fluctuation wavenumber spectrum $S(k_\perp)$ falls off monotonically, following a power law $S(k_\perp) \propto k_\perp^{-3.67}$,it is accordant with most experiments $S(k_\perp) \sim k_\perp^{3.5\pm 0.5}$. in a higher plasma current discharge condition. I_p =165kA ,B_t=1.8T and plasma density $<ne>$=1.5~2.0*10^{19}m^{-3}.we watched the new narrow frequency spectrum fluctuation component in ETG mode range. We found there is violent instability erupted in medium and high k density fluctuation.

Acknowledgment

Author thank for China-Japan core-university program give two chance to visit JAERI. It is very important for author to build CO_2 laser collective scattering system and study the way about electron transport experiment. This experiment is supported by national natural science foundation (10335060).

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