CONDITIONS FOR ISLAND DIVERTOR OPERATION IN THE W7-AS STELLARATOR

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1 Introduction

The divertor concept of the W7-AS stellarator (R=2 m, a_{eff}~14 cm) is based on the intrinsic magnetic island configuration at $\iota_a/2\pi$=5/9. This configuration yields connection lengths of ~120m and a distance between target plate and X-point of 2.6 cm. During the first divertor experiments emphasis was placed upon the determination of the strike point position to assess up/down and toroidal asymmetries, and to estimate the anomalous cross-field transport coefficients for heat and particles in the island SOL. Since the island width for divertor operation in the W7-X stellarator is comparable to the W7-AS islands, the knowledge about the diffusion coefficients in the plasma edge of W7-AS is of particular interest in order to predict the W7-X divertor performance using the EMC3-EIRENE code [1,2].

2 Asymmetries and strike point positions

Calorimetric measurements in the divertor target plates have indicated ι-dependent asymmetries. The observed asymmetries at $\iota_a/2\pi$=5/9 were modeled using a field line diffusion code, and after that the targets readjusted. Before readjustment, at $\iota_a/2\pi$=5/9, the maximum deviation from the mean value of the deposited energy on target in toroidal direction (toroidal asymmetry) was 1.6. The ratio of the averaged values of the deposited energy on the upper and lower targets (up/down asymmetry) was 1.5. This ratio changed ~10% after the toroidal magnetic field was reversed. Additional to the misalignment of the divertor modules also drifts, which are not considered in the field line diffusion code, may add to the up/down asymmetry. After readjustment, the toroidal asymmetry reduced to 1.2, and the up/down asymmetry lowered to 1.3.

The strike point positions on target are measured during low β-discharges by means of flush mounted Langmuir probe arrays. In the case of the top divertor module, there is a good agreement between the location of the I_{sat}-peak in radial direction on the target and the strike point position determined by means of a field line diffusion code. However, at the bottom divertor module, at higher ι_a, exists an inward shift of the measured strike point by up to 2 cm.

3 Transport studies in the plasma edge

As a first attempt, the diffusion coefficient (D) and electron heat conductivity (χ_e) were determined for ECRH-discharges at low and medium electron density. Discharges at different densities were selected in order to study the dependence on density. Moderate densities and heating power were chosen from experimental reasons, in order, first, to avoid the influence of impurities and a possible configuration modification from β effect, and second, to maintain stationary plasma conditions over a period of 600 ms.

The power flowing into the SOL is P_{ECRH}-P_{RAD}=600kW, the line integrated density is 2E+19 m^{-2} for shot #51078, and 4E+19 m^{-2} for the shots #50999 and #51080 (see figures). The radiation level does not exceed 10%.

In order to evaluate the transport coefficients, profiles of the particle and heat flux onto the target plate are computed using the EMC3-EIRENE code. Thereby, the transport coefficients are varied as long as the calculated profiles fit to the measured profiles. The code considers spatially constant transport coefficients in the plasma edge, assumes $\chi_e = 3D$, $\chi_e = \chi_i$, since the ion temperature in the plasma edge is unknown, and determines the neutral flux in a self-consistent way. The input parameters of the code and the resultant computed decay lengths for particle and heat fluxes are summarized in TABLE I.

3.1 Diagnostics

The profiles of particle and heat flux are determined experimentally from Langmuir-probe measurements, partly also from H_α-measurements. The considered flush-mounted Langmuir-probe array (with a spatial resolution of 7.5 mm) is located in the bottom target plate 13, next to the watershed of the divertor module. Profiles topologically behind the target, in the private flux region, are measured with the reciprocating Langmuir probe, whereas the Thomson edge system enables profile measurements in the island region. However, due to the low edge plasma density in these discharges, the Thomson data scatter. Fig.1a shows normalized particle flux profiles determined from H_α- and Langmuir probe-measurements in discharges with plasma densities that differ by a factor of two. Generally, the H_α-profile is broader due to the line-integrated measurement. The wings of the H_α-profile, where it widens significantly, have to be attributed to incoming neutrals, which penetrate much deeper into the plasma as the plasma density decreases. Except from these, the profiles determined from probe- and H_α-measurements are consistent.

3.2 Results and Discussion

Both the H_α and the Langmuir probe measurements on the target show that the shape of the particle flux profiles does not change if the density is increased by a factor of two (see Fig.1). A sensitivity study by the EMC3 code for the lower density case shows that the width of the particle flux profile remains unchanged although D is changed by a factor of two (see TABLE I). These imply that D can not be determined in this way. The reason is the predominant cross-field diffusion, which results in a rather smooth density profile throughout the islands.

On the other hand, the power flux profile on the target plate is very sensitive to χ_e, shown both by Langmuir probe measurements and EMC3 simulations (see Fig.2 and TABLE I). The cross-field heat conduction determines the width of the power flux profile, whereas the convective contribution from the particle diffusion doesn’t play a role because of flat density profiles in the island. From Fig. 2 one infers χ_e = 2.4 m^2/s in the case of the low-density discharge, and χ_e = 1.2 m^2/s in the case of the medium density discharge. The corresponding diffusion coefficients are D = 0.8 m^2/s, and D = 0.4 m^2/s, respectively. With these sets of D and χ_e the EMC3 code yields reasonable particle flux profiles, as illustrated in Fig. 1b. The deviations in the lower part of the profiles are most likely due to asymmetries and drifts not yet included in the code.

A further approach to determine D is, to use profile measurements in the shadowed region of the discontinuous targets. Particles ionized in the island diffuse into the shadowed region and get lost onto the target through parallel motion. Thus, it is expected that the radial decay length of density in this region is directly related with D. Fig. 3a shows normalized density profiles in the private flux region. The profile corresponding to the low-density discharge is calculated for two different sets of D and χ_e, that differ by a factor of two. It can be seen, that the profile calculated with D = 0.8 m^2/s and χ_e = 2.4 m^2/s matches with the measured profile, whereas the other curve lies under it. In the case of the medium density discharge, the measured and calculated profile agree for D = 0.4 m^2/s, and χ_e = 1.2 m^2/s.

Measured and calculated temperature profiles in the private flux and island region are plotted in Fig. 3b. Despite the large scatter of the measured data, the concordance with the calculated profiles is reasonable.

Conclusions

Calorimetric measurements have indicated ι-dependent up/down and toroidal asymmetries. The observed asymmetries at $\iota_a/2\pi$=5/9 were modeled and the targets readjusted. After readjustment, the toroidal asymmetry reduced considerably, the up/down asymmetry only marginally. The measured strike point positions on target agree with the model, aside from minor differences, that can be attributed to magnetic field perturbations.

The transport studies revealed, that χ_e can well be determined by the power flux profile on the target plate, whereas the particle flux profile is insensitive to D. Instead, D is deduced from the radial density profile in the shadowed region. Both D and χ_e scale inversely with n_e for the two density cases investigated and χ_e = 3D holds. The EMC3-EIRENE results agree also well with other diagnostics at different positions.

[1] Y. Feng, et al, J. Nucl. Mater. 266-269 (1999) 812-818

[2] D. Reiter, Jülich Report 1947, Jülich (1984)

P_{up} [kW]	n_e·1E-19 [m^{-2}]	D [m^2/s]	χ_e [m^2/s]	λ_Γ [cm]	λ_Q [cm]
600	2	0.4	1.2	1.4	0.7
600	2	0.8	2.4	1.4	1.2
600	4	0.4	1.2	1.5	1.3

TABLE I. Input parameters (P_{up}, D and χ_e) and the resulting decay lengths (λ_Γ and λ_Q) of the EMC3-EIRENE code for discharges with line integrated density n_e.

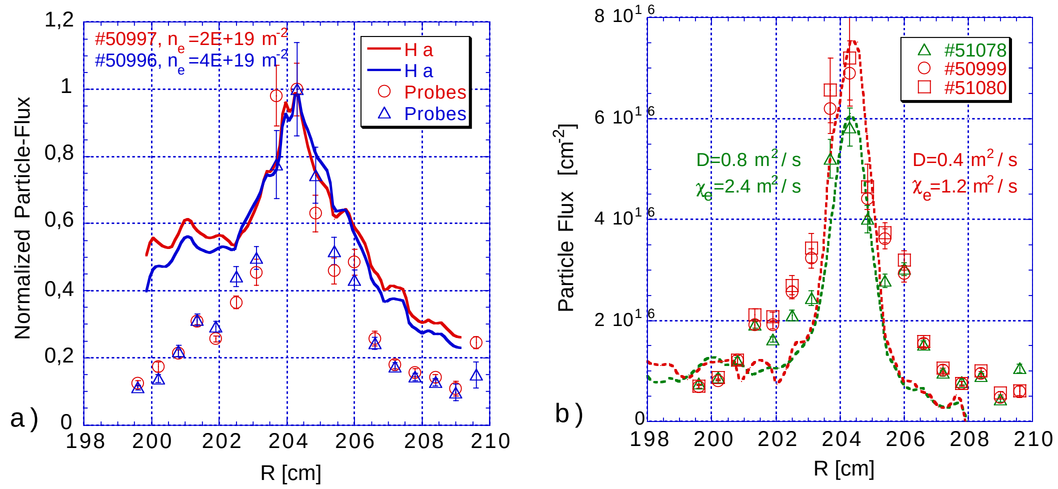

Fig.1. Particle flux profiles at the target plate for shots with plasma densities, which differ by a factor of two: a) Profiles determined from Langmuir probe- and H_a-measurements, b) Calculated (dashed lines) and measured profiles (symbols).

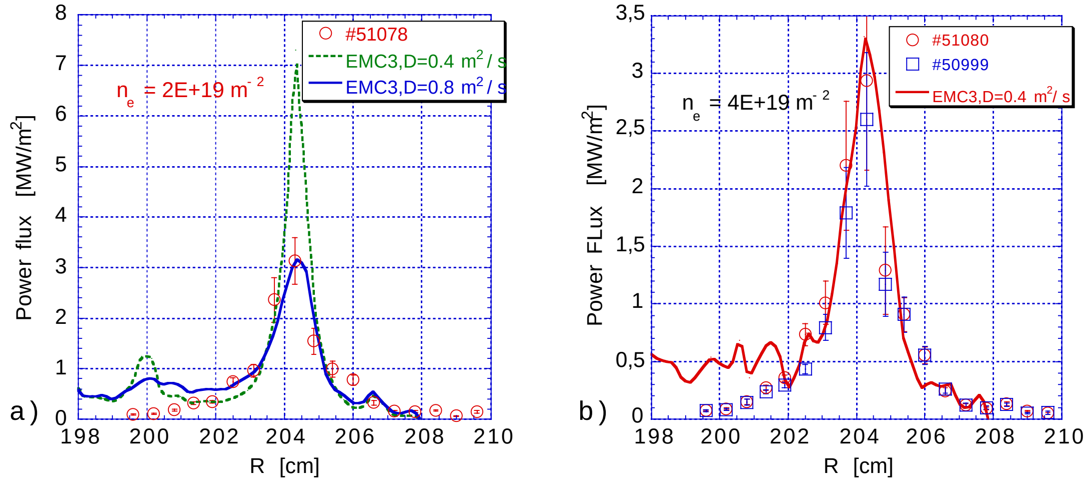

Fig.2. Calculated and measured power flux profiles onto the target plate. a) Low density case, b) medium density case. The used energy transmission factor, γ_i=4.5.

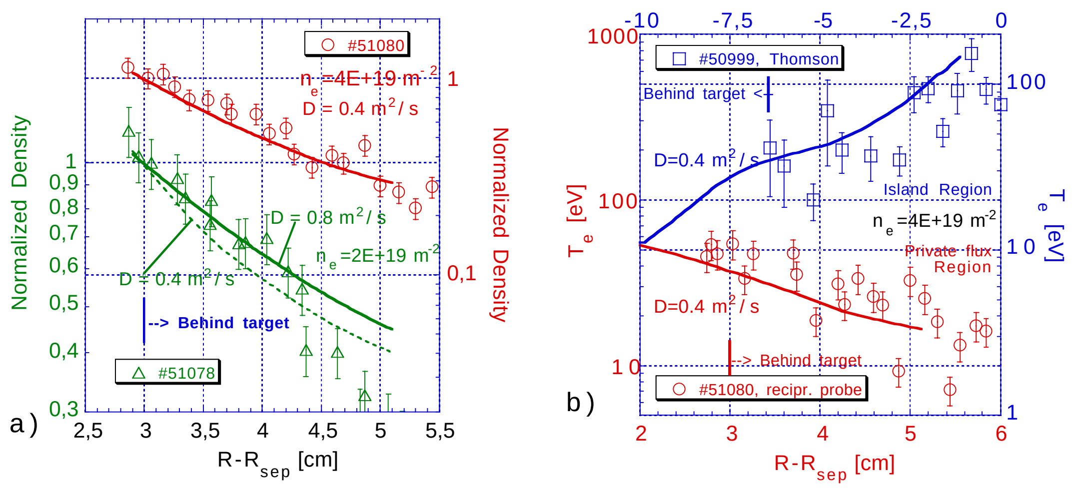

Fig.3. a) Calculated (line) and measured (symbols) density profiles in the private flux region. b) Calculated and measured T_e-profiles in the island and private flux region