SHORT WAVELENGTH FLUCTUATIONS AND ELECTRON HEAT CONDUCTIVITY IN ENHANCED REVERSED SHEAR PLASMAS IN TFTR*

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Abstract

Short wavelength fluctuations with $k \sim \omega_{pe}/c$ and $k\rho_i \sim 5$ are detected by microwave scattering in the core of TFTR plasmas with reversed magnetic shear. They propagate in the ion diamagnetic drift direction with a frequency below the ion diamagnetic drift frequency in the frame of reference where $E_r=0$. We present the raw data on the electron temperature profile from which the electron thermal conductivity is determined. The variation of the fluctuation amplitude in the plasma core correlates with the variation of the local electron heat conductivity, suggesting that these fluctuations may be the cause of anomalous electron heat transport in these plasmas. It also offers an explanation for the χ_e/χ_i ratio observed in these plasmas.

Transport barriers in enhanced reversed shear (ERS) plasmas have been formed which reduce the ion thermal conductivity χ_i to the neoclassical level in the core region ($r < r_{min}$) where long wavelength ($k\rho_i < 1$) fluctuations are absent from reflectometry data [1,2]. This was explained by the stabilization of ITG turbulence due to ExB velocity shear. However, the electron thermal conductivity χ_e remains anomalously high. This paper reports evidence of correlation between short wavelength ($k\rho_i > 1$) fluctuations and χ_e in the plasma core.

The experiment was carried out in a 1.6 MA ERS plasma in TFTR with B=4.6 T at R=2.6m, a=0.94m, Te(0)≤8keV, Ti(0)≤26keV. The neutral beam power was stepped up from 7MW to 28MW for 0.4s starting from t=2.5s, and ERS transition occured at t=2.66s. Short wavelength fluctuations with k~8.9/cm were detected by microwave scattering with the center of the scattering volume 15 cm below the magnetic axis. The schematic of the scattering setup is shown in Fig.1. The frequency spectrum of the scattering signal is shown in Fig.2. There is a peak near 130kHz whose amplitude varies in time. This variation appears to correlate with the local χ_e.

The electron temperature profile was determined from the electron cyclotron emission detected by a grating polychrometer. These results were calibrated by the Michelson interferometer and confirmed to be reliable. The raw data Te(R) are shown in Fig.3a. The plasma equilibrium and the transport coefficients were calculated by the TRANSP code, and Te(r) and $\chi_e(r,t)$ are depicted in Fig.3b and Fig.4. Since χ_e is calculated from the spatial gradient of Te, the spiky feature should not be taken seriously. Nevertheless, at t=2.6 s, two peaks of χ_e appear at r/a~0.1 and 0.45. They correspond to the flat regions of Te(r) in Fig.3b. One can even infer these from the raw data shown in Fig.3a based on the difference in dTe/dR and the neutral beam power. The analysis procedure in TRANSP is complicated and systematic error analysis is very difficult, but the qualitative feature in Fig.4 is believable.

The fluctuation amplitude is defined as the integrated signal above 100kHz. Fig.5 shows the correlation between the fluctuation amplitude and χ_e at r/a~0.15. This suggests that the short wavelength fluctuations may have significant effect on χ_e. Since $k\rho_i$~5>>1, these fluctuations are not expected to affect the ion transport due to orbit averaging effect. This explains χ_e/χ_i >>1 in the plasma core where r < r_{min} ~ 0.35a. Outside the transport barrier (r > r_{min}), reflectometry shows the presence of long wavelength fluctuations. They should have similar effects on ion as well as electron transport. Therefore, χ_e/χ_i ~ 1 at r > r_{min}. This explains the TRANSP result depicted on Fig.6.

The heterodyne detection circuit in the scattering system indicates that the short wavelength fluctuations propagate in the electron diamagnetic drift direction in the laboratory frame. After the Doppler shift correction, it was found that they propagate at the ion diamagnetic drift direction with a frequency below the ion diamagnetic frequency in the frame where the radial electric field is absent. These properties are similar to those of the current diffusive ballooning

mode.[3] However, we have $k\rho_i \sim 5 \gg 1$ in this experiment. Therefore, large Larmor-radius effects must be included in the theory before meaningful comparisons can be made.

1. F.M. Levinton et al.,Phys. Rev. Lett. 75, 4417(1995).
2. E. Mazzucato et al., Phys. Rev. Lett. 77, 3145 (1996).
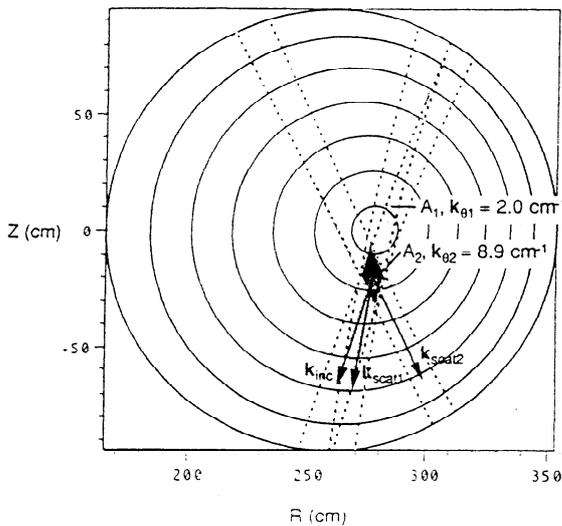3. K. Itoh et al., Plasma Phys. Control. Fusion 36, 279 (1994).

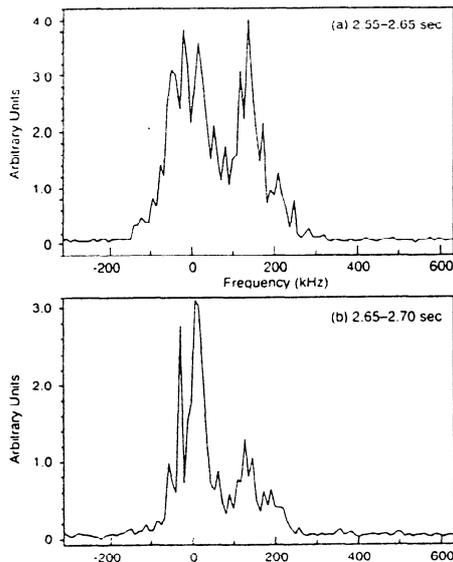Fig.1 Poloidal view showing the scattering volume and the plasma flux surfaces.

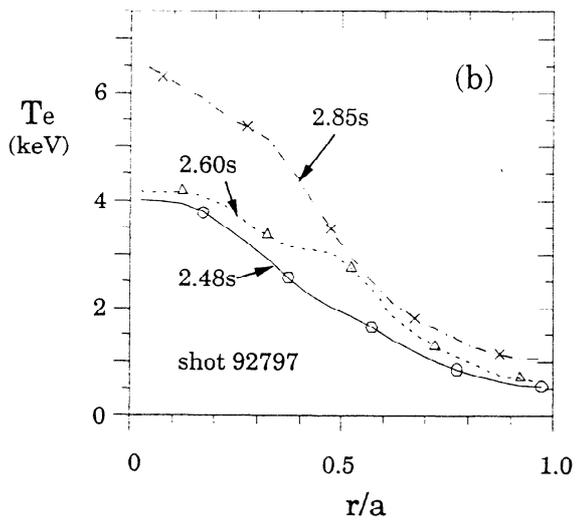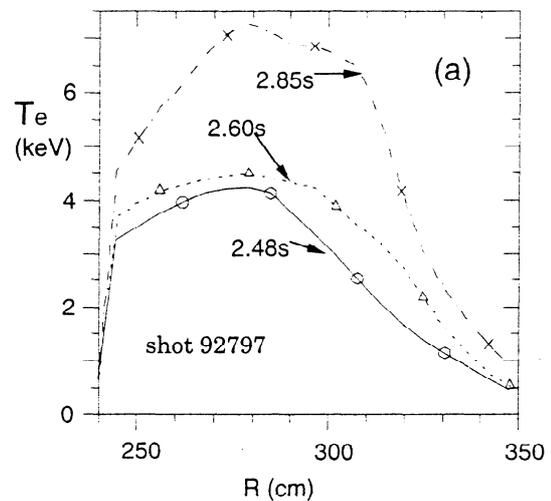Fig.2 Spectrograph of the scattering signal at various times.

Fig.3 (a). ECE data of Te as a function of major radius. (b). Te as a function of minor radius after analysed by the TRANSP code.
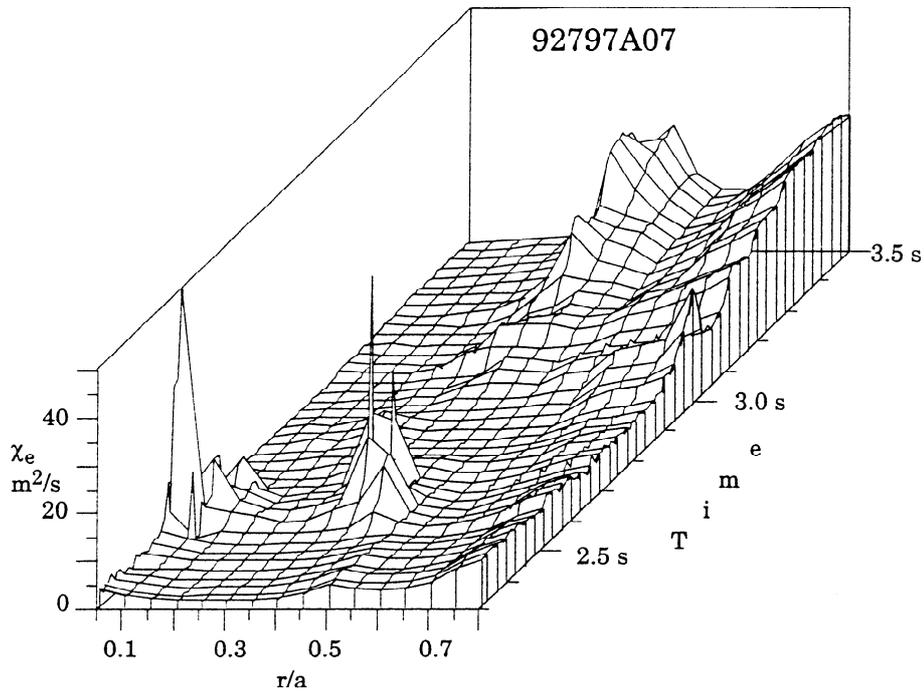
Fig.4 Evolution of $\chi_e(r)$ calculated from the TRANSP code.

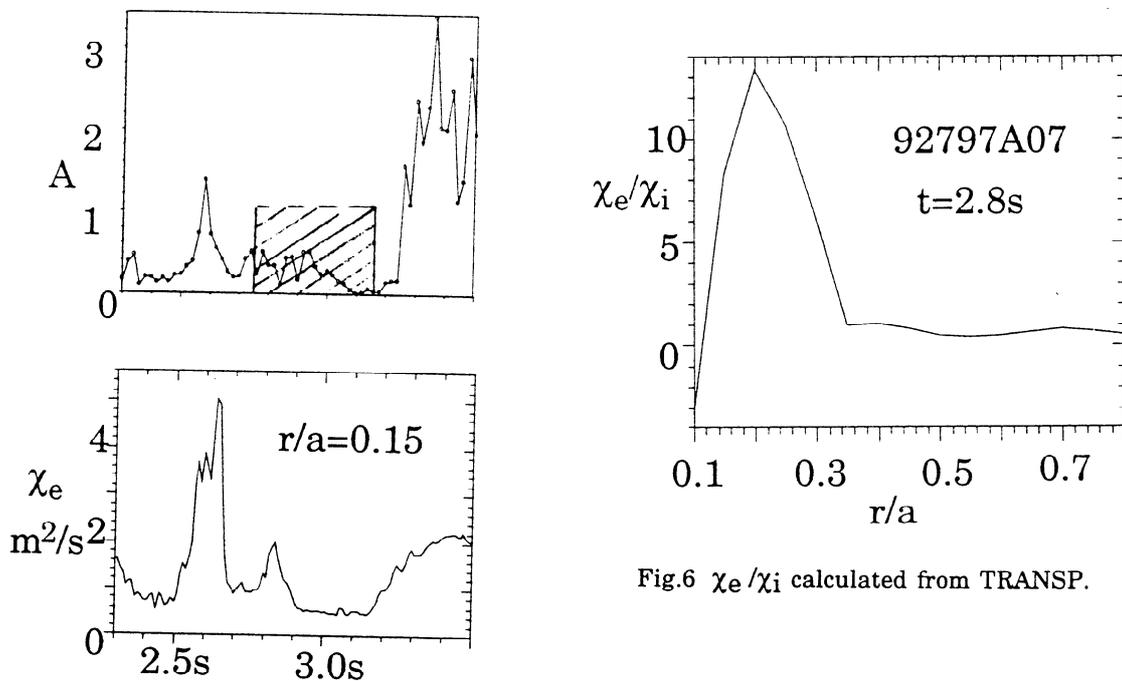r/a=0.15

92797A07
t=2.8s

Fig.6 χ_e/χ_i calculated from TRANSP.

Fig.5 (a).Variation of fluctuation amplitude.

Refraction not corrected in the shaded area.

(b). Variation of χ_e at r/a=0.15.