High-Performance Numerical Simulation of RF Wave Heating and Sheath Effects in Fusion Plasmas

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In recent years, powerful finite-difference time-domain (FDTD) modeling techniques have been developed for the simulation of ion-cyclotron resonance heating scenarios in fusion plasmas [see T. G. Jenkins and D. N. Smithe, Plasma Sources Sci. Technol. 24, 015020 (2015), and references therein]. When coupled with the power of modern high-performance computing platforms, such techniques allow the behavior of antenna near and far fields, and the flow of radiofrequency (RF) power from the antenna, to be studied in realistic experimental scenarios at previously inaccessible levels of resolution. In addition, the development of self-consistent models for the plasma sheath near antenna surfaces enables both material sputtering events, and the effects of the ensuing sputtered contaminants on the core plasma, to be explored.

In this talk, I'll give an overview of such modeling techniques and discuss some ways they are being applied to simulate magnetized fusion plasmas. Results and animations from high-performance (10k-100k core) simulation of RF antenna operation in the Alcator C-Mod fusion device will be shown. In addition to the desired long-wavelength "fast" waves, which are used to heat the core plasma, the generation of undesired "slow" waves observed in the plasma edge and scrape-off layer will be discussed; such waves reduce the overall antenna efficiency. Possible connections of the slow wave generation with experimental observations will be explored. In addition, I'll summarize ongoing efforts to accurately simulate sputtering-based impurity generation at the plasma-material interface, using particle-in-cell modeling techniques in tandem with a recently-developed FDTD model for the plasma sheath.