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1. INTRODUCTION

Correlation reflectometry was first envisaged as a means to characterize density fluctuations in the JET tokamak [1]. In radial correlation reflectometry, the radial scale of turbulence is estimated from the variation of coherence [2] with the radial separation between the cutoff positions of two distinct probing waves. Currently, the JET correlation reflectometry diagnostic has four reflectometer systems, each one equipped with a fixed-frequency channel and a variable-frequency one [3], allowing measurements around four different radial positions. Recently, after the installation of low attenuation corrugated waveguides [4, 5], good quality data with improved signal to noise ratio became available, as well as the software tools necessary for its routine analysis. From the physical point of view, correlation reflectometry measurements implicate not only the correlation length but also the level of turbulence. The correlation length of the microwaves, L, calculated from the reflected waves of the fixed and variable channels, must be corrected in terms of the level of density fluctuations to become a reliable estimate of the actual turbulence correlation length [6, 7, 8, 9]. It has been shown that the microwave correlation length is generally smaller than the turbulence's [7]. Recent studies explain this behaviour with nonlinear effects caused by even relatively low turbulence levels [10, 9]. Without including such nonlinearity in theoretical models and simulations, measured correlation lengths might be expected to be larger than the true ones [8, 9]. This work reports on correlation reflectometry results obtained in recent JET experiments, in plasmas with formation of an Internal Transport Barrier (ITB).

2. RESULTS

Estimates of the radial turbulence correlation length are obtained from the correlation length of the two microwave signals, acquired from the fixed and variable reflectometer channels. The spectral coherence $\overline{\gamma}(f)$ is calculated in terms of the Fourier spectra of the complex signals from the fixed (F) and variable (V) frequency channels, assuming that the density fluctuations at their cutoff positions are stationary random processes [2],

$$\gamma\,(f) = \frac{|\langle F(f)V^{*}(f)\rangle|}{\sqrt{\langle F(f)|^{2}\rangle\langle|V(f)^{2}\rangle}}\ .$$

The average of the spectral coherence in a predefined frequency interval (here chosen from −100kHz to + 100kHz) gives one coherence value $\overline{\gamma}(f)$ for each value of the variable frequency, which is stepped up in frequency plateaus during the measurement. These average coherence values are plotted versus ΔR, the separation between the two cutoff positions, which are determined along the line of sight of the instrument, 25cm above the midplane, by mapping available density measurements and using local magnetic field data from equilibrium reconstruction. Then, by fitting an exponential model $\overline{\gamma}(f) = \exp(-\Delta R/L)$ to the obtained curve, the correlation length is retrieved as the 1/e dropping distance.

The formation of an ITB is accompanied by a reduction of the core turbulence, and a decrease of the turbulence correlation length in the region inside the ITB foot [11, 12]. In JET, a value of 0.014 for $\rho_T^* = \rho_s/L_T$, the ion Larmor radius at the sound speed ρ_s normalized to the local temperature gradient scale length L_T, is frequently employed to determine the space and time limits of the ITB region [13]. During JET Pulse No: 69389, an ITB is formed starting at 7.5s between R = 3.49m and R = 3.54m. Figures 1 and 2 show the analysis of data collected by two reflectometer systems with fixed channels working at 103GHz and 92GHz, respectively, in two different measurements during this pulse. Coherence values below the dotted red line are considered as noise and ignored when performing the exponential fit. While the first measurement occurs before the ITB, between 6.0s and 6.36s, the second one takes place during the ITB, from 8.0s to 8.36s. For the 103GHz system, which scans the region inside the ITB foot from $R \approx 3.42$m to $R \approx 33.535$m, a reduction from L = 1.14 cm to L = 0.43cm can be observed between the two measurements, which might be associated with a reduction of the core turbulence [11]. On the contrary, the cutoff positions of the 92GHz system are located in the outboard region of the ITB from $R \approx 3.68$m to $R \approx 3.815$m, where no significant change occurs in the measured correlation length. In this case, the low $L \approx 1$ mm values are consistent with higher turbulence levels, for which the coherent reflected power is low and the measured correlation length can be much smaller than the real one [Leclert06]. A better understanding of these values and estimation of the actual radial scale of turbulence will require modelling of correlation reflectometry in JET.

CONCLUSIONS

Recent correlation reflectometry measurements in JET show a clear decrease of the radial correlation length in the region inside the ITB foot, which is compatible with a reduction of turbulence in the plasma core. The correlation length in the region outboard of the ITB remained unchanged by the ITB, which is consistent with the conclusion that turbulence in this region is unaffected by the formation of the ITB [12]. These measurements point to correlation lengths with an order of magnitude of 1cm in the plasma core of JET plasmas without ITBs, and half that value when ITBs are formed. More conclusive and quantitative results require theoretical and code modelling, which are essential to validate correlation reflectometry results.

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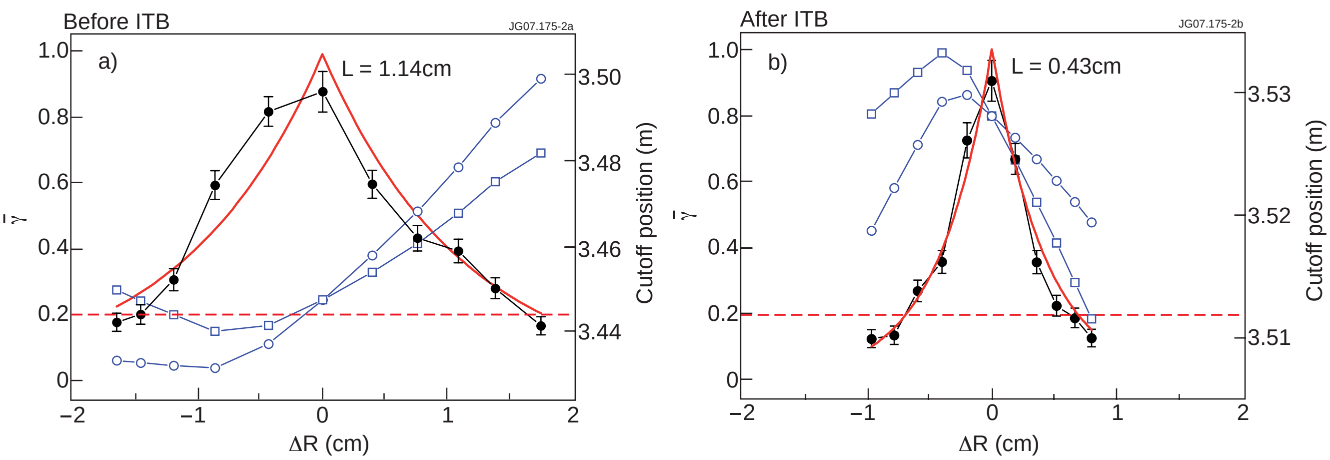

Figure 1: Coherence analysis for JET Pulse No: 69389 using reflectometer system 4 working at 103 GHz fixed frequency, showing a reduction of the correlation length L. The first measurement (a) occurs before the ITB and the second (b) during the ITB. Both measurements are localised in the region inside the ITB foot. The exponential curves fitted to the coherence data to calculate L are shown in red. Circles represent cutoff positions for the fixed channel and squares for the variable one.

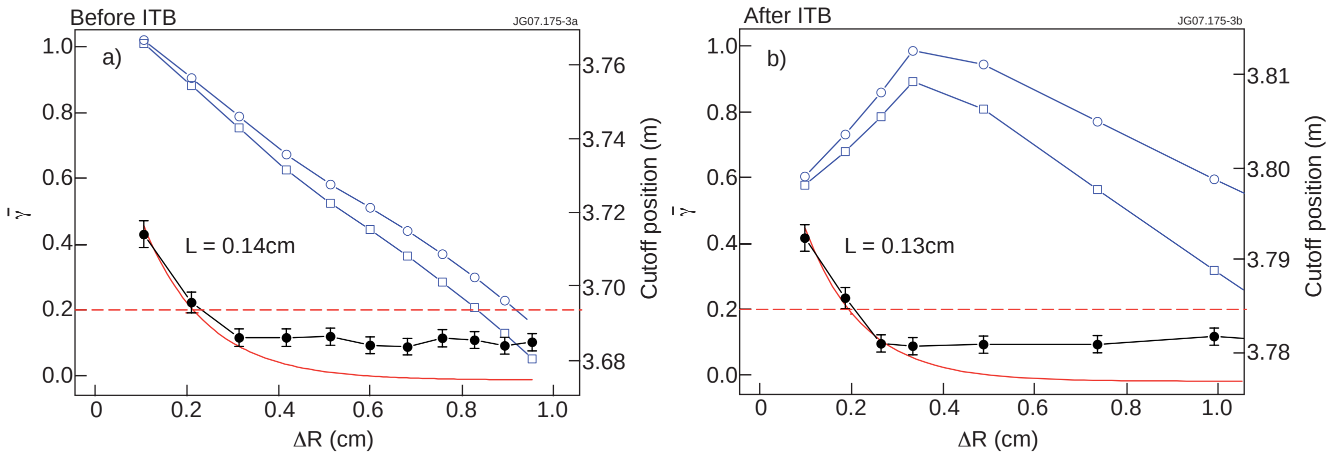

Figure 2: Coherence analysis for JET Pulse No: 69389 using reflectometer system 3 working at 92GHz fixed frequency, showing no significant change in the correlation length L. The first measurement (a) occurs before the ITB and the second (b) during the ITB. Both measurements are localised in the region outboard of the ITB. The exponential curves fitted to the coherence data to calculate L are shown in red. Circles represent cutoff positions for the fixed channel and squares for the variable one.