SciDAC Center for Fusion Relevant RF Actuators:
Particle-based approaches to RF induced impurity generation, and an MFEM based far-SOL transport solver.

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RF-SciDAC

MIT · OAK RIDGE · Lawrence Livermore National Laboratory · PPPL · CompX · THE UNIVERSITY OF NEWCASTLE
TECH-X · Rensselaer · ILLINOIS · Lodestar Research Corporation

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Coupling RF codes with transport codes via ponderomotive forces - formulation

High-order finite elements have excellent scalability

Future Work
- **Thrust 3** focuses on the coupling of RF with the physics of equilibrium time-scale transport to the antenna/wall
- Progressive approach underway, leveraging reduced models & existing codes

Concurrent modeling of plasma sheaths and RF physics is challenging due to length scale disparities

Modeling sheath rectification and impurity sputtering using a fluid approximation

Production of sputtered impurities during RF cycle varies nonlinearly with RF frequency and phase

LAPD device for sheath model validation

Scientific Objectives & Organization of the RF-SciDAC Project

A first step in coupling is to use surrogate models for the RF sheath in 2D and 3D transport simulations

Same MFEM-based AMR algorithms can be applied to a variety of high-order physics models

Thrust 4 focuses on using the developed meshing and solver tools with sheath and sputtering models to calculate RF-rectified sheaths and impurity generation

Sheath and impurity sputtering modeling with Vorpal

Fluid modeling of sheath rectification agrees well with previously published models

Sputtered impurity transport fluxes are also affected by RF frequency and phase

Petra-M solution + local sheath model predicts RF potentials on target plate

Thrust 3 focuses on the coupling of RF with the physics of equilibrium time-scale transport to the antenna/wall

RF physics can be added to EMC3-EIRENE to study 3D plasma evolution near plasma-facing components

Parallel AMR scaling to ~400k MPI tasks demonstrated

Plasma sheath formation on RF antenna surfaces: a multiscale problem

Developing improved sheath boundary conditions for RF codes

Ion impact angles are significantly affected by local magnetic field orientation and by RF oscillations

How RF affects the mean flux of sputtered impurities: low- and intermediate-frequency behavior

Future Work
- **Thrust 4** focuses on using the developed meshing and solver tools with sheath and sputtering models to calculate RF-rectified sheaths and impurity generation

Codes used and under development in Thrust 3
- Transport codes (production)
  - UEDGE: 2D fluid plasma and neutral transport
  - EMC3-EIRENE: 3D Monte Carlo fluid plasma, kinetic neutrals
- Simple / surrogate RF models
  - New 1D coupled code (ORNL)
  - Analytic models (Lodestar, Tech-X)
- RF solvers
  - PETRA-M (RF solver based on MFEM)
  - MFEM

Far-SOL MFEM-based solver on non-field-aligned mesh is being investigated

Several variable-fidelity validation targets have been identified from existing devices
LAPD Linear Device
C-Mod Tokamak

Modeling RF physics with the Vorpal (VSim) code

RF-SciDAC code and model benchmarking activities

Energy-angle distribution of sputtered impurities is also influenced by local magnetic fields

How RF affects the mean flux of sputtered impurities: high-frequency behavior