SPATIAL DISTRIBUTION OF TURBULENCE IN THE WENDELSTEIN 7-AS STELLARATOR

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1 Introduction

The significant anomalous transport observed in toroidal fusion devices plays an important role in the global transport properties of plasmas [1]. Therefore it is important that a continual effort is made to measure fluctuations in plasma parameters, since these are thought to be created by turbulent transport processes. The paper is organised as follows: In section 2 we describe the Wendelstein 7-AS (W7-AS) fusion machine and the experimental setup. In section 3, we present fits to spatially localised measurements of fluctuations in the electron density of W7-AS plasmas. The fluctuations were measured by collective scattering of infrared light [2] [3] and compared to an empirical model of the spatial distribution of density fluctuations [4] [5].

2 W7-AS and the Diagnostic

W7-AS is a modular stellarator of five-fold toroidal symmetry [6]. It has an average major radius $\langle R \rangle$ of 2 m, and an 'effective' radius $r_{\rm eff}(a)$ of maximum 18 cm (aspect ratio $\geq$ 11). The rotational transform ι can be altered between 0.27 and 0.7. The magnetic field structure varies as a function of the toroidal angle φ in W7-AS, between triangular and elliptical flux surfaces.
The measurements of density fluctuations were obtained using the LOcalised TUrbulence Scattering (LOTUS) diagnostic installed on W7-AS [7]. The setup is shown in figure 1. The main (M) CO_2 laser beam passes through a Bragg cell that creates a second, local oscillator (LO) beam, which is frequency shifted 40 MHz with respect to the M beam (heterodyning). The two beams cross in the plasma, and their angle θ_s is proportional to the wavenumber $k_\perp$ of the observed density fluctuations. The measurement volume created by the crossed beams is vertical and passes through the plasma center. We used a beam waist w = 3.3 cm and measured fluctuations having $k_\perp = 15$ cm^{-1} in the described experiments. The LOTUS diagnostic is positioned at φ = 29.14 degrees, which is close to the elliptical plane. Assuming that fluctuations (of wavenumber κ) are perpendicular to the field lines ($\kappa_\parallel \ll \kappa_\perp$) and knowing that the magnetic field angle changes 16 degrees along the measurement volume, one can turn the diagnostic angle α and thereby effectively select a region in the plasma wherefrom the detected signal originates ($k_\perp \parallel \kappa_\perp$) [3].

3 Turbulence Profiles

It is a well-known fact that slight changes in the edge rotational transform ι_a of W7-AS discharges around major low-order rationals results in dramatic changes of the confinement [8]. This confinement transition can be created in a dynamical fashion by ramping up the plasma current I_p during a discharge. At $I_p = 0$ kA the plasma is in 'good' confinement, while at $I_p = 2$ kA a 'bad' confinement phase is observed, where the energy confinement time has decreased by about a factor of two. Six identical discharges of this type were made (#48338-43), where we changed α between each shot. This is equivalent to a six-point turbulence profile. The measured scattered power is related to the absolute density fluctuations δn_e^2. These fluctuations can be extracted by assuming that the relative fluctuation profile $\delta n_e/n_e$ has the form

$$\delta n_e/n_e(r_{\rm eff}) = b + c|r_{\rm eff}/r_{\rm eff}(a)|^p \qquad (1)$$

where n_e is the electron density and (b, c, p) are fit parameters [4] [5]. The density profile used is obtained from Ruby laser Thomson scattering measurements. We performed a least squares fit to the measured scattered power profiles in order to retrieve the relative fluctuation level. Since LOTUS is not absolutely calibrated, only relative levels can be obtained. The fitted parameters were: $(b, c, p)_{\rm good}$ = (0.0029, 0.57, 7.2) and $(b, c, p)_{\rm bad}$ = (0.017, 0.56, 5.8). Here, the 'bad'/'good' subscripts mean bad/good plasma confinement, respectively. The relative ($\delta n_e/n_e$) and absolute (δn_e^2) fluctuation profiles are shown in figure 2. Note that the relative profiles are shown on a logarithmic plot to elucidate the core behaviour. We conclude that the relative fluctuation level increases significantly in the core region of the plasma during degraded confinement (compare to [5], figure 6). This is also the case for the absolute fluctuations, where the bad confinement profile furthermore develops a 'hump' somewhat inside the last closed flux surface.

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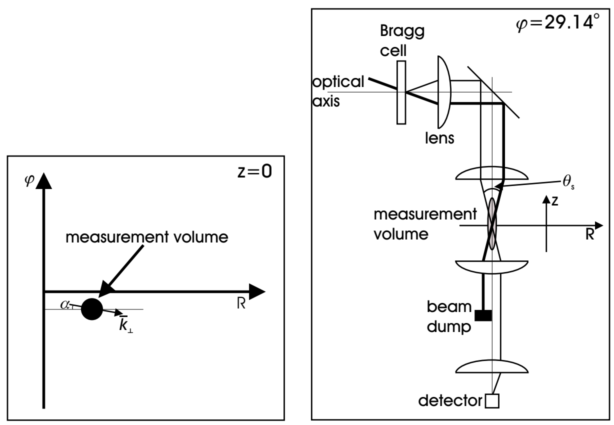

Figure 1: Left: View from above of the measurement volume created by two crossed beams having the same waist size, right: Side view of diagnostic setup. The M beam is the thick line and the LO beam is the thin line.

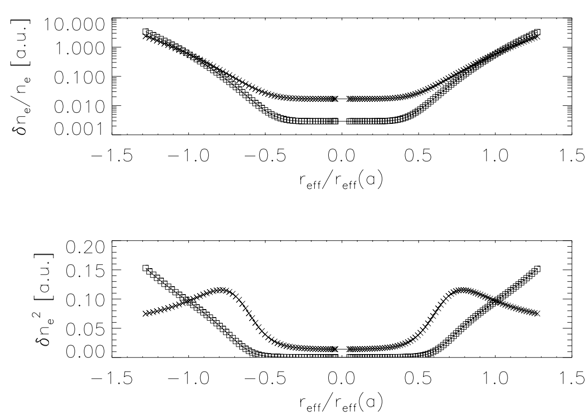

Figure 2: Fitted relative (top) and absolute (bottom) fluctuation profiles. Squares are good confinement, crosses are bad confinement profiles. Note that the data in the top plot are on a logarithmic scale.