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

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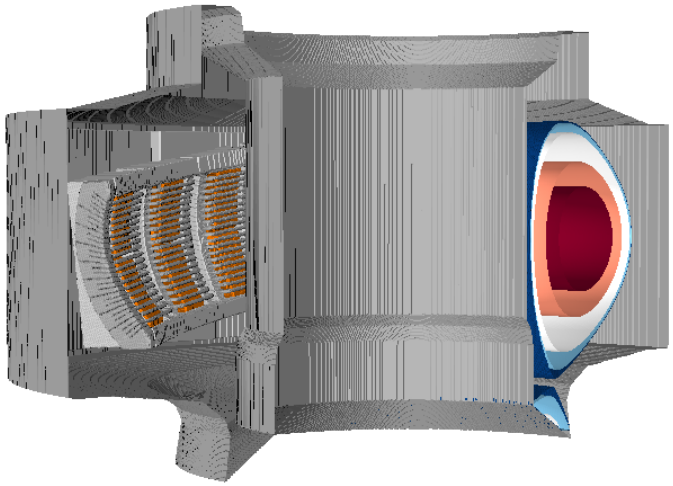
Science Objectives and Impact

- **Combine state-of-the-art finite-difference time-domain (FDTD) algorithms, cut-cell techniques, and visualization capabilities to create the most advanced 3D time-domain model of ICRF heating to date. Generate 3D animations of experimentally relevant plasma heating scenarios in the Alcator C-Mod fusion experiment (see https://nucleus.txcorp.com/~tgjenkins/movies.html).**
- **Model impurity production enhancements that arise due to plasma sheath formation on RF antenna components. Explore mitigation strategies for the impurity production, enabling reactor-scale fusion experiments (e.g. ITER) which rely on RF for plasma heating to achieve fusion temperatures more efficiently.**
- **Explore parasitic power loss mechanisms (e.g. slow wave excitation in plasma edge/SOL) which divert ICRF power from its intended use to heat the plasma core; quantify power losses as a function of edge/SOL plasma parameters and explore mitigation techniques.**

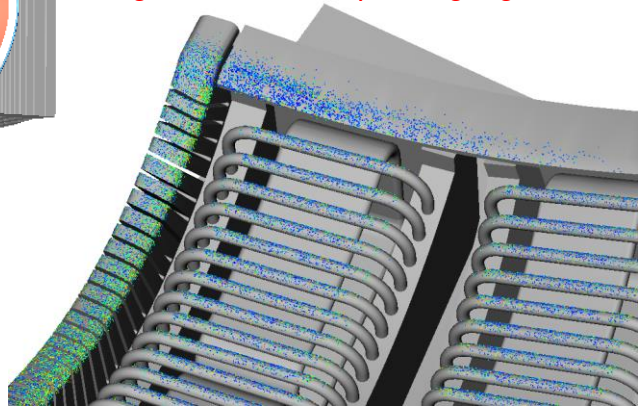
Science Results

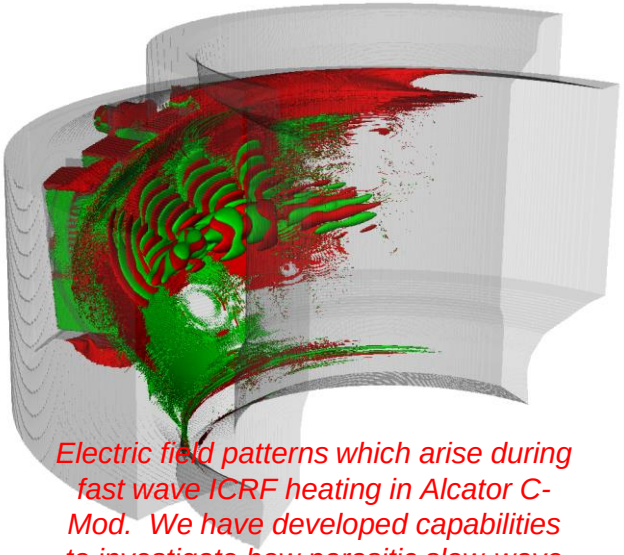
- **We have developed a half-torus model of Alcator C-Mod, in which both the detailed ICRF antenna geometry and the fast and slow plasma waves excited by this antenna are resolved, for experimentally realistic plasmas and field profiles, at sub-millimeter scales. Time-domain simulations of ICRF antenna operation, including the time-varying sheath potentials on antenna surfaces, have been carried out over hundreds of RF periods and can compute local sputtering from antenna/vessel components.**
- **The new model also enables onset criteria for the detrimental slow waves, which parasitically draw power from the desired fast waves, to be explored as a function of edge and scrape-off-layer density.**
- **More quantifiable metrics for these behaviors are anticipated as we continue to exercise the model in experimentally relevant C-Mod operational regimes.**



Half-torus model of the Alcator C-Mod tokamak, as implemented in the VSim code and exercised on tens of thousands of processers on the Titan Cray XK7.

Sputtering events which arise from fast ion collisions with the plasma-facing antenna surfaces in Alcator C-Mod. We are developing capabilities to model sputtering impurity generation in realistic experimental geometries and operating regimes.





Electric field patterns which arise during fast wave ICRF heating in Alcator C-Mod. We have developed capabilities to investigate how parasitic slow-wave power losses in the plasma edge scale with edge/SOL plasma parameters.