Coupled UEDGE/Vorpal modeling of RF-induced ponderomotive effects on edge and SOL transport

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Large-amplitude EM fields driven by RF antennas in the tokamak plasma edge induce perturbed charge and current densities on fast RF timescales as power is injected to heat the core plasma. However, these fields, charges, and currents also give rise to slow (transport-timescale) ponderomotive effects, since the time-average of products of fast quantities is nonzero on these longer timescales. Together with the conventional grad(E^2) ponderomotive force associated with nonuniform EM energy density, additional force terms dependent on density gradients, species charge signs, collisionality, and incident wave polarization arise, and these terms introduce new vorticity, energy, and parallel momentum sources to the edge and SOL transport.

We have coupled the Vorpal (FDTD EM+plasma solver) and UEDGE (2D edge plasma transport) codes in a manner enabling numerical study of these ponderomotive terms and their effects on edge/SOL transport. In NSTX-adjacent scenarios with experimentally realistic plasma profiles and antenna parameters, we observe that the ponderomotive contribution to parallel electron momentum is significant (comparable to or larger than other edge transport processes) for representative RF input power fluxes. We demonstrate that this parallel momentum source drives the transport of density away from the region immediately in front of the RF antenna. Further, as the density is reduced, we show that the polarization, propagation, and absorption of incident RF waves is accordingly modified, often in detrimental (for antenna efficiency and core power coupling) and potentially self-reinforcing ways.

Because ponderomotive effects scale in magnitude with the antenna input power flux, they become increasingly relevant for large, high-RF-power experiments such as ITER (input power flux ~1 MW/m^2). We consider the implications of these results for ITER antenna operation.

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