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Optimization of lower hybrid wave coupling for the WEST LHCD launchers

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The lower hybrid current drive (LHCD) system in WEST plays a key role for achieving long pulse operation and high performance plasmas. Up to 5 MW LHCD power has been coupled in WEST plasmas in both Lower Single Null and Upper Single Null configurations, and pulse duration of 55 s has been sustained with 3 MW of LHCD [1]. The LHCD power is launched into the plasma by two multijunction launchers (Full-Active-Multijunction and Passive-Active-Multijunction), previously used in Tore Supra.

Prior to the start of WEST, the front face of the Full-Active-Multijuntion (FAM/LH1) launcher, was reshaped in the toroidal direction in order to fit the toroidal curvature of the WEST plasmas [2], since the toroidal ripple in WEST is smaller than that in the former Tore Supra. This contribution now presents a detailed experimental analysis of the LH wave coupling in each multijunction module on the two launchers, i.e. the reshaped FAM/LH1 launcher and the non-reshaped Passive-Active-Multijunction (PAM/LH2) launcher, in different plasma configurations and at different edge electron densities. Modelling with the ALOHA coupling code [3] has been carried out, based on the experimental values of power and phase in each multijunction module. Fig. 1 shows the power reflection coefficient (RC) in each module on the upper half of FAM/LH1 versus the density measured by a Langmuir probe on the upper part of the LH1 launcher, for a database of 67 pulses. The ALOHA modelling for the upper part of LH1 using two density gradients (λ_1= 1 mm; λ_2 = 15 mm) is also plotted. Fig. 1 illustrates that low RC are obtained on all modules for the same edge density, meaning that the edge density is homogeneous along the toroidal direction and thus that the reshaping of the launcher mouth has been efficient.

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In contrast, the RC on the individual modules on the PAM/LH2 launcher behave differently depending on their toroidal location (Fig. 2). An increase in RC with increasing edge density is seen on the lateral modules, while the opposite behavior is observed on the central modules. A comparison with ALOHA is not shown in Fig. 2, because there is no single ALOHA-run that gives agreement with the experimental values in all modules simultaneously. The ALOHA-calculations suggest that the edge density in front of the lateral modules is higher than that in front of the central modules, which is consistent with the fact that the LH2 launcher has not been reshaped. The toroidal asymmetry is also evident during long pulse operation (up to 55 s), where a local overheating of the edge modules is seen using the infrared monitoring [4]. A reshaping in-situ of the LH2 lateral modules is therefore foreseen in view of WEST phase 2 aiming at 1000 s pulses.

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Nevertheless, good coupling and low RC (< 5%) on all modules on LH1 and LH2 can be obtained by adjusting the plasma and launcher positions and by tuning the plasma shaping with feedforward control of the upper and lower gaps (at ± 25 cm with respect to the mid-plane). Local gas puffing systems, located near the launcher side protections and radially retracted by ~ 20 cm, are available but have not been exploited significantly, since the weak pumping capability in WEST does not allow large flexibility gas fuelling. It can be noted that the LH wave coupling tends to improve when increasing the injected LHCD power, an effect that can be attributed to the ionization of the neutrals in the scrape-off-layer. SOLEDGE-EIRENE [5] simulations indicate that the neutral pressure at the radial location of the LH launchers in WEST is rather high (~ λ_1 Pa), which supports this hypothesis. This behavior is quite the opposite to that observed in Tore Supra, where the ponderomotive force effect could lead to a degradation in LH coupling when increasing the injected LHCD power [6].

References

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