Topic: **TWH**

Full Wave Simulations for Fast Wave Heating and Power Losses in the Scrape-off Layer of Tokamak Plasmas

N. Bertelli[1], E. F. Jaeger[2], J. C. Hosea[1], C. K. Phillips[1], L. Berry[3], P. T. Bonoli[4], S. P. Gerhardt[1], D. Green[3], B. LeBlanc[1], R. J. Perkins[1], R. I. Pinsker[5], R. Prater[5], P. M. Ryan[3], G. Taylor[1], E. J. Valeo[1], J. R. Wilson[1] and J. C. Wright[4]
[1] Princeton Plasma Physics Laboratory, Princeton, NJ 08543,
[2] XCEL Engineering Inc., Oak Ridge, TN 37830, USA
[3]Oak Ridge National Laboratory, Oak Ridge, TN 37831-6169, USA
[4]Plasma Science and Fusion Center, MIT, Cambridge, MA 02139, USA
[5]General Atomics, PO Box 85608, San Diego, CA 92186-5608, USA

Email: nbertell@pppl.gov

In fusion experiments, fast wave heating in the ion cyclotron range of frequency (ICRF) has been successfully used to sustain and control the plasma performance. Consequently, ICRF heating will likely play an important role in the ITER experiment [1]. However, many ICRF heating experiments have found regimes in which significant fractions of the coupled RF power does not appear in the core, in some cases as much as 50% or more of the applied power. Experimental studies employing high harmonic fast wave (HHFW) heating on the National Spherical Torus eXperiment (NSTX) [2], a low aspect ratio tokamak, have shown that substantial HHFW power loss (up to 60% of the HHFW power coupled from the antenna) can occur along the open field lines in the scrape-off layer (SOL) when edge densities are high enough that the FWs can propagate close to the antenna. The mechanism behind this loss in the SOL is not yet understood [3-7]. This paper examines HHFW power loss in the SOL by using the numerical full wave simulation code AORSA [8], in which the edge plasma beyond the last closed flux surface (LCFS) is included in the solution domain [9]. A collisional damping parameter is used as a proxy to represent the real, and most likely nonlinear, damping processes [10, 11] in order to predict the effects, and possible causes, of this power loss. 2D, single dominant toroidal mode, full wave simulations demonstrate for the first time a direct correlation between the location of the fast wave cut-off layer, large amplitude RF fields in the SOL, and the observed power losses in the SOL driven by the RF field (see Fig. 1) [12]. In particular, a significant transition to higher SOL power losses has been found when the FW cut-off is moved away from in front of the antenna by increasing the edge density in the antenna region (n_{ant}) (see Fig. 2), consistent with the experimental observations [4]. The simulated power losses increase significantly when waves in the SOL transition from evanescent to

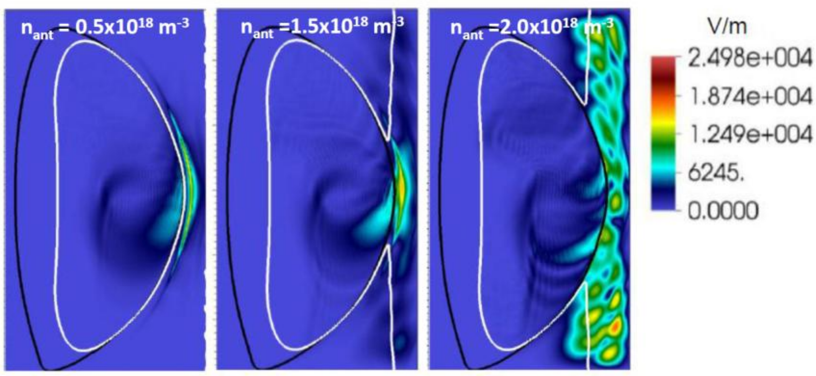

Figure 1: *Electric field amplitude for different density values in front of the antenna (n_{ant}) (shown in the plots) with toroidal mode numbers $n_\phi = -21$. The white and black curves indicate the FW cut-off layer and the last closed flux surface, respectively.*

propagating as n_{ant} is increased. The fraction of power lost in the SOL evaluated with 3D full wave simulations, using 81 toroidal modes to reconstruct the full antenna spectrum, is similar to that found in the 2D full wave simulations. A similar transition in SOL power losses as a function of n_{ant} is observed in 3D simulations, although it is less pronounced than in the 2D simulations, due to the contribution from several toroidal modes. Larger SOL power losses are predicted in the 3D simulations compared to the 2D simulations, both for low and high values of n_{ant}. Moreover, 3D simulations show that the absorbed power in the SOL is largest near the LCFS and near the front of the antenna, as observed experimentally [7]. The full wave simulations predict that plasmas in NSTX-Upgrade (NSTX-U) [13], run at twice the toroidal magnetic field achievable in NSTX, will have a wider range of n_{ant} for which RF power losses in the SOL are low. Numerical full wave simulations for "conventional" tokamaks with higher aspect ratios, such as DIII-D, were also performed and showed similar behavior to that described for NSTX and NSTX-U. Hence, these full wave simulations may provide a means of predicting the magnitude of the edge losses for the ICRF heating in current experiments and in future devices, in particular in ITER. However, it is important to note that the ITER geometry and the main plasma parameters are different with respect to those of the NSTX, NSTX-U, and DIII-D experiments. Therefore, further numerical and experimental studies are needed to identify the actual physical mechanism(s) causing the observed RF edge losses in NSTX, and in order to permit conclusive edge loss projections for ITER.

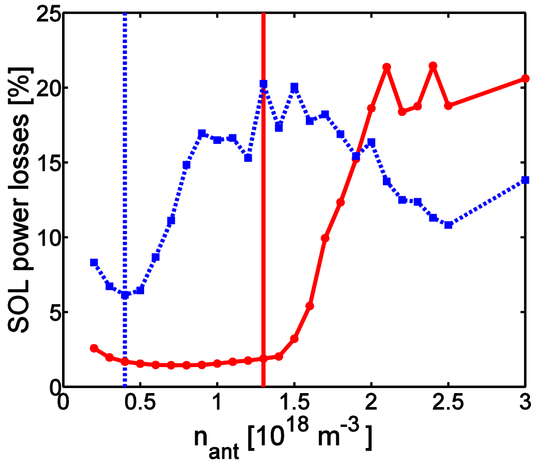

Figure 2: *Fraction of power lost to the SOL as a function of the density in front of the antenna for $n_\phi = -21$ (solid curve) and $n_\phi = -12$ (dashed curve). The vertical lines represent the value of the density for which the FW cut-off starts to be "open" in front of the antenna (see Fig. 1).*

This work is supported by U.S. DOE Contract # DE-AC02-09CH11466

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