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High-Performance Computational Modeling of Plasma-Surface Interactions and RF Antennas

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The heating of confined tokamak plasma to fusion-relevant temperatures can cause sputtering of high-Z impurities from plasma-facing components, and such impurities radiatively cool the plasma, especially as transport effects carry them to the reactor core. The sputtering process is believed to be exacerbated by the large electromagnetic fields generated by RF antennas, since these fields alter the dynamics of sheaths that form on antenna components in contact with plasma. Recent advances in finite-difference time-domain (FDTD) modeling techniques [T. G. Jenkins and D. N. Smithe, Plasma Sources Sci. Technol. 24, 015020 (2015)] enable the physics of localized sheath potentials to be modeled concurrently with the physics of antenna near- and far-field behavior and RF power flow. When implemented on high-performance computing platforms, such techniques enable the study of plasma-surface interactions in realistic experimental ion-cyclotron resonance heating scenarios at previously inaccessible levels of resolution. We will present results and 3D animations of high-performance (10k –100k core) FDTD simulations of Alcator C-Mod's field-aligned ICRF antenna on the Titan supercomputer, considering (a) sputtering and impurity production, as driven by self-consistent sheath potentials at antenna surfaces; (b) the use of localized dielectric coating material on antenna components, as a design-based impurity mitigation strategy, and (c) the physics of slow wave excitation in the immediate vicinity of the antenna hardware and in the scrape-off layer for various edge densities.

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