Core plasma density fluctuation measurement in low hybrid drive experiment in HT-7 tokamak

Y.D.Li, W.Y.Zhang, S.Y.Lin, X.Gao, X.D.Zhang, J.Li and HT-7 Team

Institute of Plasma Physics, Chinese Academy of Sciences, Hefei,China

Understanding the mechanism of plasma transport in tokamaks is one of the great challenges of fusion research. Indeed, since most explanations of his phenomenon are based on some type of plasma turbulence, particularly difficult problem to explain the transport of electron energy, since in tokamak reactor a large fraction of the energy of charged fusion products-necessary to sustain the nuclear fusion reactions-would be released directly to the electrons. Both theory and experiments suggest that a short-scale turbulence was considered as the cause of the anomalous electron transport in tokamak[1,2] . Magnetic shear is thought to be important because it can stabilize some short-scale turbulence such as trapped electron modes, a candidate to explain the observed anomalous electron transport in tokamak.[3]

The magnetic shear $s=(r/q)dq/dr$ is the rate of change of the average pitch of the magnetic field, denote here by the tokamak safety factor q ,with respect to minor radius. Most tokamaks operate with inductive current drive, which normally produces a peaked current density profile at the magnetic axis due to the strong dependence of the plasma conductivity on the electron temperature. Noninductive current drive can generate a nonmonotonic safety factor q or a hollow current density profile. the lower hybrid current drive is a kind of noninductive current drive ,It can provide a power tool for achieving magnetic shear .Increasing LHCD power, the target q profile can be modified, especially toward a more revered profile [4-6].Turbulent transport in toroidal plasmas is usually driven by microscopic drift wave instabilities of which the linear properties can be affected by magnetic shear[7]. On the HT-7 tokamak (a circular cross-section superconducting tokamak with R=1.22m, a=0.27m), a three channel CO_2 laser coherent scattering diagnostics is dedicated to short-scale turbulence and magnetic shear studies in the low hybrid current drive experiment[8]. As shown in Fig.1. The core density fluctuation in the poloidal direction was observed with a range of wavenumber measurement of k_θ=12cm^{-1} to 30cm^{-1} ($k_\theta\rho_s=1$ *to* 4),and the poloidal direction wave number

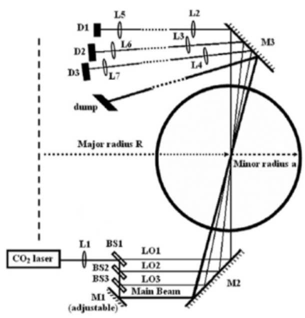

Fig.1 CO2 laser collective scattering system. Measure range k_θ=12~30cm^{-1},Δk=2.5cm^{-1}.

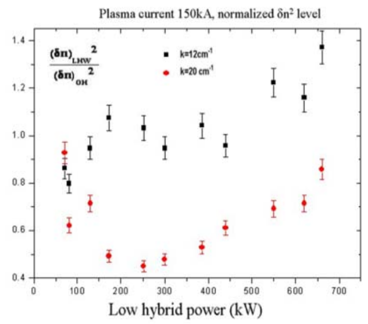

Fig.2 the ohmic normalized density fluctuation level as a function of LHCD power. B_t=1.8T, n_e=1.5×10^{19}m^{-3} and I_P=150kA.

resolution of scattering system is $\Delta k_\theta \approx 2.5$cm^{-1} ,where ρ_s is the ion Larmor radius at T_e.

To study the effects of magnetic shear on short-scale turbulence in tokamak, we have conducted an experimental study of turbulent fluctuation in plasma with LHCD power scanning on HT-7 tokamak. After the Boronization wall condition, The plasma parameter were toroidal magnetic field B_t=1.8T,central line average density $n_e=1.5\times10^{19}$m^{-3} with deuterium as the working gas. The level of density fluctuation within LHCD power scanning was divided by within a regular ohmic shot and selected during the flat top phase of both plasma current and density. When plasma current at I_P=150kA, with a low hybrid wave power scanning from 50kw to 650kw, the ohmic normalized density fluctuation level [9] as a function of LHCD power was shown in fig.2. The ohmic normalized density fluctuation level of k_θ=12cm^{-1} was higher than that of k_θ=20cm^{-1} on the same LHCD power scanning. $k_\theta \rho_S$=1.38~1.57 for k_θ=12cm^{-1} and $k_\theta \rho_S$=2.2~3.22 for k_θ=20cm^{-1}. When plasma current at I_P=120kA, with the same power sanning, the ohmic normalized density fluctuation level of k_θ=12cm^{-1} was lower than that of k_θ=20cm^{-1} .

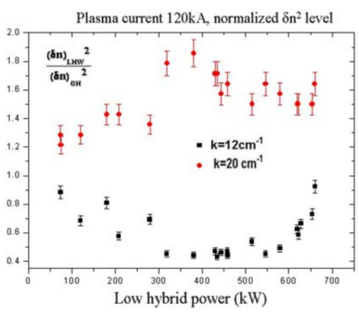

Fig.3 the ohmic normalized density fluctuation level as a function of LHCD power. B_t=1.8T, n_e=1.5×10^{19}m^{-3} and I_P=120kA.

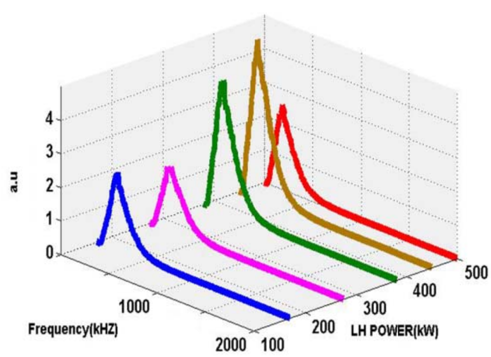

Fig.4 I_P=130kA n_e=1.5×10^{19}m^{-3} frequency spectrum k_θ=12 cm^{-1}

Fig.3 was shown the ohmic normalized density fluctuation level as a function of LHCD power .The shape of frequency spectrum for k_θ=12cm^{-1} and k_θ=20cm^{-1} were not changed during the LHCD power scanning. The effect of the LHCD driven current profile in plasmas current 150kA and 120kA was dissimilar. So that magnetic shear was.

After litium coating wall condition, three series deuterium plasmas discharges with LHCD power scanning were performed at toroidal magnetic field B_t=1.9T. The poloidal beta was $\beta_P\approx$0.3~0.5. The ohmic noralized fluctuation level had been probed on k_θ=12cm^{-1} and k_θ=24cm^{-1} simultaneously. The first series parameter were plasma current I_P=130kA, central line average density $n_e=1.5\times10^{19}$m^{-3} .Fig.4 show the shape and amplitude of the ohmic normalized fluctuation frequency spectrum change with LHCD power scanning on k_θ=12cm^{-1}. And Fig.5. show that on k_θ=24cm^{-1}.

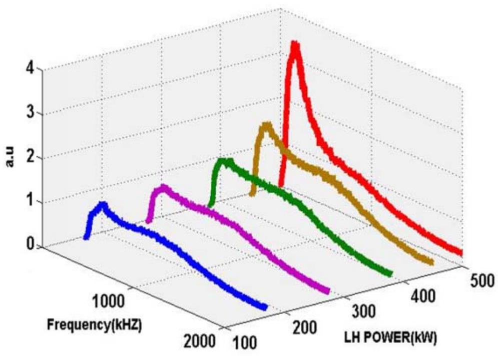

Fig.5 I_P=130kA $n_e=1.5\times10^{19}$m^{-3} frequency spectrum k_θ=24 cm^{-1}

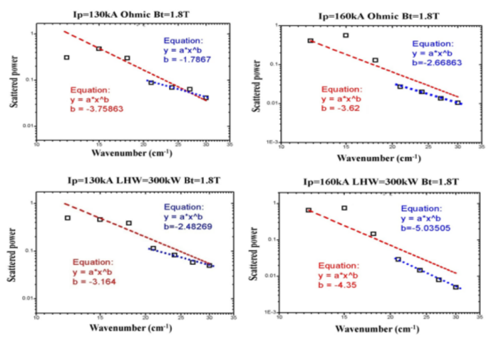

Fig.6 the k_θ wavenumber spectrum compare with ohmic and LHCD plasma discharge in totoidal magnetic field . B_t =1.8 T.

A LHCD power threshold P_{LH}~500kw has been found. While LHCD power beyond the threshold, the fluctuation level of different wavenumber range act differently, the profile of ohmic normalized frequency spectrum remain unchanged on k_θ=12cm^{-1} while a 200kHz frequency peak increasing on k_θ=24cm^{-1}.The ohmic normalized fluctuation level of k_θ=12cm^{-1} and k_θ=24cm^{-1} were increasing with LHCD power before the power threshold. But when LHCD power reaches the threshold. the ohmic normalized fluctuation level of k_θ=12cm^{-1} suddenly drop to a low level and that of k_θ=24cm^{-1} has a massive increase. Some time a improved confinement has been observed and a electron interal transport barrier (ITB) may be formed on the HT-7. ($k_\theta\rho_S$=1.11~1.57 was in TEM modes wavenumber range for the k_θ=12cm^{-1}and $k_\theta\rho_S$=2.23~3.14 for was in ETG modes wavenumber range for the k_θ=24cm^{-1}). In the second series parameter , the plasma current I_P=160kA and the central line average density n_e=2.0×10^{19}m^{-3} . a increasing LHCD power threshold has been found during LHCD power scanning. In the third series parameter, the plasma current I_P=160kA and the central line average density n_e=1.5×10^{19}m^{-3}. The LHCD power threshold has not been found during power scanning from 100kw to 550kw. The different come from the magnetic shear generated by the low hybrid current drive remains localized off-axis was moved outwards .

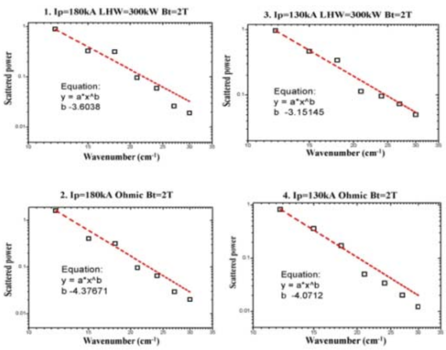

Fig.7 the k_θ wavenumber spectrum compare with ohmic and LHCD plasma discharge in totoidal magnetic field . B_t =2.0 T.

After the Boronization wall condition, The density fluctuation wavenumber spectrum compare experiment was done in low hybrid current drive plasma and ohmic plasma with different plasma parameter. Fig.6. shown the k_θ wavenumber spectrum on the toroidal magnetic field B_t=1.8T, the central line average density n_e=2.0×10^{19}m^{-3}, the low hybrid current drive power P_{LH}=300kW and plasma current I_P=130kA, 160kA. Fig.7. shown the k_θ wavenumber spectrum on the toroidal magnetic field B_t=2.0T, the central line average density n_e=2.0×10^{19}m^{-3}, the low hybrid current drive power P_{LH}=300kW and plasma current I_P=130kA, 180kA.

The work was supported by the National Natural Science Foundation of China (Grant No. 10875147 ,10975159), National Science Research Program of China (Grant No. 2009GB107005)

Reference

[1]E.Mazzucato,R.E.Bell,S.Ethier et al Nucl.Fusion **49** (2009) 05501

[2] E.Mazzucato Plasma Phys.Control.Fusion **48** (2006) 1749

[3]F.M.Levinton,M.C.Zarnstorff,S.H.Batha et al Phys.Rev.Lett.**75** (1995) 4417

[4]C.Castaldo,R.Cesario,A.Cardinali et al Phys.Plasmas **9** (2002) 3205

[5]Li Duo-chuan, Li You-yi Chin.Phys.Lett.**15** (1998) 582

[6]Kuang Guang,Xu Wei-hua,Zhang Xiang-qin et al Chin.Phys.Lett.**15** (1998) 435

[7] E.Mazzucato,S.H.Batha,M.Beer et al Phys.Rev.Lett.**77** (1996) 3145

[8]Li Yadong, Li Jiangang, Zhang Xiaodong et al Plasma Sci. and Tech **11** (2009) 529

[9]P.Devynck, F.Clairet, X.L.Zou, et al Phys.Control.Fusion **39** (1997) 1355