LLNL FESP Theory and Modeling Program Overview

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Associate Program Leader

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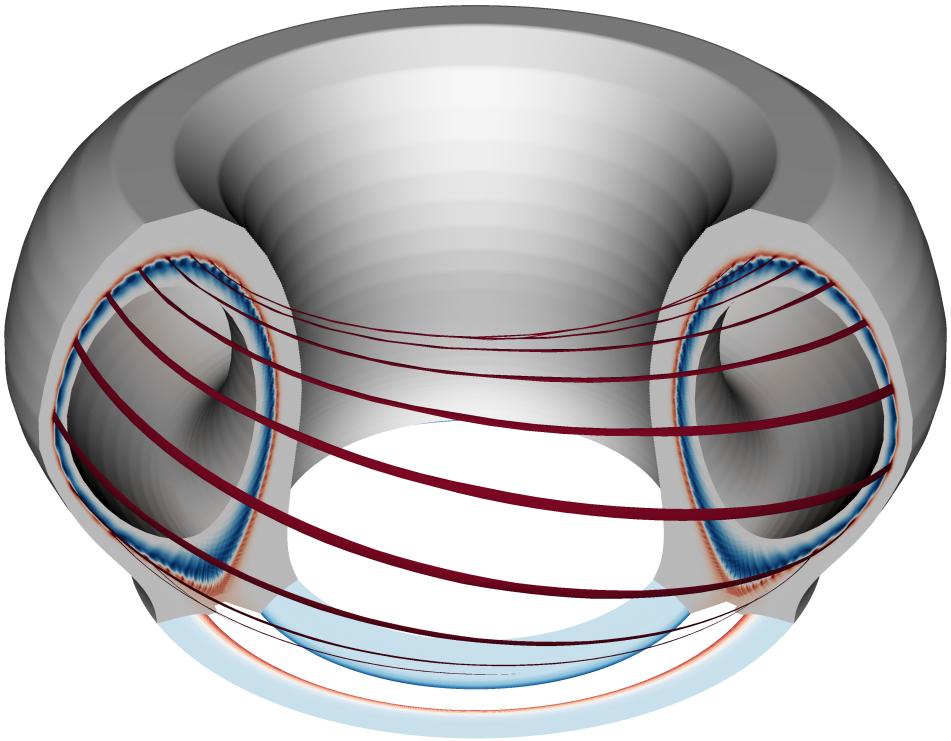
10th US-PRC Magnetic Fusion Collaboration Workshop (MFCW 2021)



***BOUT++** simulations reveal the dynamics of filamentary eruptions of hot plasma from the edge and heat flux footprints on divertor targets in a **DIII-D** experiment.*

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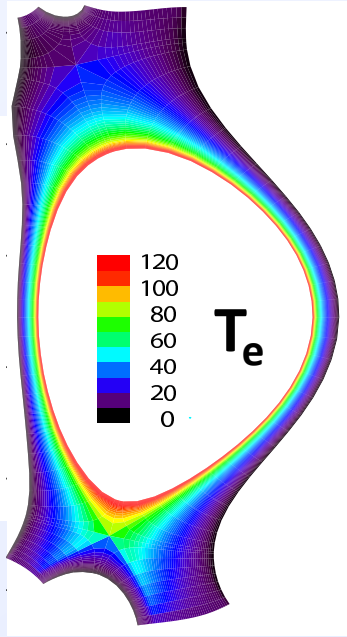
Overarching Goals

- **Our mission: To advance the understanding and predictability of MFE plasmas**
- **We pursue knowledge and innovation, with a focus in two main task areas**
  - **Edge Physics**: turbulence, transport, and divertor physics
  - **Integrated Modeling:** predictive & whole device modeling, timescale bridging
- **We also engage in emerging areas of broad interest**
  - Effective use of advanced computer architectures
  - Quantum information science, machine learning
- **We emphasize connections to experiments**
  - Planning, analysis, and modeling
  - **DIII-D, NSTX-U, MAST, EAST, KSTAR, …**
  - Studies toward future machines: **ITER, CFETR, SPARC/ARC, possible new U.S. device**

UEDGE *electron temperature* (T_e) *prediction for the* ***DIII-D*** *tokamak.*



We employ a range of advanced codes and analytic theory

Edge Physics: Recent FESAC and community reports emphasize the importance of predicting and mitigating heat flux and impurity erosion of divertor and first wall.

- **BOUT++** is both a code and a flexible framework, capable of employing a broad range of fluid models for tokamak plasma simulation in 2D and 3D, including simulation of ELM activity and edge plasma turbulence.
  (Many of our collaborations with Chinese institutions center on BOUT++.)
- **UEDGE** can perform 2D edge and divertor transport calculations, including coupled plasma, neutral, sheath and radiation physics, in flux surface-aligned geometry. Uniquely, it offers iteration to a steady-state w/o laborious time-stepping.
- **COGENT** (part of the ESL collaboration) is the only code in the world capable of continuum kinetic simulations in tokamak geometry, in 4D and 5D.

Integrated Modeling: Integrated models are important for machine design, operating scenario development, and experimental modeling.

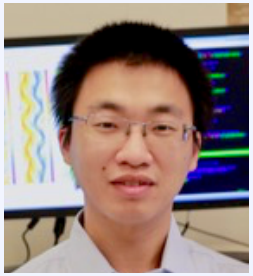
- **CORSICA** offers a unique interactive environment for modeling design and operation, including studies of equilibrium configurations, startup, and stability.
  (L. LoDestro has presented well-attended tutorials on CORSICA in China.)

Theory and Computations Staff

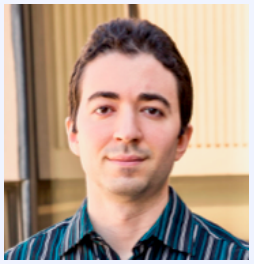
Alex Friedman Group Leader

Ilon Joseph Deputy GL
PI QIS; PI MFEM LDRD
Co-PI PSI SciDAC

Xueqiao Xu
Co-PI TDS SciDAC



Ben Zhu
BOUT++, MFEM



Michael Campanell
PI Electron Emitting Surfaces LDRD

Mikhail Dorf
Co-PI ESL
Co-PI AToM SciDAC

Lynda LoDestro
Integrated Modeling
Co-PI MGK SciDAC

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Emeritus Deputy GL
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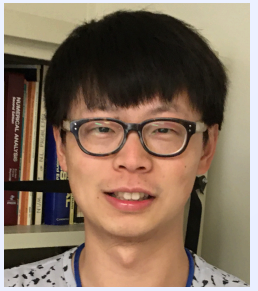
PI PFCs

Andris Dimits
Co-PI RF SciDAC

Nami Li BOUT++
(starting as postdoc)



Menglong Zhao
(postdoc) UEDGE

Bruce Cohen & Ron Cohen
Emeritus GL's;
subcontractors

Dmitri Ryutov
(retired but active)

Major Research Projects

DOE / FES

- Toroidal Theory and Integrated Modeling (Friedman)
- Experimental Modeling with UEDGE (EMU) initiative (multi-institutional collab.)
- Fusion technology, reactor design, & PFC modeling (Rognlien, Umansky)
- International Collaboration project using BOUT++ (Holcomb, Xu)
- Edge Simulation Lab (w/ GA's P. Snyder): COGENT code (Dorf, Ghosh)
- DOE/FES SciDAC's:
  - Dorf: Adv. Tokamak Modeling
  - LoDestro: Multiscale Gyrokin.
  - Dimits: RF Actuators
  - Joseph: Plasma-Surface Interactions
  - Xu: Tokamak Disruption Simulation
- Exascale Computing Program (via CASC): timescale bridging (LoDestro)
- "Quantum Leap for FES": quantum computing for fusion (Joseph)

LLNL LDRD

- Scalable and accurate simulation of magnetized edge plasmas using CASC's Modular Finite Element Method (MFEM) library (Joseph)
- A novel way to mitigate surface damage in tokamaks (Campanell)