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Modeling of 3D Material Erosion and Impurity Transport During Application of Resonant Magnetic Perturbations with the ERO2.0 Code

Marcos Navarro Gonzalez[1], Jonathan van Blarcum[2], Juri Romazanov[2], Andreas Kirschner[2], Edward Hinson[3], Tyler Abrams[4], Jong-Kyu Park[5], Heinke Frerichs[1], and Oliver Schmitz[1]

[1] University of Wisconsin-Madison, [2] Forschungszentrum Jülich, [3] Oak Ridge National Laboratory, [4] General Atomics, [5] Princeton Plasma Physics Laboratory

e-mail (speaker): navarrogonza@wisc.edu

ERO2.0 modeling of the plasma wall interactions in a three-dimensional boundary by use of resonant magnetic perturbations (RMP) demonstrated that there is enhanced particle redeposition in the regions between flux lobes at the DIII-D divertor targets. This is contrary to expectations where the helical lobes in this 3D boundary would lead eroded impurities away from the strike line and would be a major concern for the divertor lifetime of a fusion power plant, where RMP fields are one of the main ways to mitigate edge localized modes in high-performance scenarios. The work workflow and estimates presented here can be similarly applied to the design of a system where the perturbed fields can be swept to evenly distribute the particle loads along divertor targets. The results for the DIII-D scenarios (Figure 1) for a carbon divertor show higher toroidally averaged net erosion for the no-RMP reference case compared to the two RMP setups (i.e. 0°, 60°) for an n = 3 perturbation, and the effect is increased when the impurity diffusion coefficient is increased.

It is seen that particle re-erosion contributes to significant impurity deposition between the lobe structures because their trajectories move radially outwards [1]. A similar analysis of plasma wall interactions and global impurity transport for the ELM suppression window [2] in KSTAR has shown that carbon erosion at the divertor plates is a strong function of the resonant magnetic perturbation (n = 1) coil current and relative phasing. The resulting transport leads to deposition of impurities along the targets positioned at the high-field side of the device. An attempt at calculating the resulting effective charge state has demonstrated a similar dependence on the perturbation coil current and has been able to predict with some success the experimentally observed values by including contributions of all carbon charge states.

References

[1] Marcos Navarro et al 2024, Nuclear Fusion 64 046015

[2] J.K. Park et al, Nature Physics 15, 1223-1228 (2018)

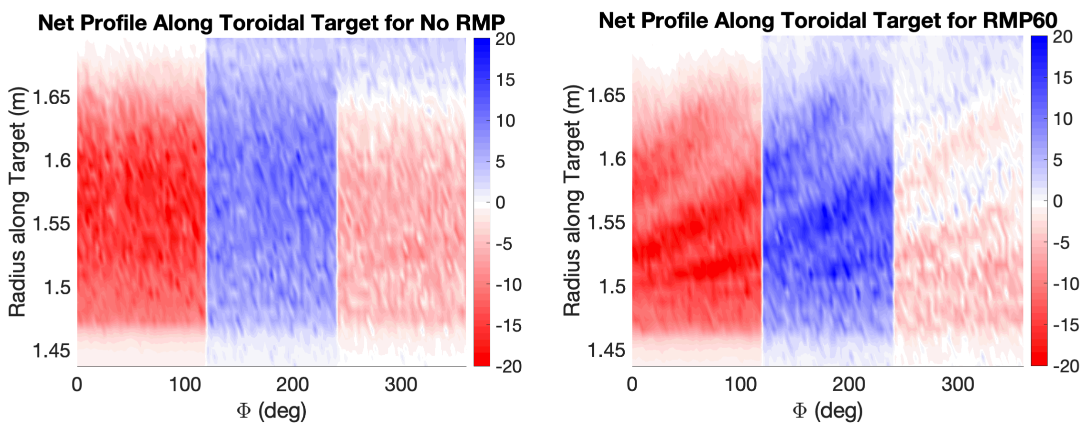

Figure 1. Carbon rates (nm/s) for the no RMP scenario; bottom: carbon rates for the 60° phasing scenario. The three sectors demonstrate the gross erosion fluxes (left), total deposition flux (middle) and net flux (right); a blue rate (positive) means net deposition, and a red rate (negative) indicates net erosion.