§4. Change of Fluctuation Properties during Non-local Temperature Rise in LHD from 2d Phase Contrast Imaging

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Modification of turbulence characteristics is an important ingredient for reducing outward flux and achieving improved confinement. Turbulence measurements are helpful to verify or understand this mechanism. We present an example where confinement improvement through reduction of outward heat flux, as a result of non-local core temperature rise is associated with an increase of the edge density fluctuation amplitude and a possible change of the radial wave-vector spectrum, one interpretation of which is that an inward-directed anomalous heat flux perturbation is generated.

It has recently been observed in LHD that the core electron temperature can rise after edge cooling induced by TESPEL (tracer encapsulated solid pellet) impurity pellet injection or argon gas puff [1]. The core temperature rise, which is unexplainable by a local diffusive transport model, implies that the total outward heat flux reduces, or in other words that there must be an inward directed perturbation to the total heat flux as shown in Fig. 1a (computed using the technique in Ref [1]).

The 2d phase contrast imaging diagnostic [2] can measure the spatial profile of a quantity closely related to the density fluctuation amplitude with wave-numbers in the range 1-10cm^{-1} (configurable), clearly relevant to the regime of ITG-TEM turbulence. Fluctuation properties are measured simultaneously above and below the mid-plane (represented by the sign of ρ). The time-evolution of the fluctuation profile immediately after TESPEL injection, plotted in Fig. 1b, is clearly seen to be peak at the edge of the plasma (however, peaks localized towards mid-radius are sometimes observed). The spatial resolution $\Delta\rho$ is nominally of the order of 0.1 however some of the power at the edge can bleed to the centre because of limitation of dynamic range. Because the fluctuation amplitude towards the core is considerably weaker than the edge, we cannot make comparisons about the core amplitude. Changes in the shape of the fluctuation profile do not relate simply to the shape of the perturbed flux profile, with a hardly detectible change in the core amplitude. This suggests that other, non-detectible fluctuations may be responsible for core transport, such as higher k ETG scale turbulence.

However, we can make an argument about the relationship between the perturbed part of the edge flux/density, and the edge fluctuations, both on top and bottom, as shown in Fig 2. The edge fluctuation amplitude decreases during the initial phase when the perturbed flux is outwards, then increases beyond the initial level as the inwards directed perturbed flux manifests. One explanation is that the confinement improvement is not due to fluctuation suppression, rather an increase of inwards-directed anomalous heat flux. Another explanation is that these measured fluctuations are not directly related to the transport. The cause of the rise of the density fluctuations is likely due to an increase of the temperature gradient, however this is poorly resolved at the edge. Possibly the edge turbulence is being non-locally regulated by the temperature profile from inner radii.

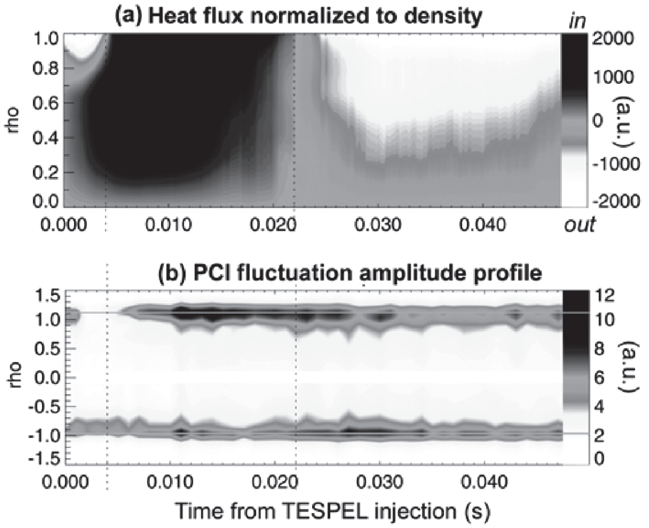

Fig 1 Time and spatial depdendence of (a) Perturbed heat flux normalized to density. and (b) a quantity related to the density fluctuation amplitude measured by 2D PCI.

Another subtle observation from Fig. 2 is that the sign of the difference between the top and bottom amplitude is also seen to correlate closely with the sign of the perturbed heat flux. It has been demonstrated recently [3] that observed asymmetry in PCI data may be due to a difference of the radial k spectrum (inward/outward propagating fluctuations). However, it is also a reasonable explanation that fluctuation amplitude is not constant on a flux surface.

It is future work to consider in detail the reasons for different fluctuation responses under different regimes (such as collisionality) and how this observation may relate to the cause of the non-local temperature rise.

[1] N. Tamura et al, Nuclear Fusion **47** 449, 2007.
[2] C.A. Michael et al, RSI, **77** 10E923, 2007.
[3] C.A. Michael et al, to appear in Plas. Fus. Res.

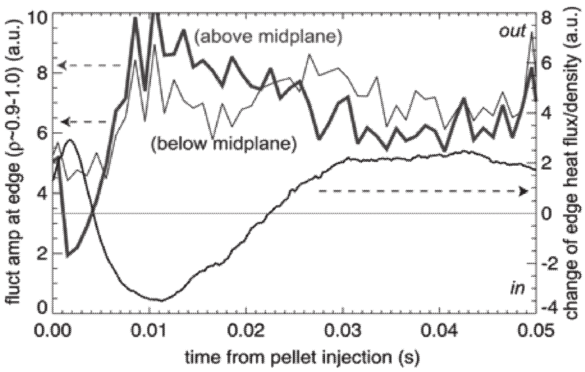

Fig 2 Change of perturbed heat flux at the edge compared with edge fluctuation amplitude