26^{th} EPS Conf. on Contr. Fusion and Plasma Physics, Maastricht, 14 - 18 June 1999 ECA Vol.23J (1999) 405 - 408

Correlation measurement during ITB degradation phase by using core correlation reflectometer in JT-60U reversed shear plasma

K. Shinohara, R. Yoshino, R. Nazikian*, T. Fujita and Y. Kishimoto

Naka Fusion Research Establishment, Japan Atomic Energy Research Institute, Naka-machi, Naka-gun, Ibaraki 311-0193, Japan

**Princeton Plasma Physics Laboratory, P.O. Box 451, Princeton, New Jersey 08543*

1. Introduction

Recently high performance plasmas with reversed or weak magnetic shear profile were found in many tokamak devices [1-6]. These plasmas have an internal transport barrier, ITB, near a q-minimum position, or in the weak magnetic shear region, where q is a safety factor. It is important to understand what happens in the ITB region in order to operate such high performance plasmas in fusion reactors. There has been research in done to understand ITB formation [7-9] and ITB degradation [10]. Here we present the first radial correlation measurements in the ITB region during ITB degradation in JT-60U reverse shear plasmas.

2. Diagnostics

Core correlation reflectometer has been newly installed on the JT-60U tokamak in collaboration with PPPL[11]. The reflectometer measurements can be used to model the electron density fluctuations near the cut-off layer at which the launched millimeter wave is reflected. The target of this reflectometer is to infer the fluctuation and its correlation in the core region, especially in the ITB region of reversed shear plasma.

The reflectometer consists of four channels, two of which operate in fixed frequency and the other two channels are tunable. The frequencies of the launched waves are 115 and 130 GHz for the fixed frequency channels, and $122.5 \pm f_{bank}$ GHz, where f_{bank} = 2.73, 5.28, 6.37, 6.93 and 7.27 GHz, for the variable channels. The tunable channels can step through the five frequencies every 60 ms. The correlation of the fluctuations is determined from the correlation between fixed and variable frequency channels and therefore the radial profile of the correlations can be measured every 60 ms in a discharge. The right hand polarized extraordinary, X-mode, is used. Quadrature phase detection is used to measure the complex amplitude, namely electric field, of the reflected wave. The cut-off position of the reflectometer is located within the ITB region of the electron density profile in the discharges presented in the following sections.

3. Measurement at minor collapse

Figure 1 shows the temporal evolution of the discharge with a minor collapse. Large

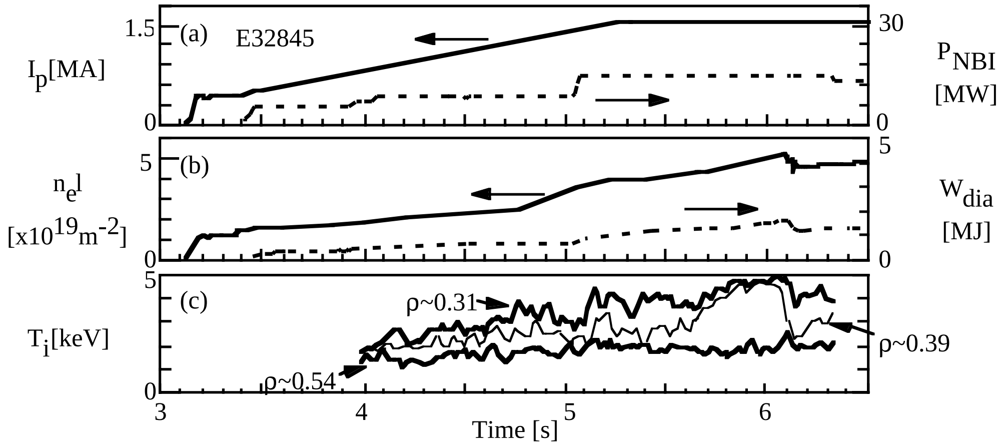

Figure 1: Waveform of R/S plasma with a minor collapse at about 6.1s. The toroidal field is 3.73 T. The discharge gas is hydrogen.

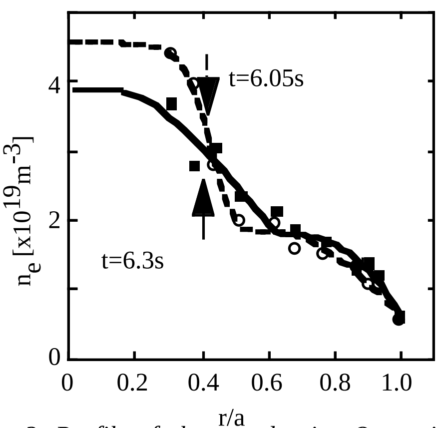

Figure 2: Profile of electron density. Open circle shows the value at 6.05s. Closed square shows the value at 6.3s. The measured point is shown by an arrow.

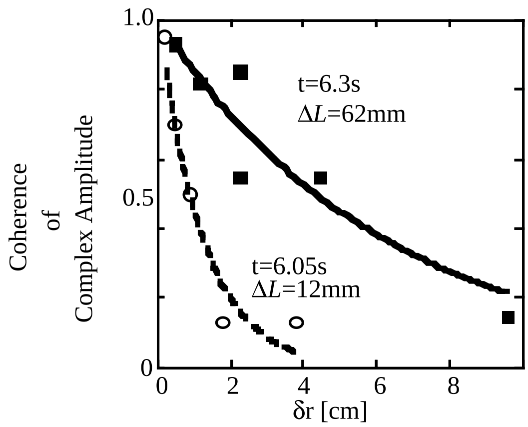

Figure 3: Profile of coherence of measured complex amplitude. Open circle shows the value at 6.05s. Closed square shows the value at 6.3s. The decay length is shown.

difference between T_i(ρ~0.31) and T_i(ρ~0.54) at 5.5 – 6 s in Fig. 1(c) indicates the existence of the ITB of the ion temperature. A minor collapse occurs near 6.1 s. Drops of the electron density, the stored energy and the ion temperature can be seen in Figs. 1(b) and (c). The ITB of the electron density relaxes after the collapse as shown in Fig. 2. The correlation of the complex amplitude for frequencies higher than 10 kHz is plotted in Fig. 3 as a function of the radial separation, δr, of two channels. For this case, the measurement location lies in almost the middle of the ITB of the electron density as shown in Fig. 2. The complex amplitude in the range of the frequency can be dominated by the wave scattered by the density fluctuations near the cut-off layer, and the radial profile of the correlation of the complex amplitude can be used to infer that of the density fluctuations. The measured value is fit by an exponential function, $\exp(-\delta r / \Delta L)$. The radial decay length, ΔL, which can scale with the correlation length, is also shown in the figures. The decay length increases from 12 mm to 62 mm, which suggests that the density correlation length significantly increases after the minor collapse. Therefore, in the case of an abrupt degradation with a minor collapse, the relaxation of ITB correlates with the radial correlation length of the electron density fluctuations.

4. Measurement during gradual ITB degradation

Figure 4 shows a temporal evolution of the discharge with a gradual ITB degradation.

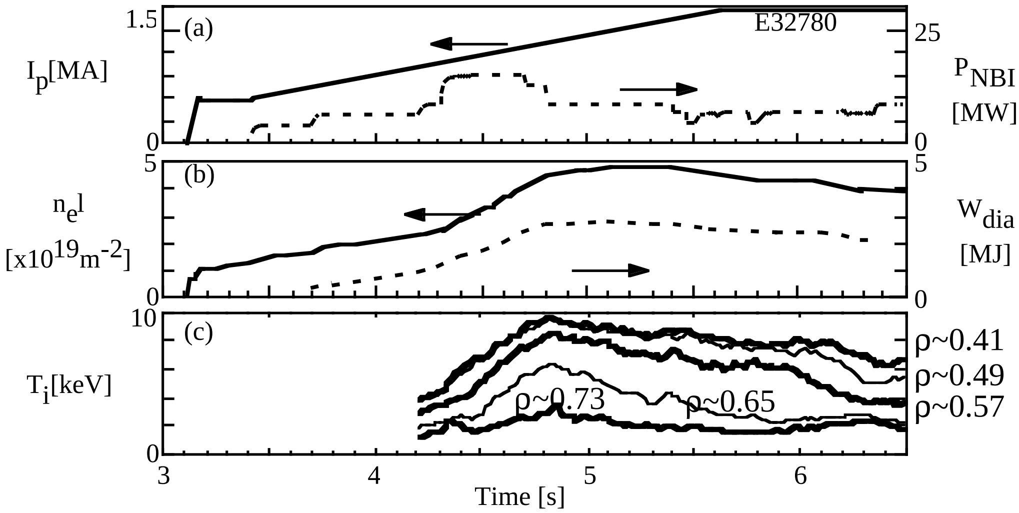

Figure 4: Waveform of R/S plasma with gradual degradation. The toroidal field is 4.05 T. The discharge gas is deutrium.

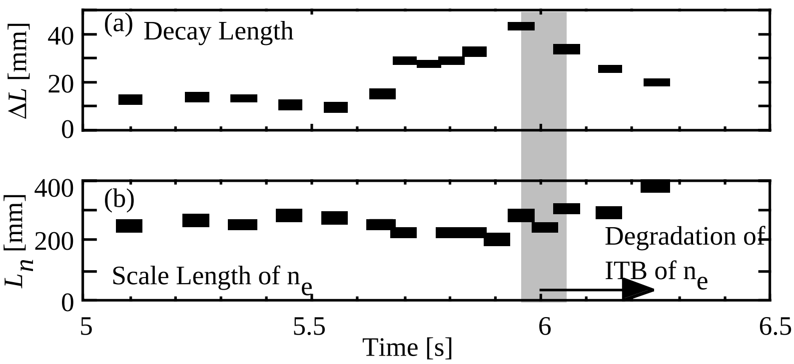

Figure 5: Temporal evolution of decay length of complex amplitude (a), scale length of electron density (b).

The rapid development of the ITB of the ion temperature is seen ~4.45 s as shown in Fig. 4(c). The ion temperature and the stored energy keep increasing until around 4.8 s before the injected power of the neutral beam is reduced from 14.7 MW to 6.4 MW. The ITB of the electron density is sustained with a steep gradient till about 6 s and then the ITB of the electron density starts to relax. Figure 5 shows a temporal evolution of the measured decay length, ΔL, of the complex amplitude, and the scale length of the electron density at the measured point of the reflectometer. The decay length at 6.15 s, after the degradation of the ITB of the electron density, is longer than that at 5.1 s, before the degradation. On the other hand, we also observed the increase of the decay length from about 5.6 s, even though the scale length of the electron density is almost constant.

5. Discussion and Summary

The radial mode width of the electrostatic drift wave in the linear theory is estimated by the equation, $|\rho_i L_{Ti} / s|^{1/2}$, where ρ_i is the ion Larmor radius, L_{Ti} is the scale length of the ion temperature and $s=r/q\, dq/dr$ is the magnetic shearing parameter [12]. The radial mode width estimated by the above equation is 20 – 40 mm and is comparable with the observed radial decay length. However the relation between measured decay length and η_i or ITG mode is not clear so far.

The increase of the decay length before the degradation of the ITB of the electron density might suggest the causality between the radial mode width of the density fluctuations and the degradation of the ITB of the electron density. However plasma parameters such as a profile of toroidal rotation is not constant since the co- and counter tangential beam powers were not kept constant. We need further investigation in order to understand this increase of the decay length.

By using a newly installed X-mode reflectometer, radial correlation measurement in the ITB region have been performed for the first time during ITB degradation phase in a JT-60U reversed shear plasma. It was observed that the radial decay length became longer when the ITB of the electron density deteriorated in two types of the discharges; an abrupt degradation case with a minor collapse and a gradual degradation case.

References

[1] T.Fujita *et al*., Phys. Rev. Lett. **78**, 2377 (1997).
[2] F.M.Levinton *et al*., Phys. Rev. Lett. **75**, 4417 (1995).
[3] E.J.Strait *et al*., Phys. Rev. Lett. **75**, 4421 (1995).
[4] M.R. de Baar *et al*, Phys. Rev. Lett. **78**, 4573 (1997).
[5] C.Gormezano *et al*, Phys. Rev. Lett. **80**, 5544 (1998).
[6] O.Gruber *et al*., *(Proc. 17th Int. Conf. Yokohama), IAEA-F1-CN-69/OV4/3*, Vienna, 1998, IAEA.
[7] R.Nazikian, K.Shinohara, R.Yoshino, T.Fujita, H.Shirai, G.J.Kramer and the JT-60 Team., *(Proc. 17th Int. Conf. Yokohama), Post Deadline*, Vienna, 1998, IAEA.
[8] E.Mazzucato *et al*., Phys. Rev. Lett. **77**, 3145 (1996).
[9] C.L.Rettig *et al*., Phys. Plasmas **4**, 4009 (1997).
[10] E. J. Synakowski *et al*., Phys. Rev. Lett. **78**, 2972 (1997).
[11] K.Shinohara, R.Nazikian, T.Fujita, and R.Yoshino, submitted to Rev. Sci. Instrum. (1999).
[12] Y.Kishimoto, J-Y.Kim, W.Horton, T.Tajima, M.J. LeBrun, S.Dettrick, J.Q.Li and S.Shirai, *(Proc. 17th Int. Conf. Yokohama), IAEA-CN-69/TH1/2*, Vienna, 1998, IAEA.