Current effect on the edge profiles in the island at W7-X

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Abstract

In the second operational campaign of W7-X in 2018 (OP 1.2b) operation with an island divertor configuration allowed for considerably longer discharges than those in the previous limiter configuration. In the main configuration the so-called standard configuration a $\iota_{\text{edge}} = 5/5$ island chain is present in the edge, it is partiallyintersected by the divertor. The manipulator plunged multiple times during a discharge which allowed the observation of time dependent changes in the plasma edge. The long discharge durations allowed for a considerable toroidal current to develop.

The effect of the toroidal current on the edge islands can be estimated with a modified field line tracing calculation that axis-centered current added to the original calculation using coils of W7-X. The profilesof the electron temperature and density profiles measured with the Multi-Purpose Manipulator were obtained in multiple plunges during discharges with an evolving toroidal current. A clear inwards shift of electron temperature profile matching the predicted inwards shift of the last closed flux surface is observed.

Introduction

The stellarator Wendelstein 7-X (W7-X) was operated with an island divertor configuration with an uncooled graphite divertor. The edge island has a profound effect on the edge transport and the configuration used range from a $\iota_{\text{edge}} = 5/5$ edge island chain in the standard configuration to a limiter like configuration. In this paper the focus will be on the standard configuration, since the effect of the island on the measured edge parameters is most pronounced there. The profiles measured in the edge island can be affected by controlled external means like heating or preset density, but also more dynamic effects like additional impurities released from the wall and the evolving toroidal net current that modified the edge topology.

MPM measurements

The MPM was used in conjunction with a combined probe for the measurement of electron temperature and densities, the setup is described in [1]. The combined probe was operated as a triple probe, such that the electron temperature and density can be obtained using the following equation:

$$T_e = \frac{U_+ - U_{\text{float}}}{\ln 2} \tag{1}$$

$$n_e = \frac{I_{\text{sat}}}{A_{\text{eff}}\, e\, 0.49\sqrt{Z_{\text{eff}}\, T_e + T_i / m_i}} \tag{2}$$

With A_{eff} being the effective collection area, e the electric charge and 0.49 the sheath collection coefficient in strongly magnetized plasmas [2]. The data was filtered with a low pass filter using a cut-off frequency of 50 kHz. The error was calculated, using the same data set filtered with a cut-off frequency of 500 kHz, from the weighted standard deviation. The effective charge of the plasma has been assumed to be $Z = 1$, a pure hydrogen plasma. The selected discharges featured an evolving net current, while other plasma parameters like the heating power and density were kept constant, to isolate the effect of the net current from other effects such as the Shafranov shift due to an increasing plasma beta.
The measurements used in the following analysis are detailed in table 1. While the heating power for the first plunge is slightly different, the features of the local peaking and the position of the profile, taking the off-set from the additional heating in discharge #44 in account, are very similar.

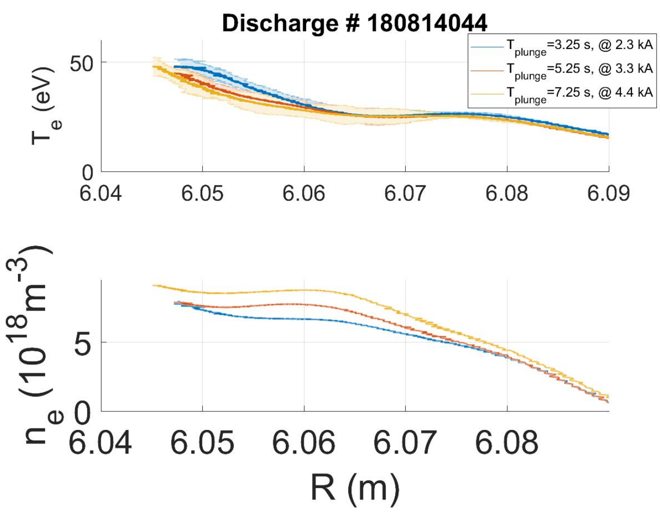

Figure 1: *Comparison of the electron temperature profile shift and the change of the LCFS position due to an evolving current.*

Fig. 2 shows the measured electron temperature and density profiles, in the SOL, of discharge number #44. The profiles temperature profiles have a distinct peaking in the edge at about $R \approx 6.09$ m [4], while a local minimum is found at $R \approx 6.065$ m. The structure of the local temperature maximum and minimum remain fixed during the discharge with an evolving current. The feature in the temperature profile that is visibly affected by the change of toroidal current

#	P_{ECRH} (MW)	I_{tor} (kA)
20180814.043	3	1.6, 2.3, 3
20180814.044	4	2.3, 3.5, 4.4
20180814.045	4	2.5, 3.7, 4.7
20180814.046	3	2, 2.7, 3.4
20180814.047	3	1.9, 2.7, 3.4

Table 1: Summary of the discussed discharges with MPM measurements

is the position of the inner part of the profile on the left side.

In the following it will be used for the testing of the calculation of the position of the last closed flux surface (LCFS) with the field line tracing service [3]. The density profiles has initially a flattening at $R \approx 6.065$ m, located at the temperature minimum, which in second and third plunge becomes a local density maximum.

Estimating the effect of the evolving toroidal current

The temperature profile or rather the inner part of it shows a clear change with an evolving toroidal current and is therefore used in the following analysis. The aforementioned increase of the density in the edge is also visible but not directly depending on an increase of the toroidal current, since it can also easily be observed during an increase of the heating power.

The field line tracing service was modified by superimposing an artificial coil on the magnetic axis and inserting the measured toroidal current. Figure (Fig. 2 shows the results of the connection length distribution calculation conducted for $0, 2, 4$ kA, the red dashed line is indicating the path of the manipulator plunge. Three effects of the toroidal current can be observed here, a general increase of the edge connection length, a growth of the con-

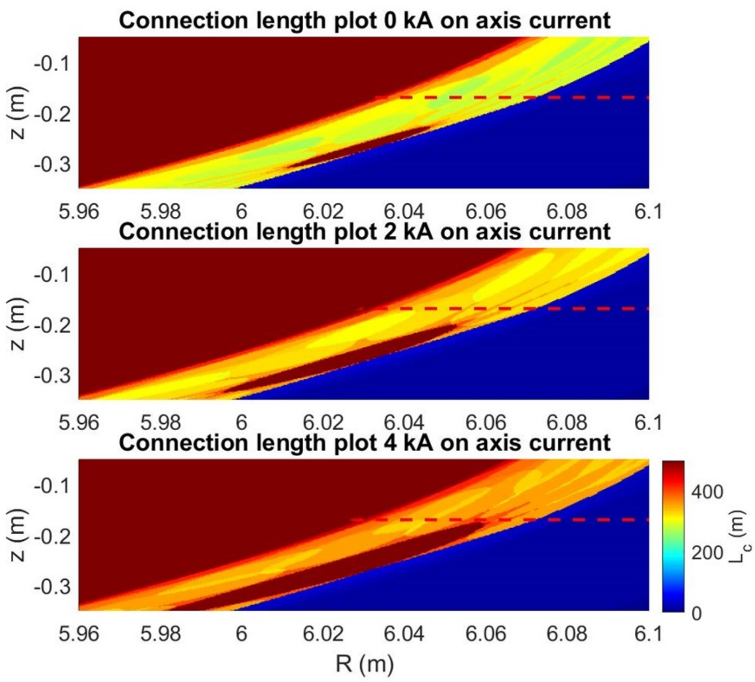

Figure 2: *Connection lenght distribution calculated with an axis-centered toroidal current.*

fined region in the 5/5 island and an successive inwards shift of the last closed flux surfacce.

Fig. 3 shows the comparison of the electron temperature profile shift in dependence of the toroidal current and the position of the LCFS calculated by the modified field line tracing calculation. The results of both measurement and calculation show a strong dependence on the toroidal current. This result suggests that at low toroidal currents the axis centered approach for the field line tracing calculation is valid. The rise in density though not directly dependent on the evolving toroidal current is interesting and necessary to be further analyzed.

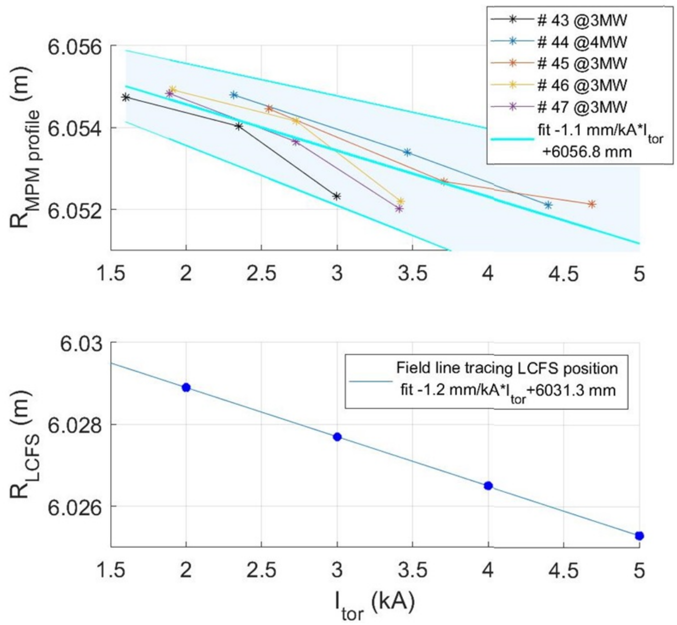

Figure 3: *Comparison of the electron temperature profile shift and the change of the LCFS position due to an evolving current.*

Acknowledgements

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