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A.C.A. Figueiredo, C. Giroud, N. Hawkes, J. Hillesheim, M. Leyland,
L. Meneses, E. Poli and JET EFDA contributors

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A.C.A. Figueiredo[1], C. Giroud[2], N. Hawkes[2], J. Hillesheim[2], M. Leyland[3], L. Meneses[1], E. Poli[4] and JET EFDA contributors*

JET-EFDA, Culham Science Centre, OX14 3DB, Abingdon, UK

[1]Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Universidade de Lisboa, 1049-001 Lisboa, Portugal
[2]Culham Centre for Fusion Energy, Culham Science Centre, Abingdon, OX14 3DB, UK
[3]York Plasma Institute, Department of Physics, University of York, York, YO10 5DD, UK
[4]Max-Planck-Institut für Plasmaphysik, 85748 Garching, Germany
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INTRODUCTION

In JET, nitrogen (N) seeding has been in use to decrease the power loads on the divertor by increasing its radiation and thereby lowering its temperature. Furthermore, in recent experiments with the ITER-like wall (ILW) it was observed that the injection of the extrinsic impurity N in high-triangularity ELMy H-mode plasmas led to a recovery of the edge pedestal pressure, which had dropped by 40% with the change from the carbon wall to the ILW [5, 6]. Existing pedestal models did not predict this effect [8], and a better understanding of the underlying physics is necessary.

The recovery of pedestal pressure with N can arguably be related to changes in the properties of turbulence within the pedestal. It is therefore important to have diagnostics dedicated to the measurement of such properties. Radial correlation reflectometry (RCR) is capable of making localized measurements of density fluctuations, and the recently upgraded RCR diagnostic in JET can be programmed in a flexible way to adapt to different experimental conditions [10]. This paper describes RCR measurements inside the edge pedestal during N seeding experiments in high triangularity plasmas with 2.5MA and 2.7T, using the same divertor configuration reported in [5].

1. RESULTS AND DISCUSSION

In order to circumvent the complexity that in general might be involved in the interpretation of reflectometry measurements, the simpler *qualitative* analysis method that has been introduced in [3] is here used to reach as robust conclusions as possible. In the discussed pulses the RCR diagnostic has been programmed to measure at approximately constant radial positions. The impact on the measurements of the radial dependence of the level of density fluctuations has thereby been avoided, as well as variations in the field depth effect. A two stage approach has been used to analyse the data and interpret the results. Spectra and radial correlation lengths are first calculated from the reflectometry data [2], and their *variations* are subsequently scrutinized in view of the changes in the experimental conditions to identify correlations between the former and the latter. Naturally, the presence or absence of N is the fundamental difference between the analysed pulses. Instrumental effects are taken into account in the interpretation of the results, together with potential differences in the alignment between the microwave (MW) beams and the plasma, which have been investigated in ray- and beam-tracing analyses with TORBEAM [11].

Figure 1 (left) shows that the spectra of RCR signals from measurements inside the edge pedestal become broader when N is used. Spectral broadening is a well-known consequence of an increased level of density fluctuations [9], and it is therefore concluded that N seeding causes a rise of turbulence within the edge pedestal. To validate this conclusion instrumental effects have been considered. Namely, the larger signal power in the N pulse, which might hypothetically be caused by the MW beams being less scattered away from the line of sight of the RX antenna due to a turbulence reduction, is in fact a consequence of the TX power response of the system of reflectometers and waveguides. While in Figure 1 (left) the power difference is around 70% between signals from beams with a 2 GHz frequency separation, considering beams with comparable MW frequencies the difference drops to about 15%. The possibility that different alignments of the MW beams with the magnetic flux surfaces might be the cause of the observed variation of signal power by pointing the MW beams in different directions from the cutoff position towards the RX antenna, has also been investigated. As shown in Figure 1 (right) ray-tracing analysis indicates that such differences lead to a beam separation at the plane of the antennae that is safely under 1cm. This value is rather small compared with the radius of the beams when they reach the RX antenna, which has been estimated to be of the order of 15 cm by beam-tracing analysis. Notice that the beam radius is about 50% larger than the distance between the point where the central rays reach the antennae plane and the RX antenna, as can be seen in Figure 1 (right). Therefore, misalignment effects on signal power are indeed negligible.

The values of the RCR correlation length L_{RCR} shown in Figure 2 have been calculated using magnetic field profiles from equilibrium reconstruction with Faraday constraints and electron density profiles from the high resolution Thomson scattering (HRTS) diagnostic. Evidently, L_{RCR} is larger in the two pulses with N seeding than in the pulse without N, approximately by a factor of two. No dependence on other factors has been found, such as the 4.7MW of RF heating on top of 16.3MW of NBI heating in pulse 85412 versus the 20MW of NBI only heating in pulse 85413.

Although L_{RCR} is not the real turbulence correlation length, when interpreted together with the simultaneous rise of the level of density fluctuations, the increase of L_{RCR} implies that the actual correlation length of the density fluctuations is also larger with N seeding [3, 7]. Furthermore, pedestal widths have been calculated from mtanh fits, whereby it has been found that the larger turbulence correlation lengths occur along with wider electron pressure pedestals, as summarized in Table 1. Notice that pedestal widening is not visible in the mtanh fits to density profiles shown in Figure 2 (left) as it occurs mainly in the temperature profiles [8]. There is no apparent relation between the variations of L_{RCR} and of the pedestal gradients. Although the availability of edge rotation profiles is limited for the analysed pulses, they do not suggest that sheared flow is responsible for the observed variation of the correlation length.

2. SUMMARY

A clear impact of nitrogen seeding on density fluctuations has been observed inside the edge pedestal of JET plasmas using RCR. The analysis results show significant spectral broadening and a large increase in the RCR correlation length when nitrogen is used. These measurements have been interpreted as a simultaneous increase of both the level and the correlation length of density fluctuations, which, moreover, has been found to occur together with a widening of the edge pedestal in electron pressure profiles.

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REFERENCES

[1]. M.N.A. Beurskens *et al.*, Nuclear Fusion **49** (2009).
[2]. A.C.A. Figueiredo *et al.*, Review of Scientific Instruments **79** (2008).
[3]. A.C.A. Figueiredo *et al.,* "Measurement and qualitative interpretation of the radial scale of turbulence in JET plasmas", P2.167, 36th EPS Conference on Plasma Physics, Sofia, 2009. In Europhysics Conference Abstracts **Vol. 33E**, ISBN 2-914771-61-4.
[4]. L. Frassinetti *et al.*, Review of Scientific Instruments **83** (2012).
[5]. C. Giroud *et al.*, Nuclear Fusion **53** (2013).
[6]. C. Giroud *et. al.*, "Progress in integrating ITER-relevant core and edge plasmas within the constraints of an ITER-like Wall", invited talk in this conference.
[7]. G.J. Kramer *et. al.*, Review of Scientific Instruments **74** (2003).
[8]. M.J. Leyland *et al.*, "The H-mode pedestal structure and its role on confinement in JET with a carbon and metal wall", submitted to Nuclear Fusion (2014).
[9]. E. Mazzucato *et al*., Physical Review Letters **71** (1993).
[10]. L. Meneses *et. al*., Fusion Engineering and Design **86** (2011).
[11]. E. Poli *et al.*, Computer Physics Communications **136** (2001).

		Width			Gradient		
Pulse	L_{RCR} (cm)	Pressure (cm)	Density (cm)	Temperature (cm)	Pressure (kPa m^{-1})	Density (10^{19} m^{-4})	Temperature (keV m^{-1})
85407	0.33 ± 0.05	1.94 ± 0.22	1.60 ± 0.14	2.29 ± 0.16	333 ± 36	456 ± 80	24 ± 3
85412	0.62 ± 0.07	2.30 ± 0.21	1.41 ± 0.12	3.19 ± 0.18	297 ± 21	530 ± 87	23 ± 2
85413	0.56 ± 0.03	2.31 ± 0.31	1.69 ± 0.21	2.94 ± 0.23	431 ± 44	517 ± 129	28 ± 4

Table 1. Summary of RCR correlation lengths, electron pedestal widths and gradients.

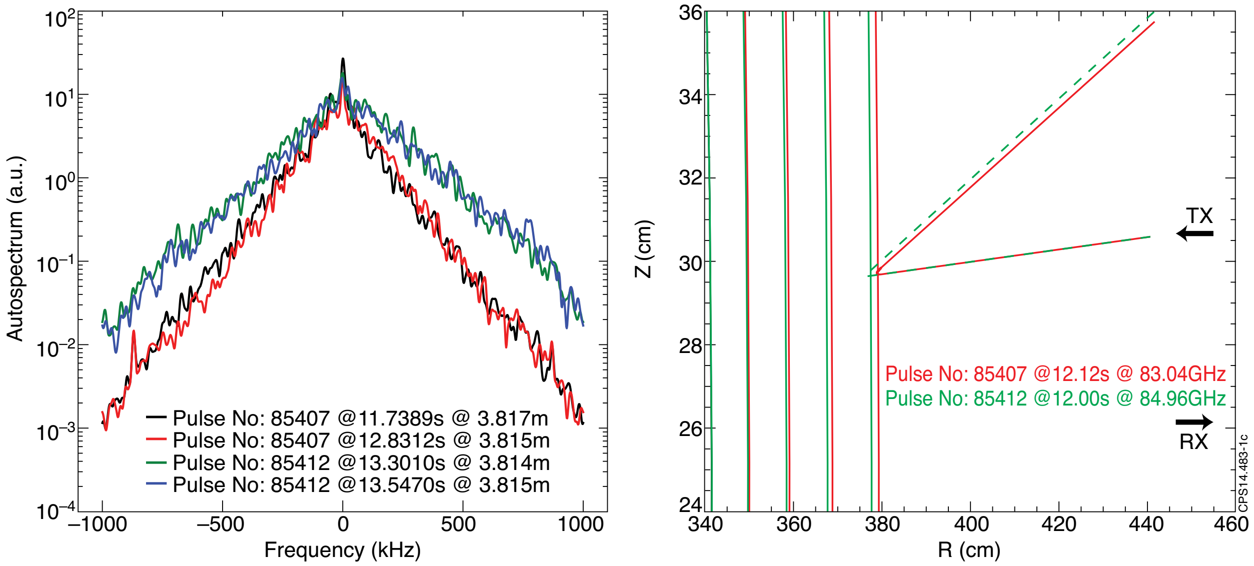

Figure 1. (Left) due to a higher level of density fluctuations, spectra from MW beams that are cut off around R = 3.815m are broader in pulses with N, such as pulse 85412, than in pulses without N, such as pulse 85407. (Right) ray-tracing analysis shows only a very small deviation between the central rays of the MW beams due to differences in the alignment with the magnetic flux surfaces in the two pulses.

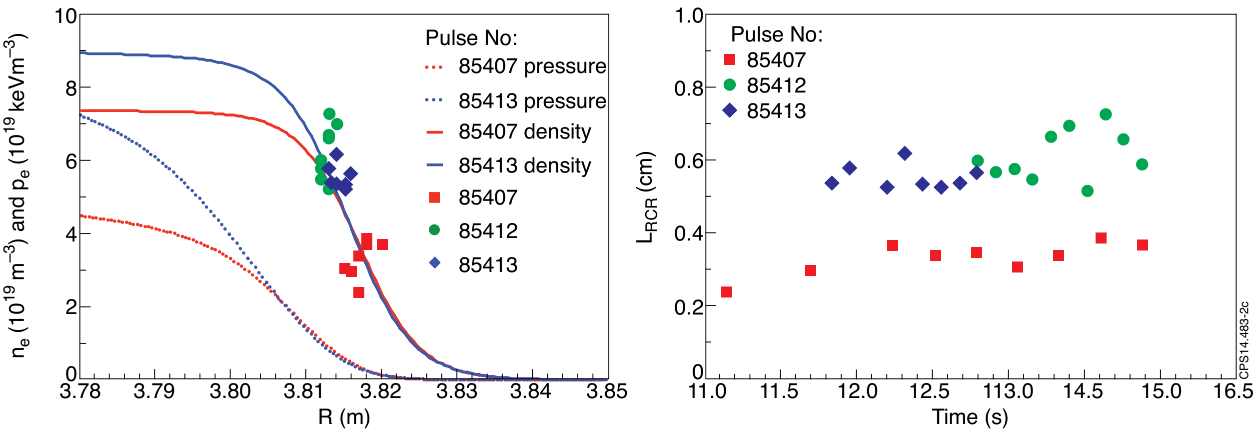

Figure 2. (Left) the RCR correlation length L_{RCR} measured inside a narrow region of the edge pedestal shows a clear increase in pulses 85412 and 85413 that had N seeding with respect to pulse 85407 without N. The lines are fits to the experimental (solid) density and (dotted) pressure profiles with a modified hyperbolic tangent (mtanh) function that takes into account the HRTS instrumental response [1, 4]. (Right) the RCR correlation length data is plotted versus time.