§15. Investigation of Micro-turbulence and Particle Transport in LHD from 2d CO_2 Laser Phase Contrast Imaging

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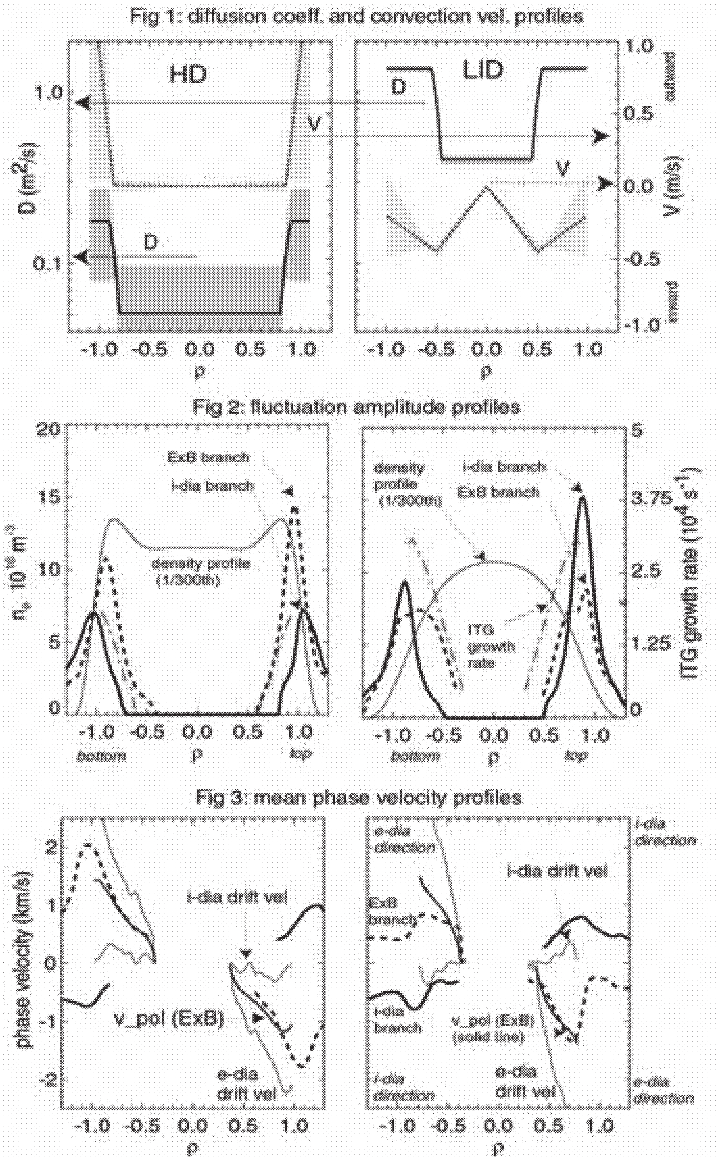
It is well known that particle and energy transport in fusion plasmas is driven strongly by micro-turbulence. Using a recently developed CO_2 2d laser phase contrast interferometer (PCI), density fluctuations are measured, and their characteristics are compared with the transport coefficients. It is our goal to classify the turbulence and compare it with theoretical predictions in order to understand the driving terms for particle transport.

The principle of the diagnostic technique is to image line-integrated fluctuations in an area of 19x6mm onto a 6x8 CdHgTe detector array using a CO_2 laser beam and phase contrast imaging system [1]. Their position along the line of sight is determined according the propagation direction, assuming fluctuations propagate perpendicular to the field lines. The peak wavelength is comparable or greater than the size of the image. Therefore, to maximize spatial resolution, it is necessary to extrapolate the image beyond the measured region using high resolution non-linear spectral analysis techniques.

A comparison is made between two discharges with different divertor configuration, helical divertor (HD) and local island divertor (LID). The gas-feed was modulated in order to estimate profiles of D and V, shown in Fig. 1 [2]. Shaded areas indicate confidence intervals, and discontinuities are a result of having only 2 fitting variables for the profiles of D and V. Transport is enhanced in this LID discharge, as a result of modification of density and temperature profiles. The fluctuation amplitude profiles are shown in Fig. 2, and their phase velocity is shown in Fig. 3. Different branches are identified, according to phase velocity and propagation direction. In Fig. 3, the plasma poloidal rotation velocity, ion and electron diamagnetic drift velocity profiles, projected perpendicular to the line of sight, are compared with the phase velocities of each branch. The E_r field was obtained from a calculation based on measured n_e,T_e profiles enforcing ambipolarity of the neoclassical particle flux [3]. For the drift velocities, it is assumed that T_i=T_e. In both cases, there appear to be two branches, one propagating with the ExB rotation velocity, the other close to the ion diamagnetic drift velocity. The ExB branch is localised slightly closer to the centre than the i-dia branch, though most of the fluctuation power in this branch is not shown since it is at wavelengths larger than the image size, giving poor spatial resolution.



The amplitude of the i-dia branch is larger in the LID case, consistent with having enhanced particle transport. Determination of the relative density fluctuation level is hampered by the spatial resolution and steep gradients in the edge, however, by comparing with the density profile in Fig. 2, it appears that the relative fluctuation level is considerably larger (>10 times) in the LID case.

Calculations of the growth rate for ion temperature gradient (ITG) turbulence were carried out based on the gyro-kinetic mode equation. The growth rate, indicated by the dash-dot line in Fig. 2, scales approximately with the peak amplitude of the i-dia branch. Based on the propagation direction in the plasma frame, and agreement of the model with the measurements we assert that ITG turbulence plays an important role in determining anomalous transport.

[1] A. Sanin et al., Rev. Sci. Instrum 75, 3439 (2004)
[2] K. Tanaka et al., to be published Nucl. Fusion
[3] C.D.Beidler et al., PPCF 36, 317 (1994)