2023 DOE-FES Collaborative Research Facilities Webinar

Agenda

- **Introduction to Collaborative Research Facilities**, Dr. Nirmol Podder, Program Manager, DOE FES
- **Basic Plasma Science Facility** (BaPSF/LAPD), Prof. Troy Carter, UCLA
- **Wisconsin Plasma Physics Laboratory** (WiPPL/BRB/MST), Prof. Cary Forest, University of Wisconsin-Madison
- **Magnetized Plasma Research Laboratory** (MPRL/MDPX), Prof. Edward Thomas, Jr., Auburn University
- **DIII-D Frontier Science Campaign**, Dr. Richard Buttery, General Atomics
- **Princeton Collaborative Low Temperature Plasma Research Facility** (PCRF), Dr. Yevgeny Raitses, PPPL
- **Sandia Plasma Research Facility** (PRF), Dr. Shane Sickafoose, Sandia National Laboratories
- **Q&A: Please use Q&A feature to submit your questions!**

U.S. DEPARTMENT OF ENERGY | Office of Science

AUBURN UNIVERSITY

WISCONSIN UNIVERSITY OF WISCONSIN-MADISON

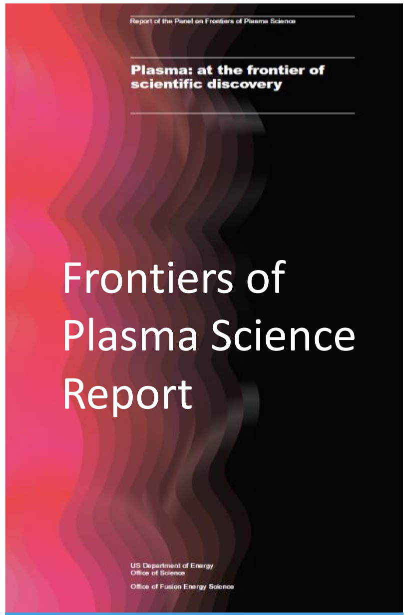
UCLA

DIII-D

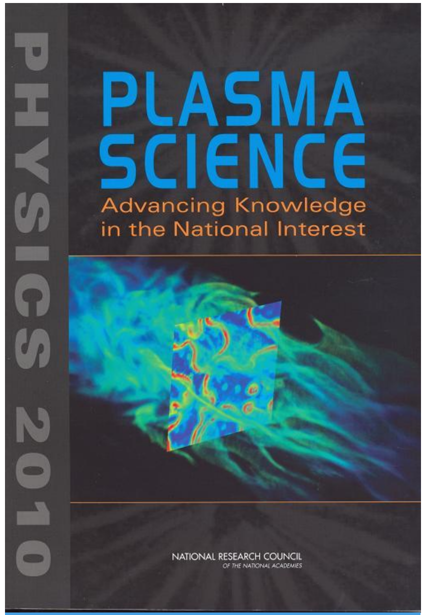
PPPL PRINCETON PLASMA PHYSICS LABORATORY

Sandia National Laboratories

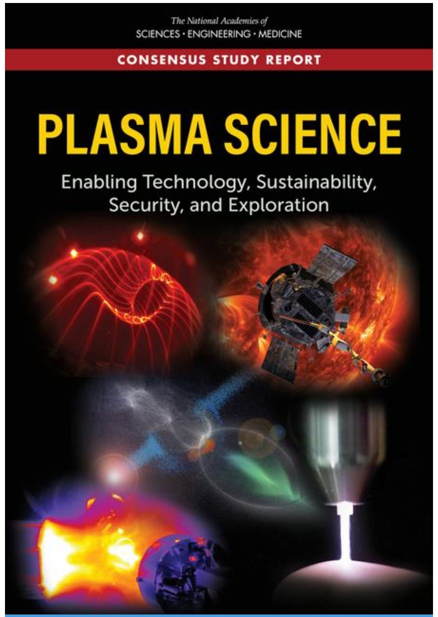
DOE Collaborative Research Facilities



"There is a need for creation and exploration of new regimes in the laboratory." (2016 PSF Report)



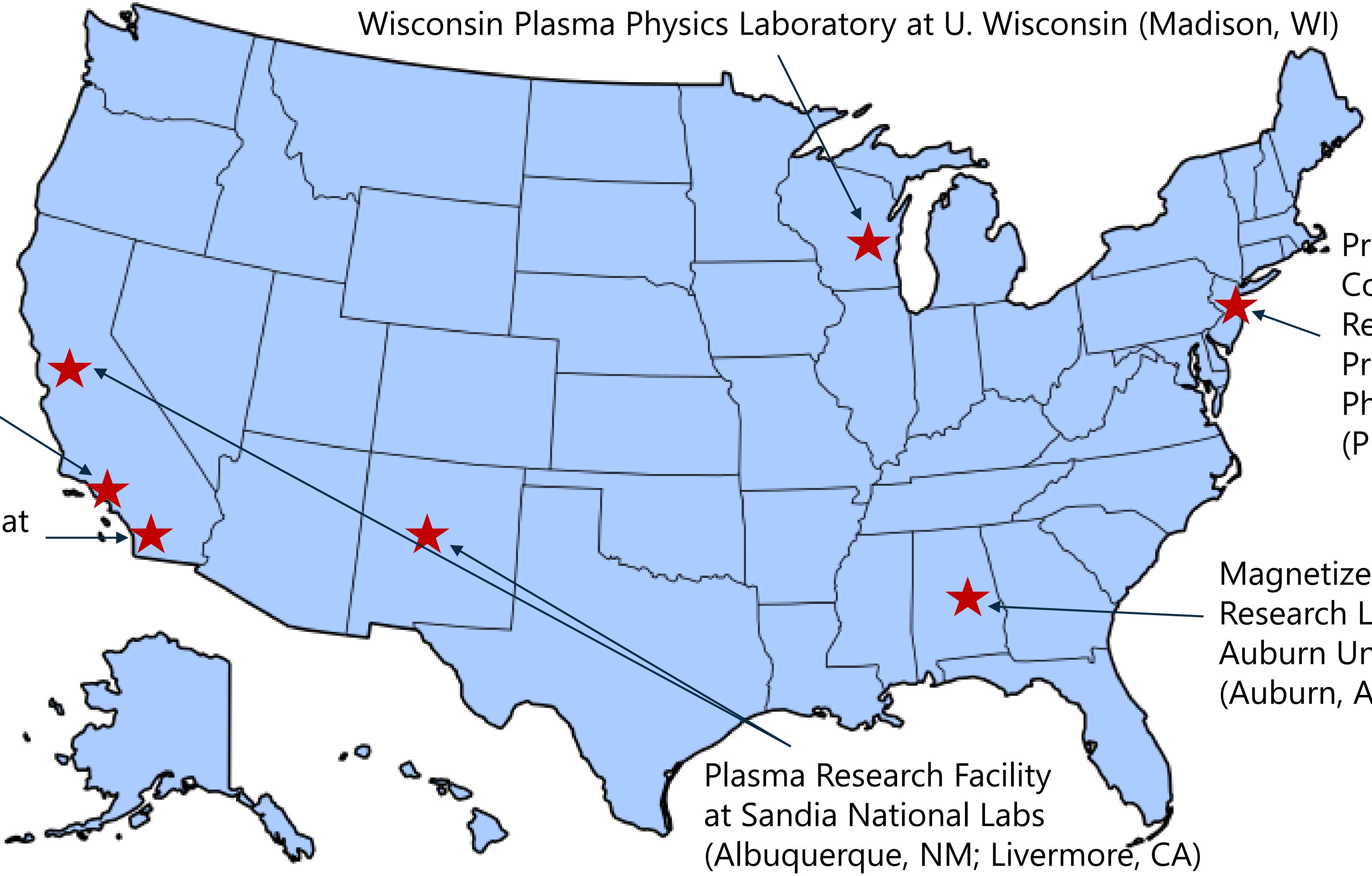
"Several areas of basic plasma science would benefit from new intermediate-scale facilities." (NAS 2010 Decadal Study)



"Federal agencies should implement a program for one-time, short-term funding for users of basic plasma science facilities." (NAS 2020 Decadal Study)

- DOE collaborative research facilities (CRFs) are expected to advance plasma science research significantly
- Discovery and innovation promoted by both external collaborators and host research team
- DOE CRFs are operated in the same spirit as larger DOE Office of Science scientific user facilities:
  - Open to all
  - Access to CRF resources (runtime, expertise) determined by peer review
  - Provide sufficient technical resources for safe and efficient execution of external collaborators' research projects
  - Facilitate a formal collaborator (user) group, …
- For most of the CRFs, approximately 40-50% facility runtime available for external collaboration
- Annual call for runtime proposals are issued by the CRFs usually in the Fall or at the end of the calendar year

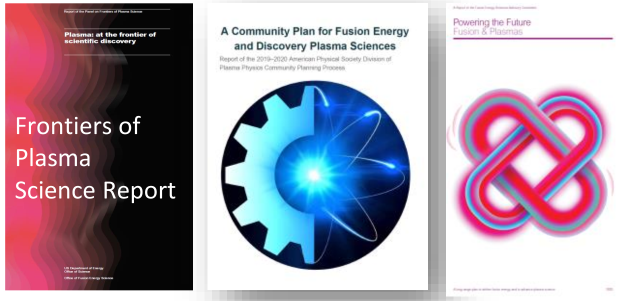
DOE Collaborative Research Facilities Locations



Process for Creating a New Collaboration with a DOE CRF

Much of the information may be available thru the website

- Basic Plasma Science Facility at UCLA
  https://plasma.physics.ucla.edu/
- Wisconsin Plasma Physics Laboratory at UW Madison
  https://wippl.wisc.edu/
- Magnetized Plasma Research Laboratory at Auburn Univ.
  https://aub.ie/mprl
- DIII-D Frontier Science Campaign at GA
  https://fusion.gat.com/global/diii-d/frontier
- Princeton Collaborative Research Facility at PPPL
  https://pcrf.princeton.edu/
- Sandia Plasma Research Facility at SNL
  https://www.sandia.gov/prf/



Have a research idea or plan?

Discussion with one of the DOE CRF Directors/POC

Troy Carter, BaPSF/UCLA, tcarter@physics.ucla.edu

Cary Forest, WiPPL/UW Madison, cary.forest@wisc.edu

Edward Thomas, MPRL/Auburn Univ., etjr@auburn.edu

Richard Buttery, DIII-D Frontier Science Campaign/GA
buttery@fusion.gat.com

Yevgeny Raitses, PCRF/PPPL, yraitses@pppl.gov

Shane Sickafoose, Sandia PRF/SNL, smsicka@sandia.gov

Developing a white paper for runtime competition and submission to “Call for Runtime Proposals” issued by the CRFs

Approved for runtime and have questions about DOE Funding Opportunity Announcements? Contact DOE Program Manager, Nirmol Podder at nirmol.podder@science.doe.gov

Process for Creating a New Collaboration with a DOE CRF: Application for Runtime (Step 1)

Separate calls for runtime proposals depending on facility:

- BaPSF/WiPPL/MPRL/DIII-D: **https://callforruntimeproposals.org/**
  - January 5, 2024 deadline
  - Requires a Record of Discussion with a facility contact
- Sandia: **https://www.sandia.gov/prf/plasma-research-facility/proposals/**
  - December 15, 2023 deadline
- PPPL: **https://pcrf.princeton.edu/solicitation/**
  - December 15, 2023 deadline

Runtime proposals for each call will be reviewed based on the following criteria:

- Intellectual merit
- Technical approach
- Team and facility readiness
- Promoting inclusive and equitable research (PIER) plan

Please visit websites above for specific submission process and contact information

Joint: BaPSF, WiPPL, MPRL, DIII-D

Sandia

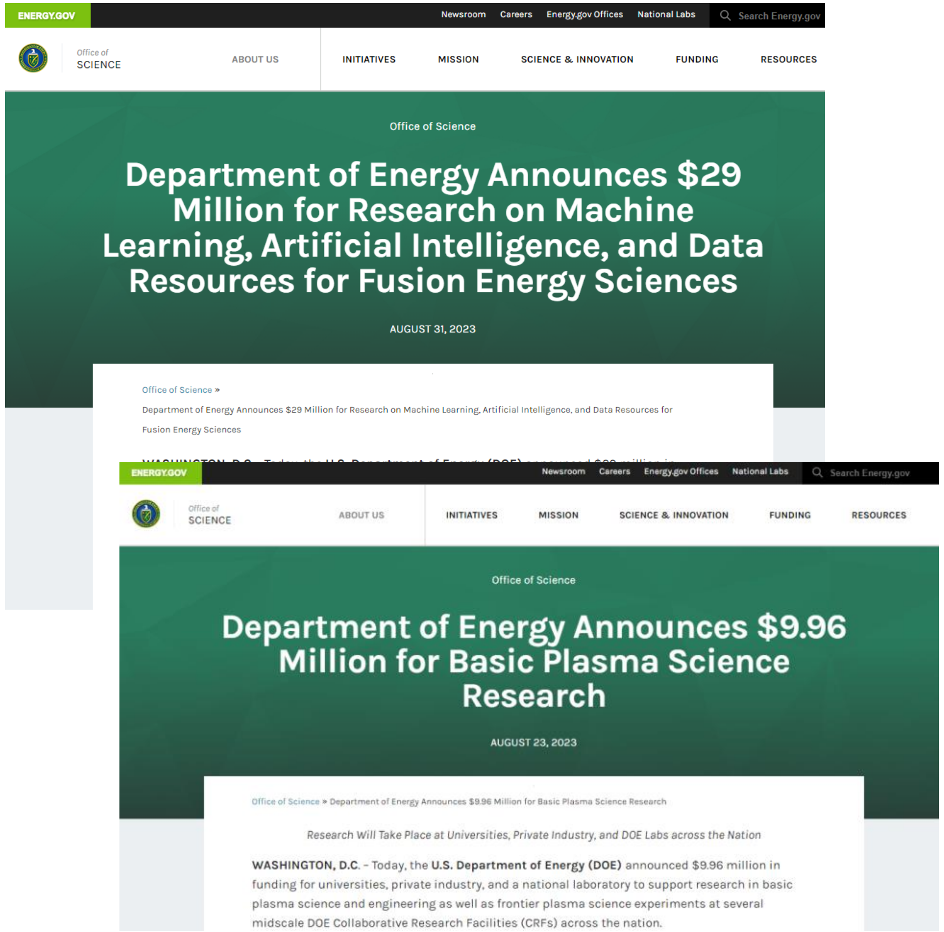
PCRF

If Needed, U.S. Applicants May Apply for Federal Funding (Step 2)

A List of Last Year's Funding Opportunities from the Office of Fusion Energy Sciences

- FES funds universities via competitive Funding Opportunity Announcements (FOAs)
- Check https://science.osti.gov/fes/Funding-Opportunities for updates

FOA Title (FY 2023)	Total Funding (All years)	# of Awards
Scientific Discovery through Advanced Computing (SciDAC) – FES Partnerships	$112M	12
Machine Learning, Artificial Intelligence, and Data Resources for Fusion Energy Sciences	$29M	7
Innovative Fusion Technology and Collaborative Fusion Energy Research in the DIII-D National Program	$10M	6
High-Energy-Density Laboratory Plasma Science	$4.65M	11
Quantum Information Science Research for Fusion Energy Sciences	$12M	10
Research in Basic Plasma Science and Engineering	$8.5M	13
Research on General Plasma Science Collaborative Research Facilities	$1.5M	17
Inertial Fusion Energy Science & Technology Accelerated Research (IFE-STAR).	$42M	TBD
LaserNetUS for Discovery Science and IFE	$28.5M	10
FES-RENEW	$6.3M	9
FES-FAIR	$2.25M	3



The Basic Plasma Science Facility

BaPSF

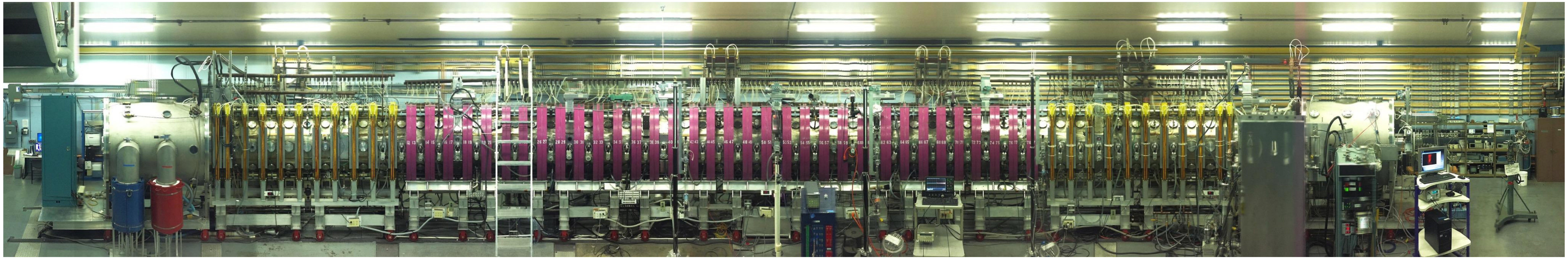
UCLA

PSTI UCLA
Plasma Science and Technology Institute

BaPSF: a flexible facility for experiments at the frontier of fundamental plasma science

- The purpose of BaPSF is to provide the plasma science community access to frontier-level research devices (principally the Large Plasma Device) that permit the exploration of plasma processes which can not be studied in smaller devices or are difficult to diagnose in large fusion facilities.
- Example processes:
  - Alfvén waves, Alfvénic turbulence/instabilities
  - Magnetized collisionless shocks
  - Turbulent transport
  - Interaction of energetic particles with waves
  - Magnetic Reconnection/Flux rope interactions

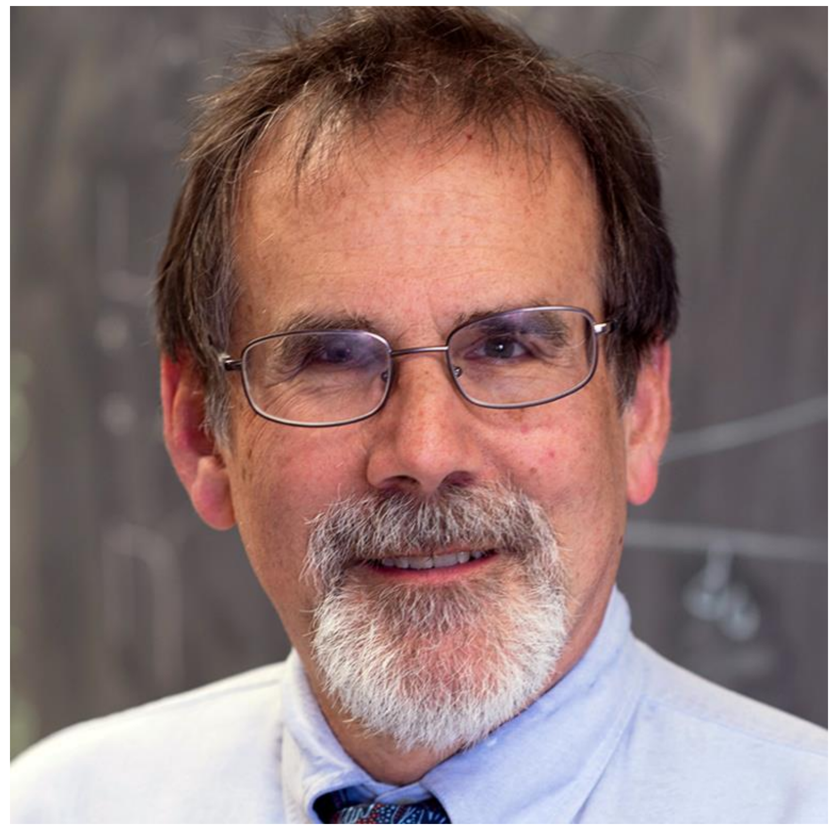
The Large Plasma Device (LAPD): a flexible experimental platform

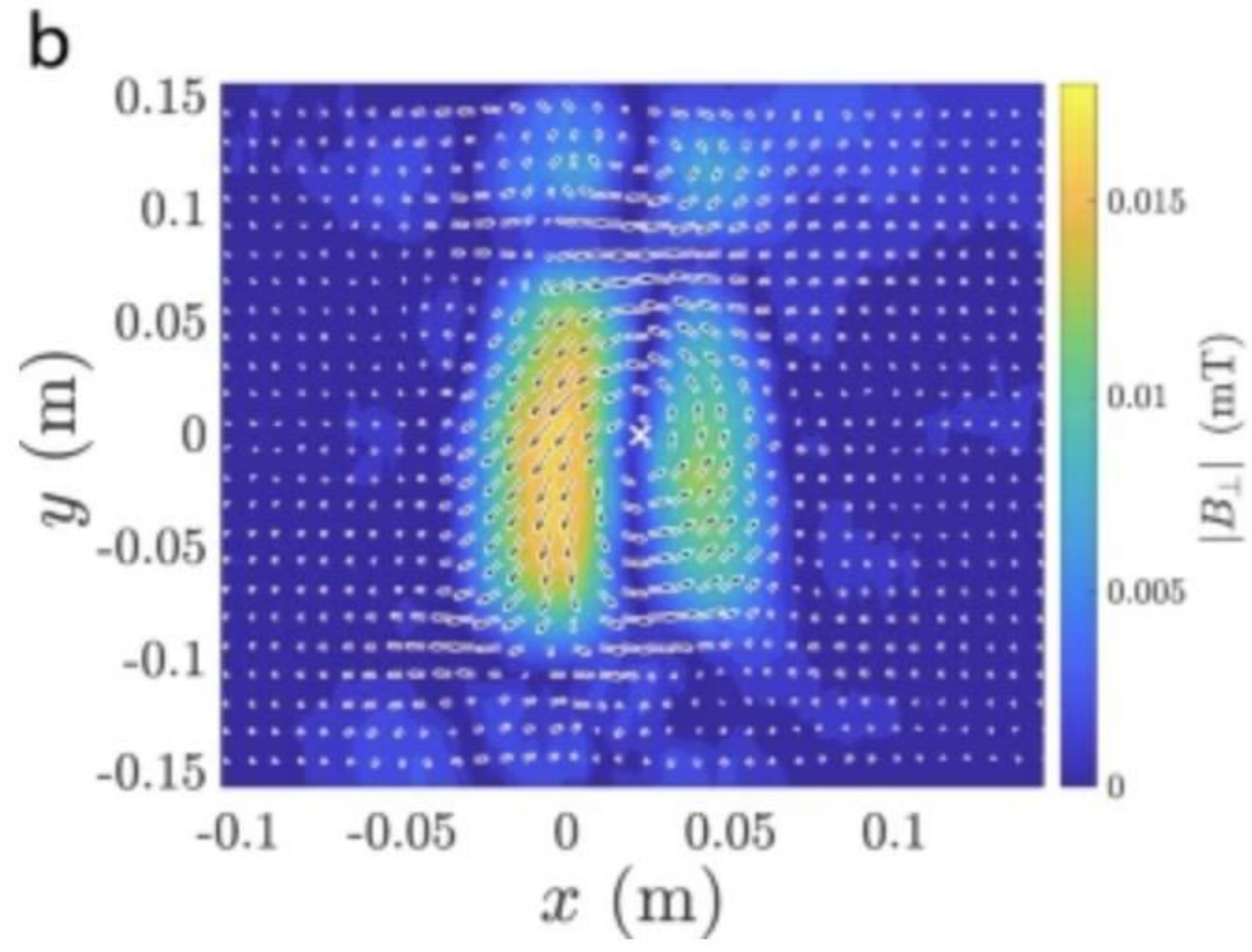


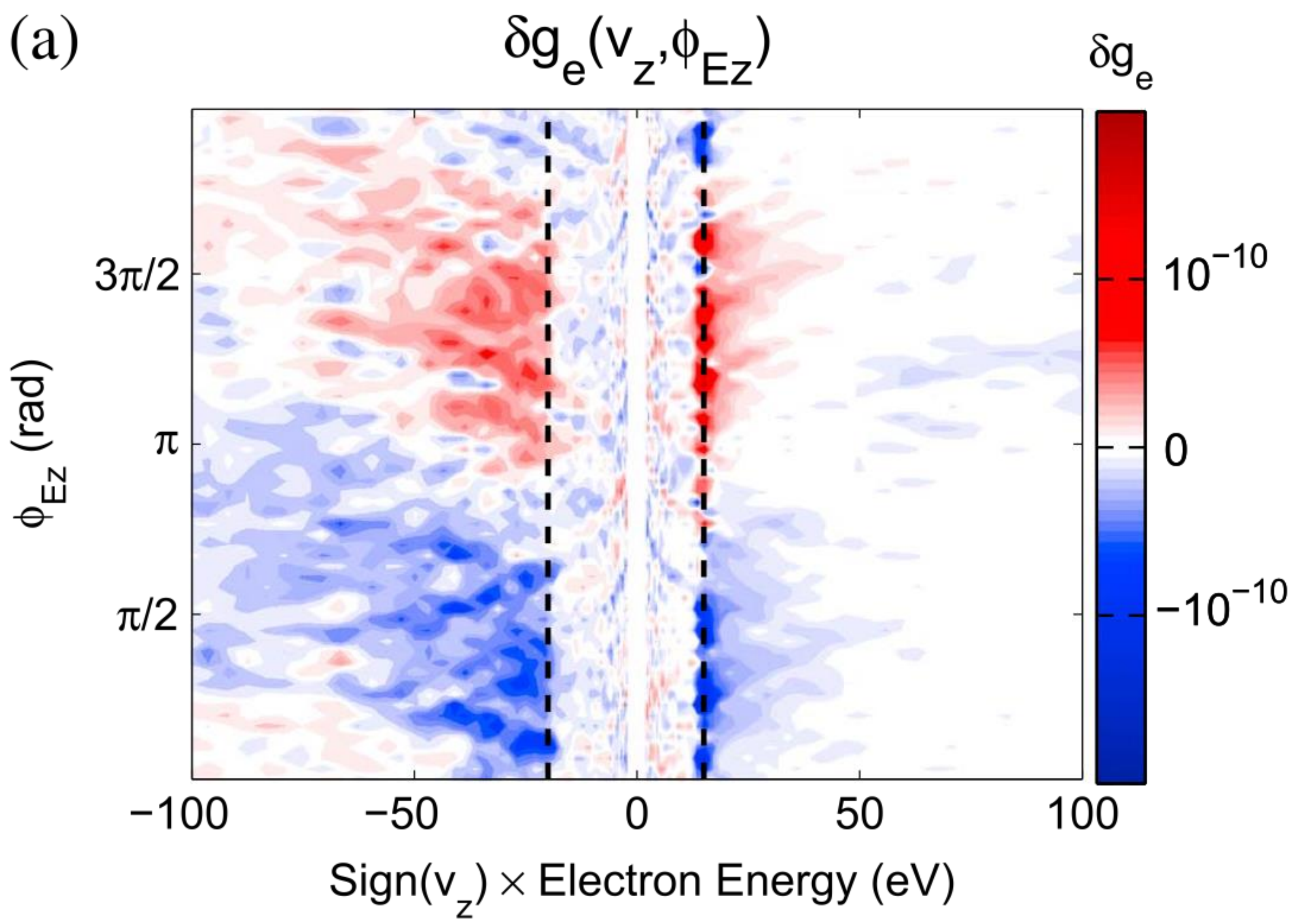
- 20m long, 1m diameter vacuum chamber; emissive cathode discharge
- LaB_6 Cathode: $n <= 5x10^{13}$ cm^{-3}, $T_e \sim$ 1-15 eV, T_i 10 eV

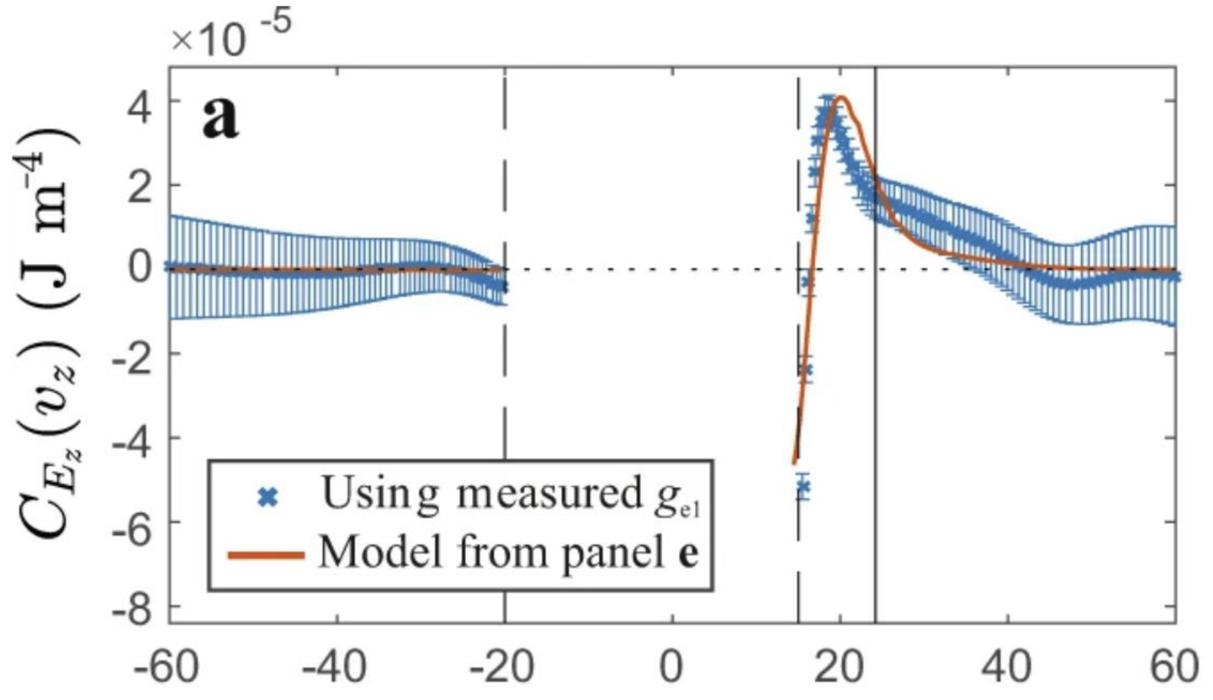
- B up to 2.5kG (with control of axial field profile)
- Reproducible plasmas at high repetition rate: 1 Hz
- US DOE & NSF Sponsored Collaborative Research Facility

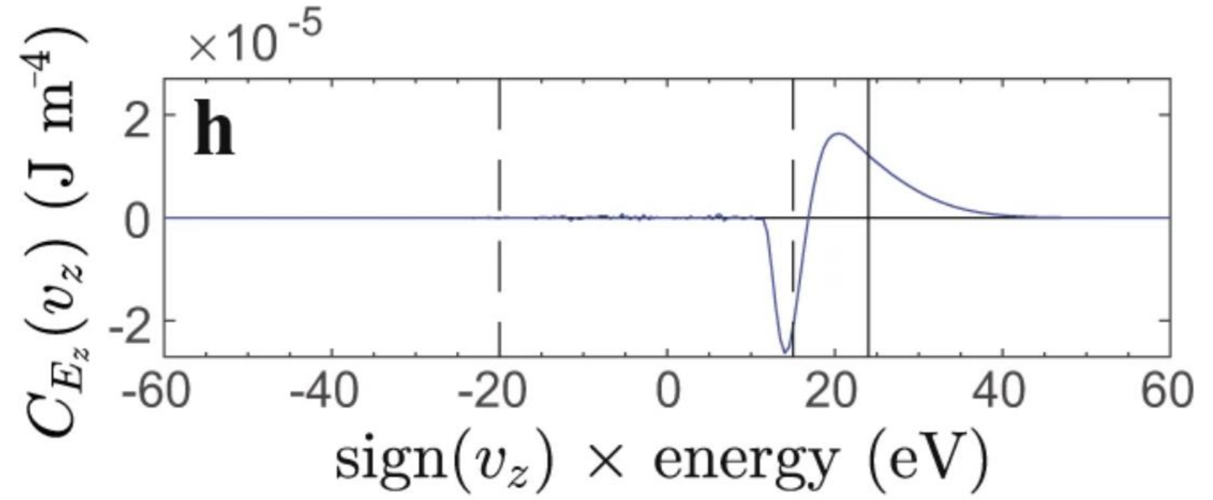
Research Highlight: Electron acceleration by inertial Alfvén waves











- Kletzing/Skiff/Howes/Schroeder (Iowa): interest in understanding electron acceleration by Alfvén waves; relevance to generation of Aurora
- Used novel electron distribution diagnostic (whistler wave absorption (Skiff)) to demonstrate acceleration of electrons by inertial Alfvén waves

Schroeder, et al., Nature Comm.12, 3103 (2021)

Research Highlight: Electron acceleration by inertial Alfvén waves

CNN Weather Climate Storm Tracker Wildfire Tracker Video • LIVE TV Edition

SPACE'S NEXT CHAPTER

The mysterious origin of the northern lights has been proven

By Jennifer Gray, CNN meteorologist
Updated 2:32 PM ET, Tue June 8, 2021

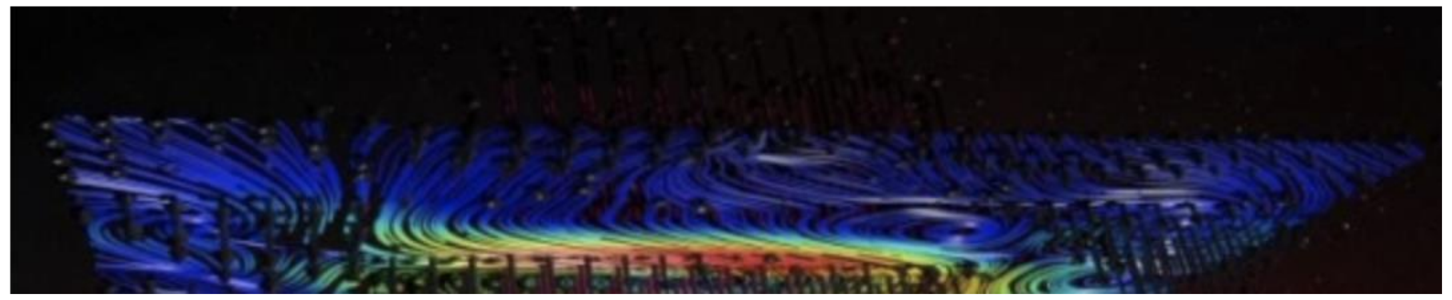
physicsworld Maga

plasma physics

PLASMA PHYSICS | RESEARCH UPDATE

Electrons 'surf' on Alfvén waves in plasma-chamber experiments

22 Jun 2021



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The Secret to Brilliant Auroras? 'Surfing' Electrons

New research sheds light on the complex physics behind the Northern lights.

By Brianna Barbu | Aug 6, 2021 8:00 AM

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We finally know what sparks the Northern Lights

It took researchers more than 20 years to figure out this light show mystery.

BY RAHUL RAO | PUBLISHED JUN 21, 2021 7:00 PM

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NEWS PHYSICS

Auroras form when electrons from space ride waves in Earth's magnetic field

The same physics could give rise to auroras on Jupiter and Saturn

Schroeder, et al., Nature Comm.12, 3103 (2021)

Current BaPSF Projects: User Projects

- 2022-2024:
  - R. Gueroult (Université de Toulouse) “Characterizing the potential distribution in a magnetized plasma column under end-electrode biasing”
  - A. Mallet (SSL) “Alfvén wave steepening observed in LAPD”
  - Vadim Roytershteyn (SSI) “Wave Excitation by Mildly Relativistic Electron Beam”
  - Saskia Mordijck (William and Mary) "Impact of plasma species, neutral collisionality and parallel flows on drift wave turbulence in LAPD”
  - J. Parker (Google) "Detection of Topological Plasma Waves in LAPD”

Current BaPSF Projects: User Projects, cont.

- 2023-2025:
  - Greg Howes (Iowa) “Developing Vlasov Tagging as a Lagrangian Diagnostic of the Dynamics of the Electron Velocity Distribution in Weakly Collisional Plasmas”
  - Derek Schaeffer (UCLA) “Laboratory Studies of Laser-Driven, Ion-Scale Magnetospheres on the LAPD”
  - Chris Chen (Queen Mary Univ) “Strong Turbulent Alfvén Wave Interactions: Residual Energy & Nonlinear Cascade” (M. Abler)
  - Richard Sydora (U. Alberta) "Melting Staircases: A Study of Layering in an Evolving Vortex Crystal” (companion DIII-D experiment)
  - Feiyu Li (NM Consortium) "Scaling of seeded Alfven wave parametric decay”

Basic Plasma Science Facility Contacts

Contacts and more information about the device and our research can be found by following this QR code

This will take you to https://plasma.physics.ucla.edu

The Wisconsin Plasma Physics Laboratory (WiPPL)

- Collaborative Research Facility with ~50% run time available for external projects
  - External projects from large & small universities, national labs, private companies, and international groups
- Two unique, versatile, complementary devices: Big Red Ball (BRB) and Madison Symmetric Torus (MST)
- Study fundamental plasma science, focused on the flow of energy between particles and fields, and other topics (turbulence, self-organization, reconnection …)
- Strong educational program with hands-on training for students
- Close collaboration with theory and simulation work

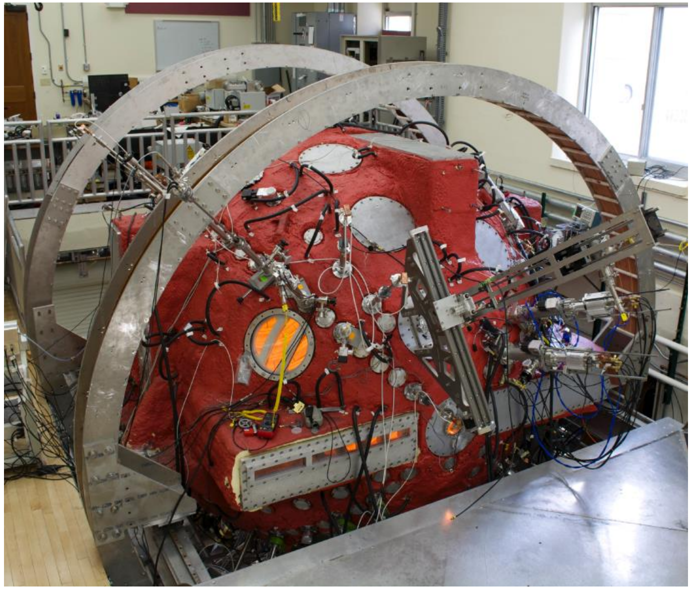
Website: wippl.wisc.edu

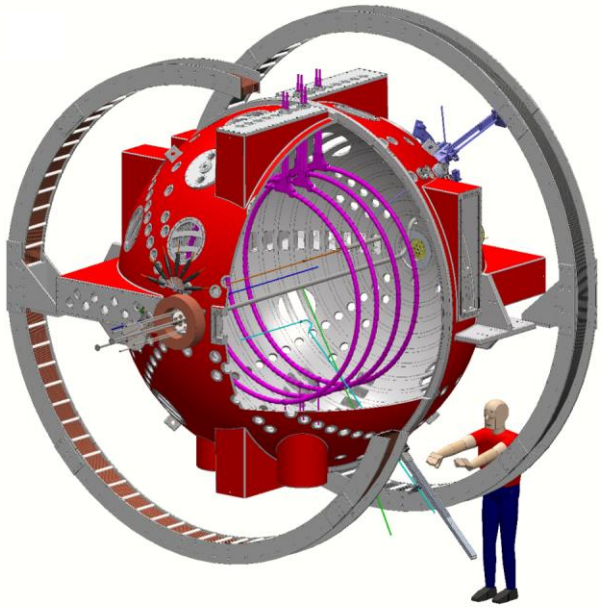
The Big Red Ball (BRB) spherical plasma device

- Spherical geometry (R = 1.5 m) where "egg can be cracked" to access interior
- Multipole cusp confinement with ~ 3k permanent magnets – interior can be unmagnetized!
- Study magnetic reconnection, shocks, dynamos, high-beta regime ...
- Tools: plasma sources, internal and external coils, compact toroid injectors …
- Diagnostics: Various insertable probes, interferometer, spectrometer …

Parameter space:

$B = 0 – 280$ G
$n_e = 10^{17} – 10^{19}$ m^{-3}
$T_e = 1 – 30$ eV
$\beta = 0.1 – 10$
$S = 10^2 – 10^5$
$Ma \leq 3$





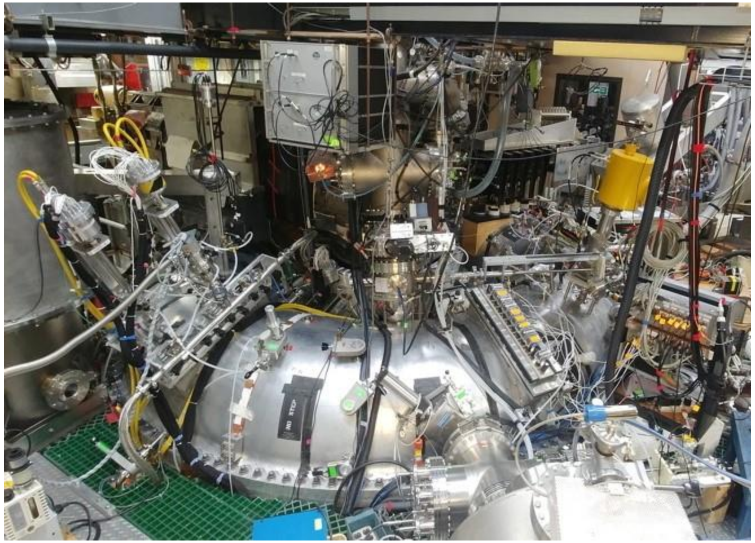
The Madison Symmetric Torus (MST) toroidal plasma device

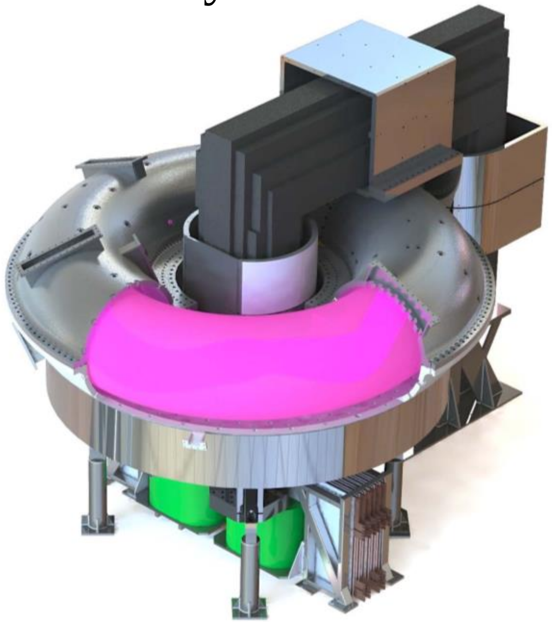
- Toroidal device (R/a = 1.5/0.52 m) which can run as reversed-field pinch (RFP) or tokamak
- 5-cm-thick, close-fit, circular cross-section wall acts as single-turn toroidal field coil
- Programmable power supply offers arbitrary waveform control over B_T & I_P
- Tools: Neutral beam injector, controlled magnetic perturbations, inductive current drive ...
- Diagnostics: Insertable probes, beam scattering, interferometry, spectrometry ...

Parameter space:

R/a = 1.5 / 0.52 m
30-80 ms pulses, >100/day
B_T = 0.14 T (tok)* / 0.3 T (RFP)
I_p = 50 kA (tok) / 600 kA (RFP)
T_e = 100 eV (tok) / 2 keV (RFP)
$n_e = 10^{17} – 10^{19}$ m^{-3}

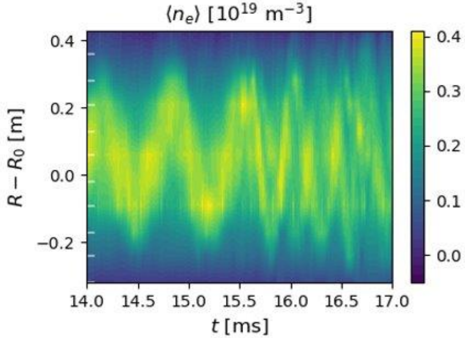
* Planned upgrade to B_T = 0.25 T

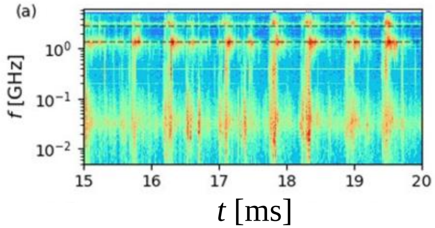




Selected WiPPL research highlights

- BRB (internal/external, UW): Reconnection drive cylinder reaches into S ~ 10^5 regime, studies of electron pressure anisotropy in progress →
- BRB (external, U. Michigan): Scaled coronal mass ejections in the lab using compact toroid injection into background magnetic field
- BRB (internal): Rotating magnetic field system under construction will emulate pulsar magnetosphere
- MST (external, LLNL/IPP): Probe-based measurements of canonical helicity flux in RFP relaxation events
- MST (internal): Helical "density snakes" in the tokamak →
- MST (internal): Low safety factor q(a) < 2 and 10X Greenwald density limit tokamak plasmas
- MST (internal): Runaway electron driven whistler waves in tokamak →





How to get involved with WiPPL research

I have a great idea for an experiment!	I want to get involved but don't have any good ideas	I want to learn more and maybe participate in the future
⬇	⬇	⬇
WiPPL staff will help you write and submit a proposal for run-time on MST or BRB	WiPPL staff can suggest some ideas, or arrange for you to participate in an existing project	Join MagNetUS, a national network of researchers and labs studying magnetized plasmas!

- Please contact WiPPL director Cary Forest: **cary.forest@wisc.edu**
- Visit the WiPPL website for more details: **wippl.wisc.edu**
- Learn about and join MagNetUS at the website: **magnetus.net**

Magnetized Plasma Research Laboratory
MPRL @ Auburn University

Edward Thomas, Jr.

Uwe Konopka, Saikat Chakraborty Thakur, Eva Kostadinova, Cameron Royer

http://aub.ie/mprl

Project support:

Department of Energy: DE-SC0019176

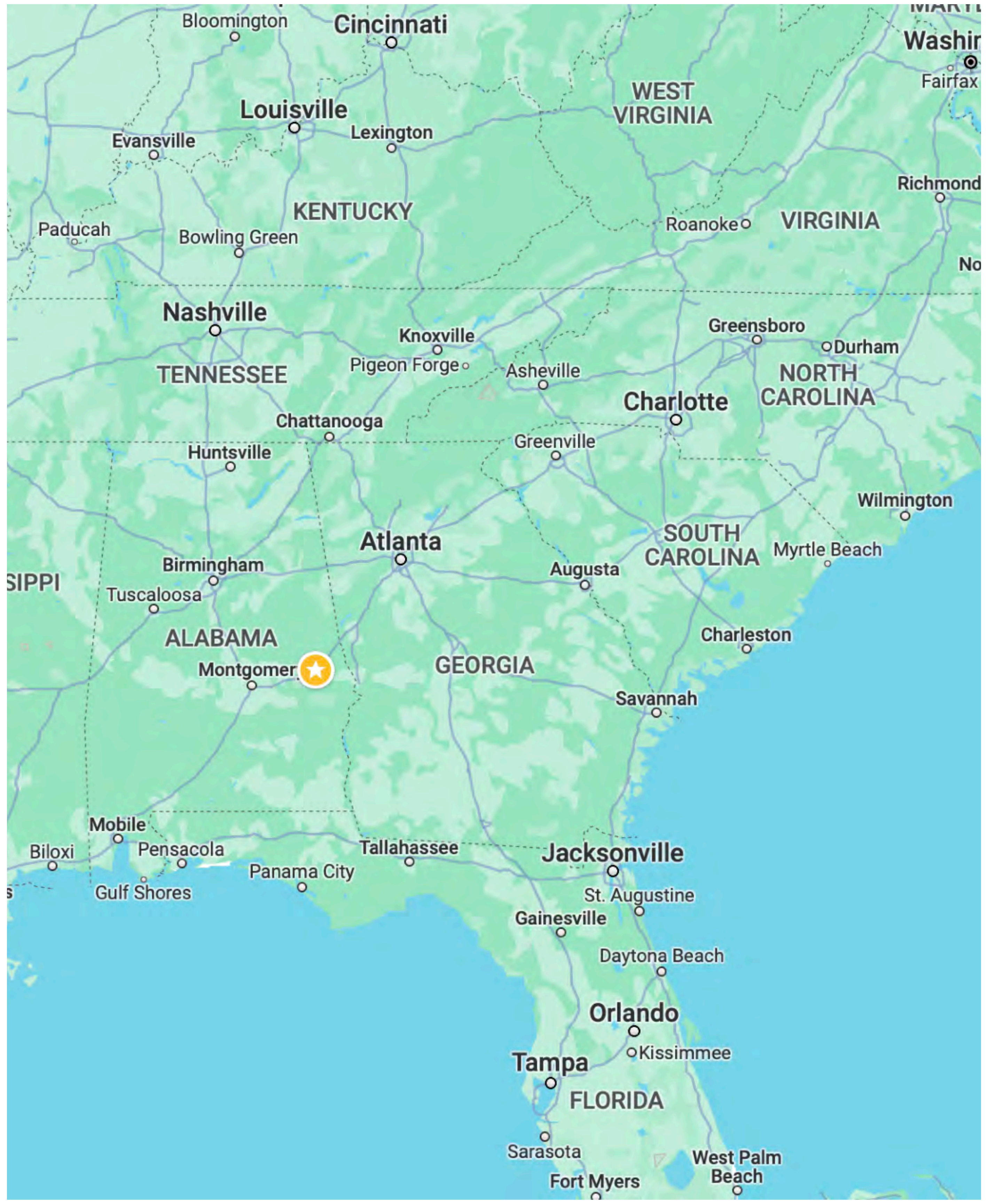
National Science Foundation: PHY-1126067, PHY-1613087

NSF EPSCoR: OIA-1655280 / OIA-2148653

NASA: JPL-RSA-1571699, JPL-1646773 & NASA EPSCoR: NASA-80NSSC19M0182

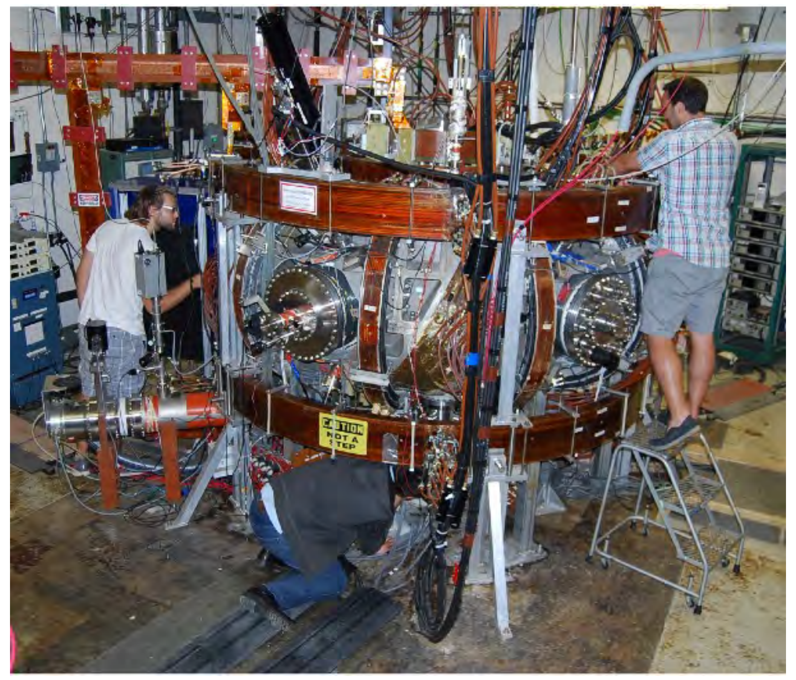
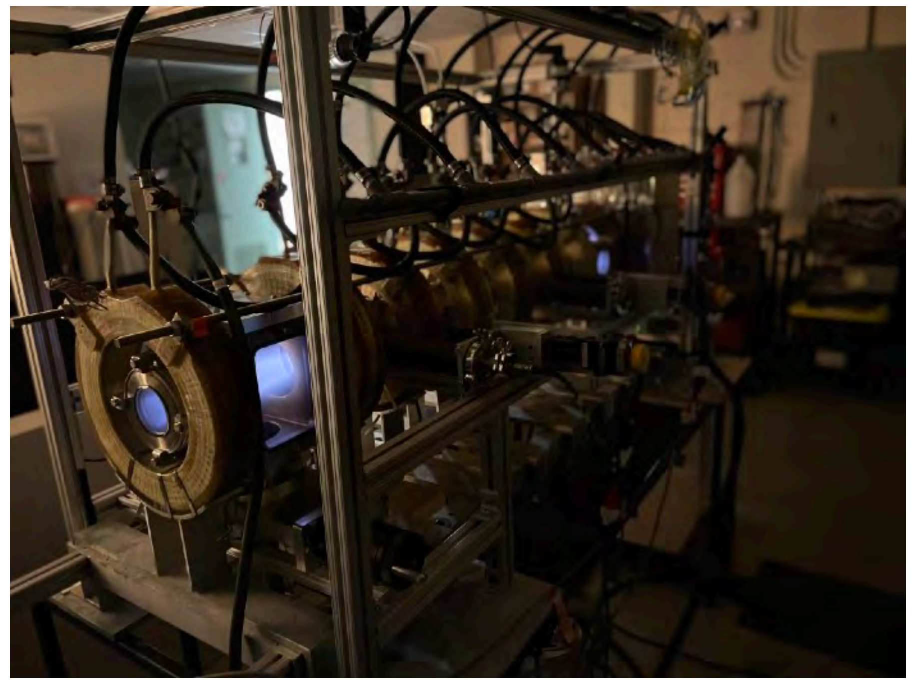
Magnetized Plasma Research Laboratory (MPRL)

Physics Department at Auburn University
Auburn, AL



<u>Plasma Physics @ Auburn</u>

- Magnetic fusion energy - stellarators
- 3D magnetic confinement
- Plasma theory, computation, and modeling
- Space plasmas: magnetosphere, solar emissions, satellite observations
- Dusty/complex plasmas
- Fundamental studies of the plasma state of matter


MPRL
Magnetized Plasma Research Laboratory

AUBURN
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Magnetized Plasma Research Laboratory (MPRL)

A Department of Energy Collaborative Research Facility

Additional support via NSF-EPSCoR (FTPP)

Major equipment funded by the NSF (NSF-MRI), DOE, and NASA

Research Mission: understand how the coupling between the plasma, dust particles, and the boundaries gives rise to self-organized plasma and dusty plasma structures in strongly magnetized plasmas.

Scientific Goals:

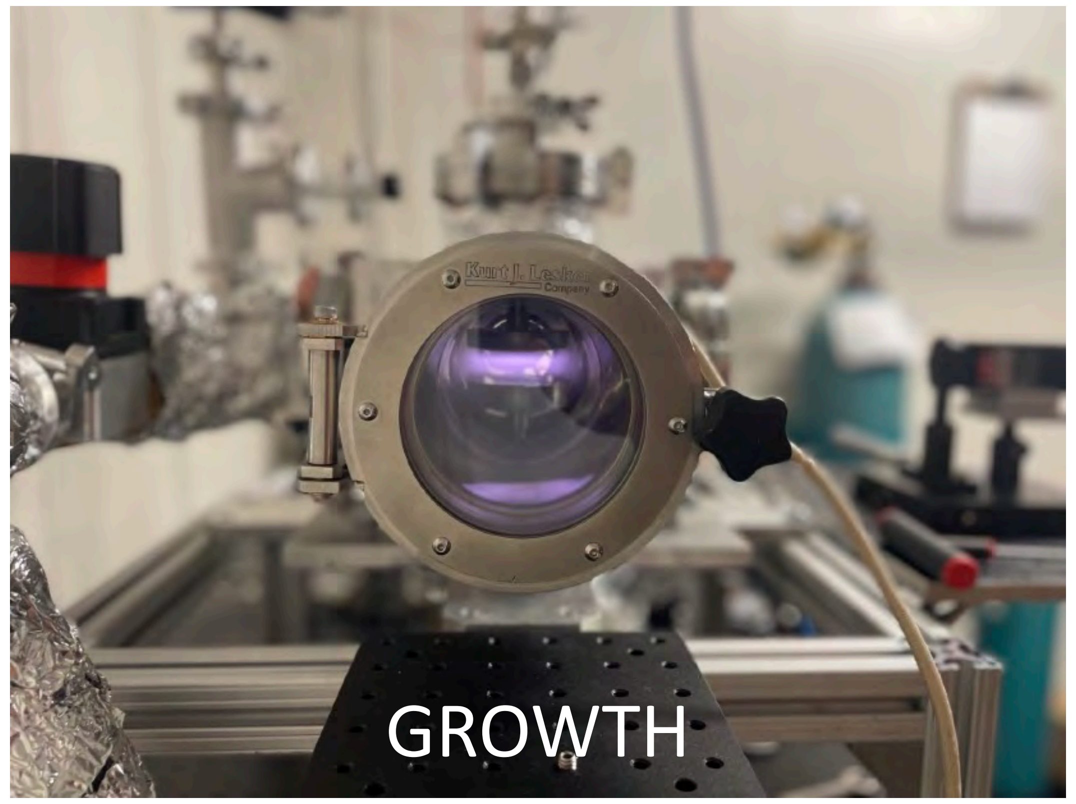
- Investigate the coupling between internal and external boundaries and particle transport contribute to the formation of structures in strongly magnetized plasmas;
- Use and manipulate the transport of charged dust particles in magnetized plasmas for plasma diagnosis or designing dusty plasma model systems;
- Understand how the spatial structure of the underlying instabilities can give rise to local and global ordering in magnetized plasmas.

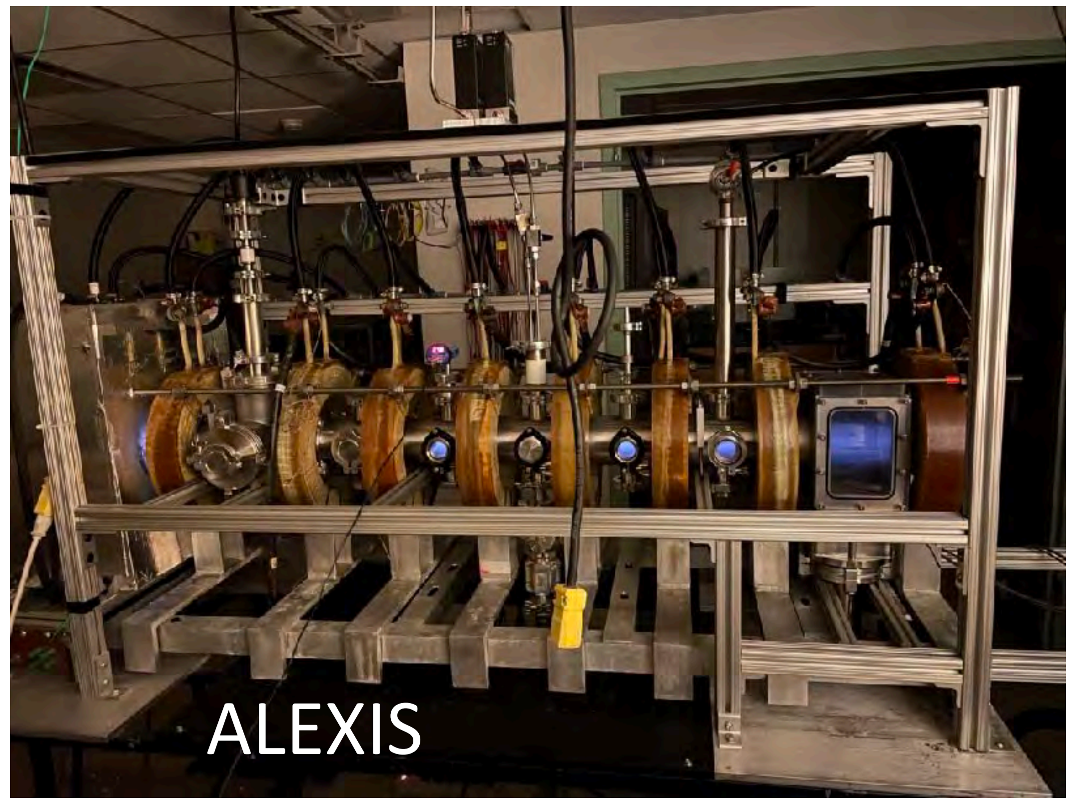
Engaging in novel, high magnetic field studies of plasmas and dusty plasmas - particularly studies that are exploratory in nature or that provide opportunities to expand the plasma research community

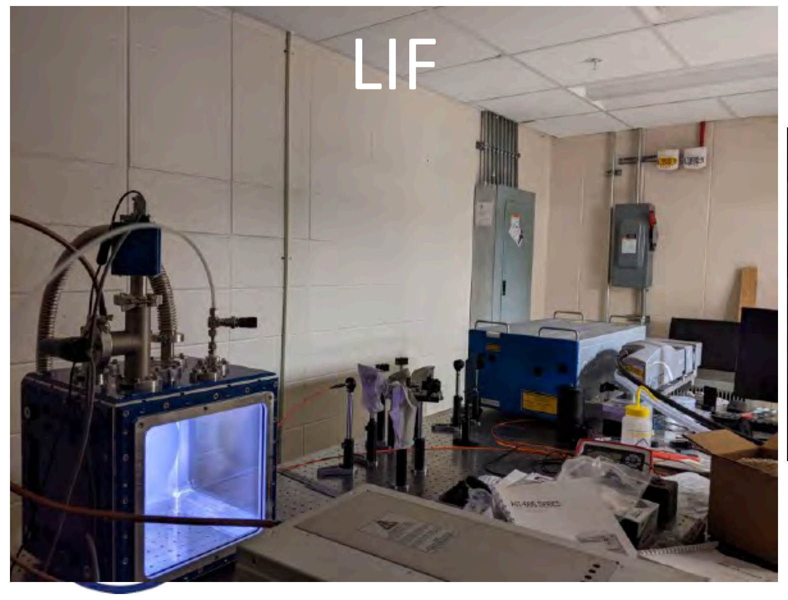
MPRL Magnetized Plasma Research Laboratory

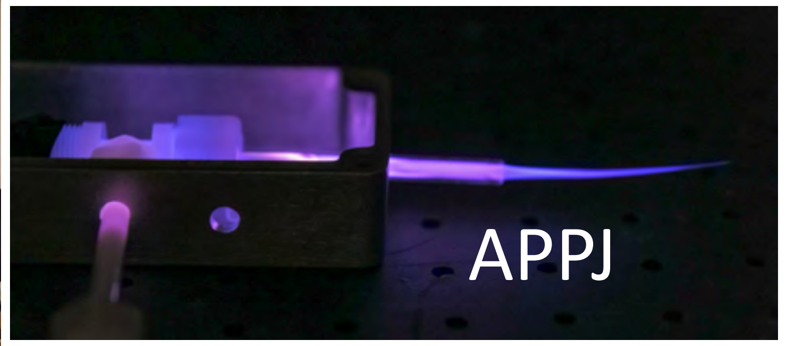
AUBURN UNIVERSITY

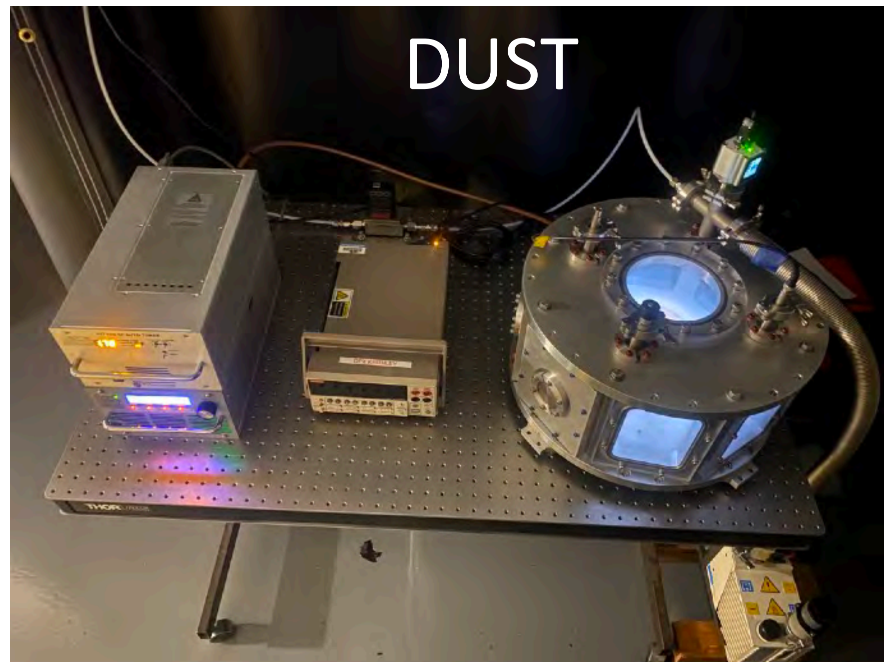
Magnetized Plasma Research Laboratory (MPRL)











MPRL device parameters

- Extensive diagnostic access
- *RF generated plasmas*:
  f = 13.56 MHz
  P_{RF} = 1 to 100 W
- *Helium, Neon, Argon, Krypton*:
  P = 0.1 to 300 mTorr
  (0.01 to 40 Pa)
- Silica microspheres
  <dia> = 0.05 μm to 10 μm
- *Particle growth*: acetylene, TTIP
- *Diagnostics:*
  Langmuir probes
  Emission spectroscopy
  DPSS lasers
  High-speed video cameras
  PTV / PIV
  LIF (development)
- *Plasma parameters (@ B = 0 T)*:
  T_e = 1- 10 eV, T_i = 1/40 eV
  $n_e \sim n_i \sim 0.1$ to 10×10^{15} m^{-3}

MDPX capabilities

Magnetic field:	3.5 T (to date); 4 T (max)
Magnet orientation:	0 to 90°relative to ***g***
Magnetic field gradient:	1 - 2 T /m
Magnet cryostat:	50 cm ID / 127 cm OD / 158 cm axial
Magnet material:	NbTi superconductor; cryogen-free

MPRL as a collaborative research facility - External Users

External Users/Collaborations (2014-present)

pre-MPRL *NSF/DOE +NSF-EPSCoR #NASA

**DOE-MPRL 2023 projects

International

Univ. Greifswald*
Univ. Delhi
IPR, India*
KAIST, South Korea*
CNRS / Univ. Saskatchewan+
German Aerospace Center (DLR)#+

Industry

Vision Research, Inc.
L3/Harris Corporation
Innovative Aerospace, LLC

Appalachian State Univ.**
Baylor Univ.#
Emory Univ.**
Eastern Michigan Univ. **
LANL**
Mississippi State Univ.**
Naval Research Laboratory
Univ. Alabama - Birmingham (UAB)+
Univ. Alabama - Huntsville (UAH)** +
UCSD
Univ. Iowa
Univ. Maryland - Baltimore (UMBC)**
U. Memphis**
U. Michigan**
U. South Alabama+
Univ. Wisconsin**
West Virginia Univ.**
William and Mary **
Wittenberg Univ.**

Representative projects

Diagnostic testing for fusion experiments - W7X, DIII-D, CTH (Wisconsin / AU)*,**

Biomaterial modification in magnetized plasmas (UAB)+

Particle growth at high magnetic fields (Univ. Saskatchewan /East Michigan/ AU)**,+

Waves, crystals, dust transport, and dusty plasma thermodynamics in magnetized plasmas (UMBC, Wittenberg, Emory, LANL, Memphis, Univ. Greifswald, IPR/India)*,**,+

Laser produced plasmas (UAH, LANL)**,+

Diagnostic and plasma source development for LTP plasmas
(WVU, Miss. State. Univ., Univ. Michigan, William and Mary, industry)**,+,#

MPRL Magnetized Plasma Research Laboratory

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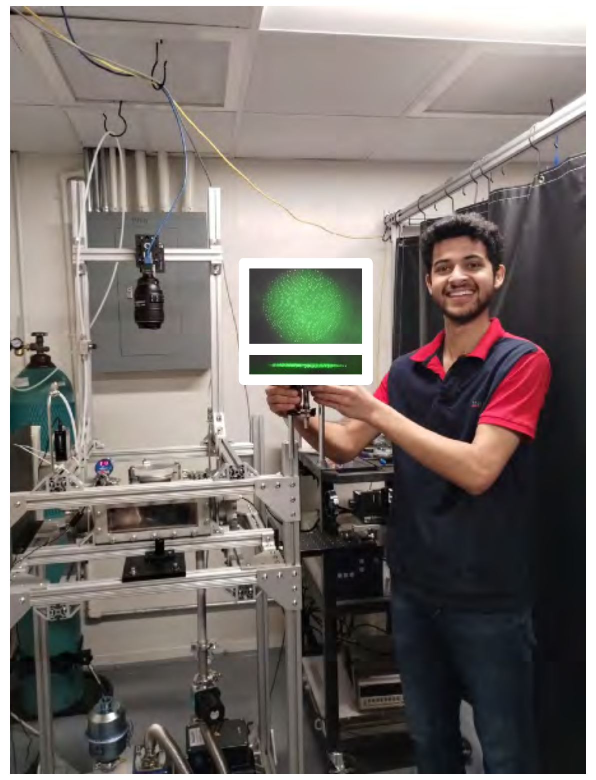
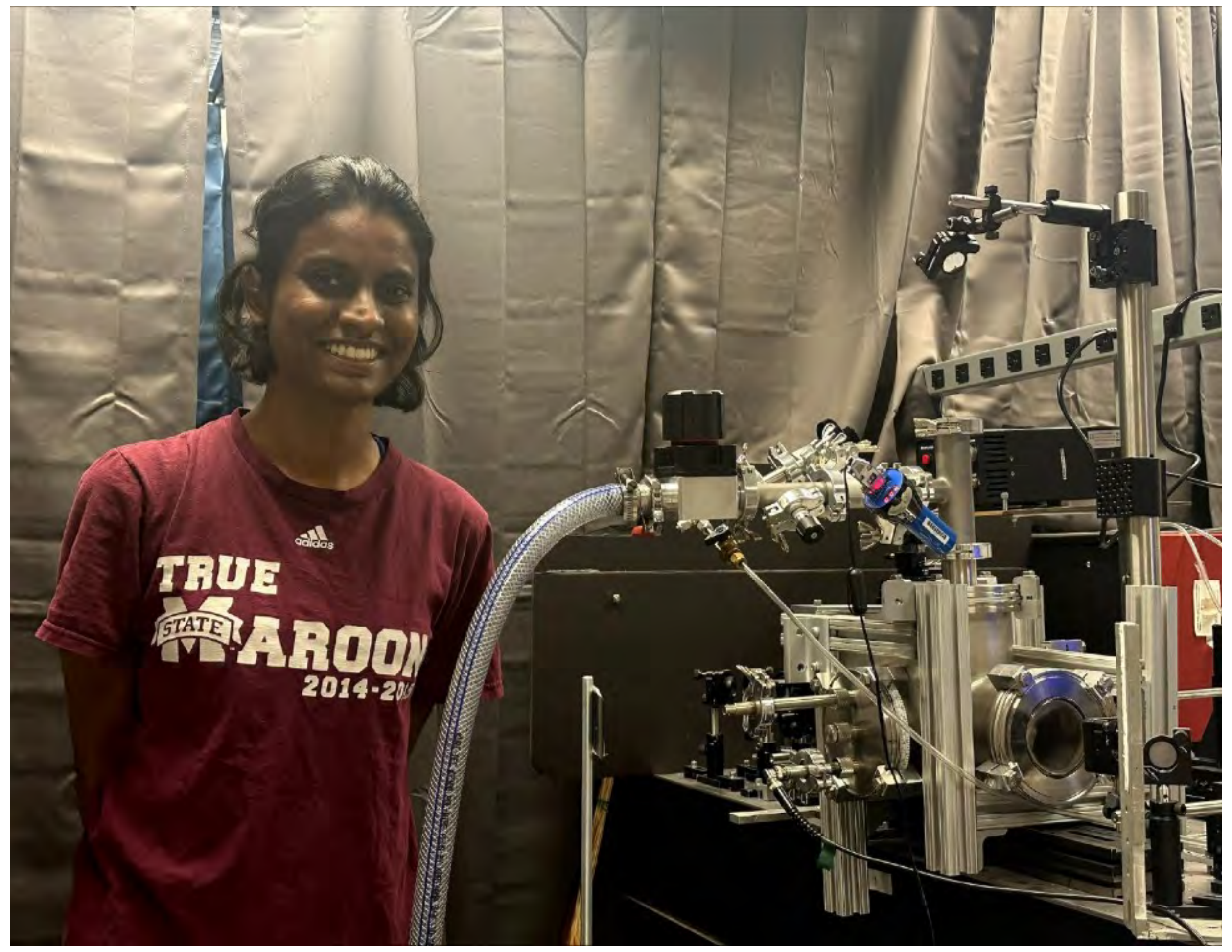
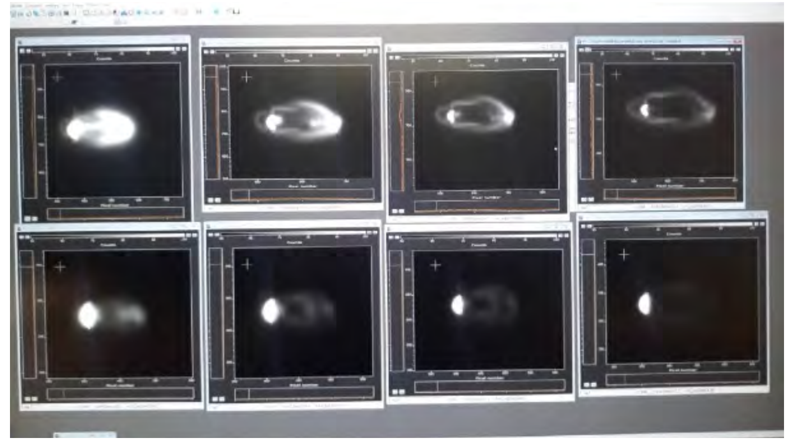
Examples of collaborative studies at the MPRL

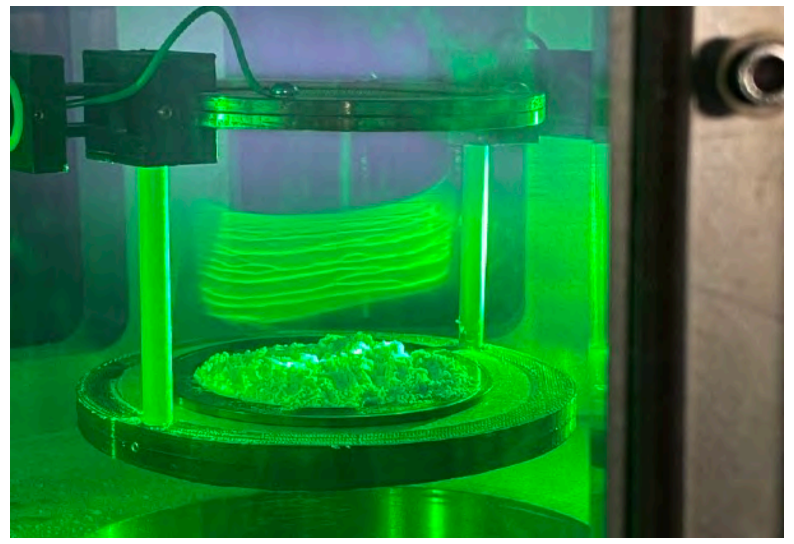
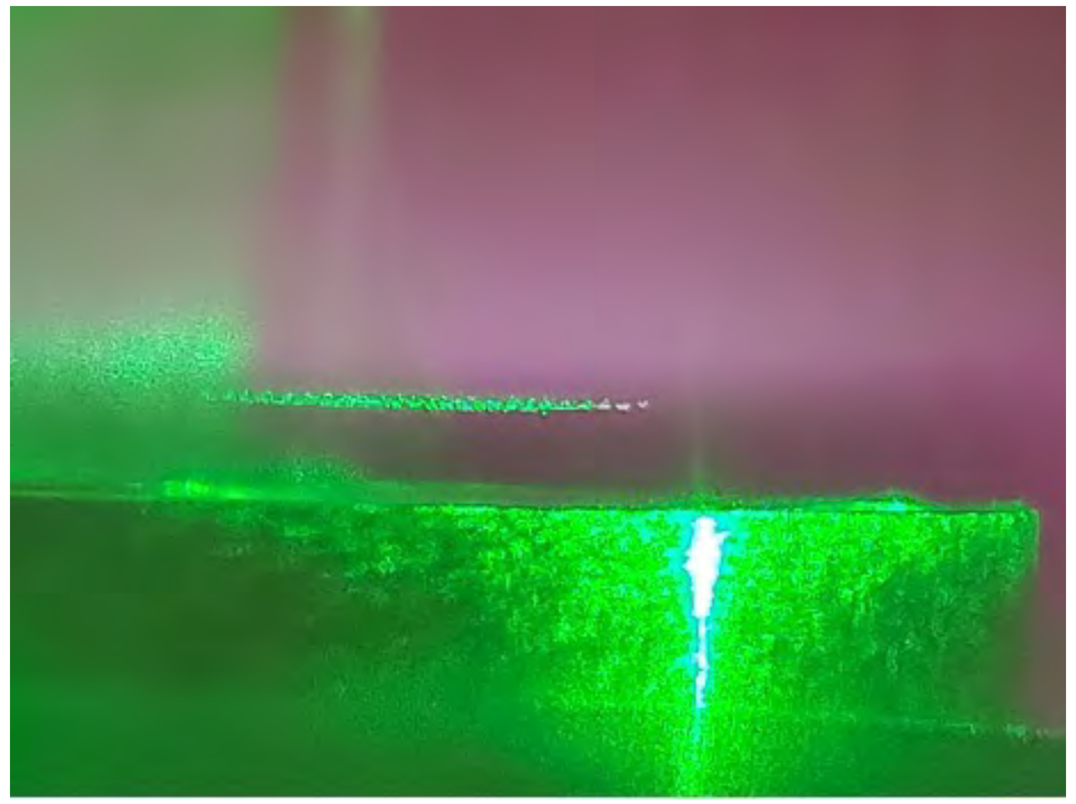




Clockwise (from top left): Univ. of Alabama Huntsville, Univ. of Memphis, Wittenberg Univ., Mississippi State Univ., Naval Research Laboratory

Plasma and Dusty Plasma Experiments



Clockwise (from top left): Laser-plasma interaction, dusty plasma crystal - top/side, argon plasmas in MDPX, dusty plasma wave

Unique capability to "swap" vacuum chambers to accommodate a wide variety of experimental configurations

MPRL
Magnetized Plasma Research Laboratory

AUBURN
UNIVERSITY

The MPRL team


E. Thomas, Jr.
Professor


U. Konopka
Professor


E. Kostadinova
Asst. Professor


S. Chakraborty Thakur
Asst. Res. Professor


J. Powell


B. Ramkorun


E. Price


S. Bachoti


B. Koford


C. Royer
Lab Manager


M. Rahman
Post-Doc

<u>Undergraduate students</u>
Edward Cowles
Jordan Nash
Matthew Shepherd
Sam Thacker

<u>High School Student</u>
Matthew Patkowski

Recent graduates (the people who ***really*** did the work)!


L. McCabe, PhD
Aug., 2022


D. Funk, PhD
May, 2023


S. Williams, PhD
Aug., 2023 (post-doc)


B. Doyle, PhD
Dec., 2023


T. Hall, PhD
Dec., 2019


S. LeBlanc, PhD
Dec., 2019


M. Menati, PhD
Aug., 2020


M. McKinlay, PhD
Aug., 2022

You need a great team of diverse people working together to solve increasingly difficult, multi-disciplinary problems.

MPRL Magnetized Plasma Research Laboratory

http://aub.ie/mprl

AUBURN UNIVERSITY

Working with the MPRL

POINTS OF CONTACT:

Saikat Chakraborty Thakur (Research Professor, szc0199@auburn.edu)
Cameron Royer (Laboratory Manager, cmr0008@auburn.edu)

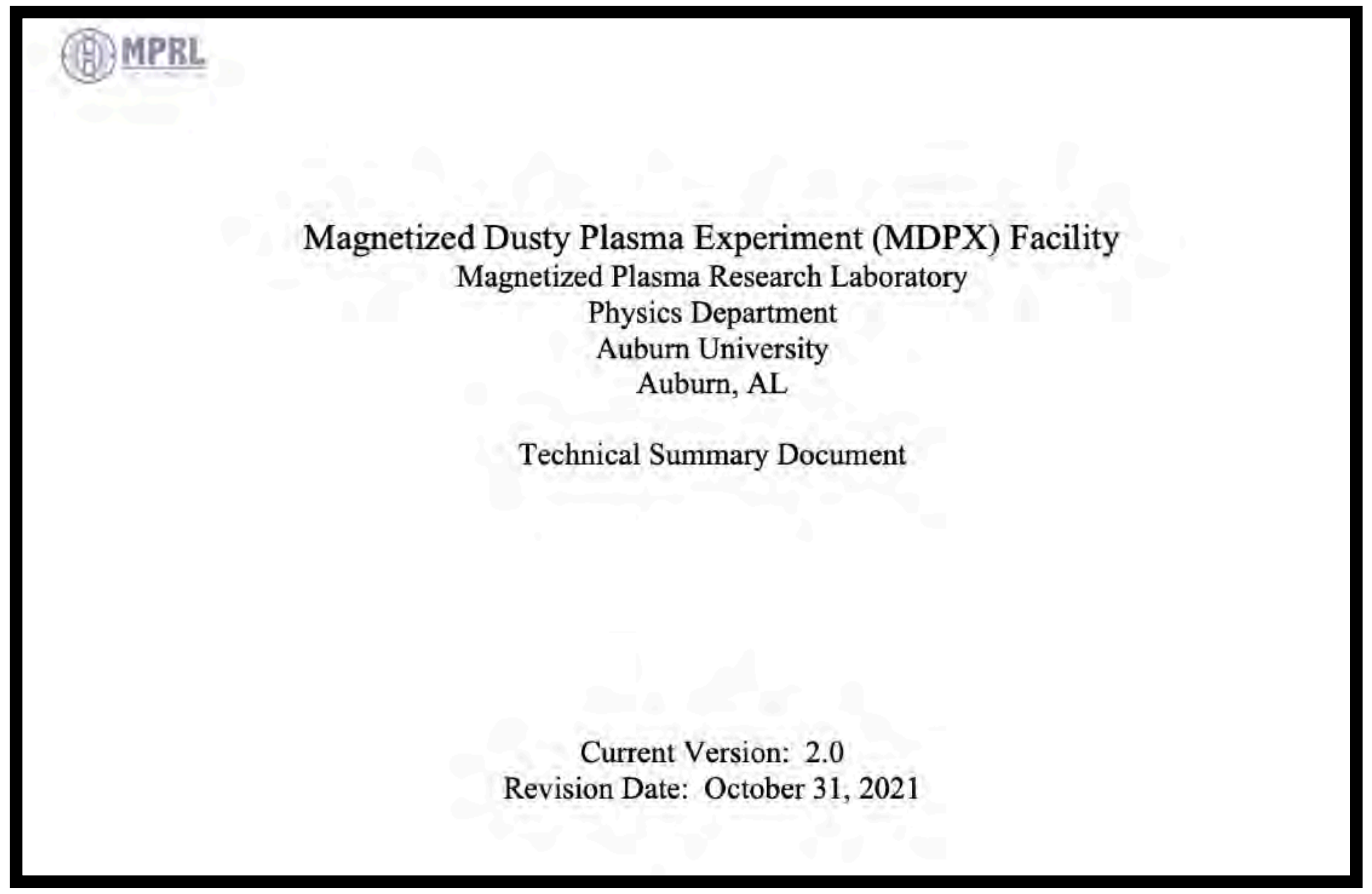
FACULTY:
Edward Thomas, Jr. (etjr@auburn.edu)
Uwe Konopka (uzk0003@auburn.edu)
Eva Kostadinova (egk0033@auburn.edu)

http://aub.ie/mprl

MPRL facility support:

- Extensive technical support from MPRL staff / post-docs/ students
- Provide logistical support for experiment planning @ MPRL
- Assist with home institution experiment development

- Timeline to perform a study at MPRL after a run-time award:
  - 8 - 10 weeks before: refine the experimental requirements
  - 6 - 8 weeks before: 1 - 2 day pre-visit to MPRL
  - 2 - 6 weeks before: complete hardware development
  - Runtime: 2 - 3 week visit to perform the project


MPRL

Magnetized Dusty Plasma Experiment (MDPX) Facility
Magnetized Plasma Research Laboratory
Physics Department
Auburn University
Auburn, AL

Technical Summary Document

Current Version: 2.0
Revision Date: October 31, 2021

MDPX user handbook

MPRL Magnetized Plasma Research Laboratory

AUBURN UNIVERSITY

Collaboration on Frontiers Science at DIII-D

Presented by

Richard Buttery

on behalf of the DIII-D team to

DOE Collaborative Facilities Webinar

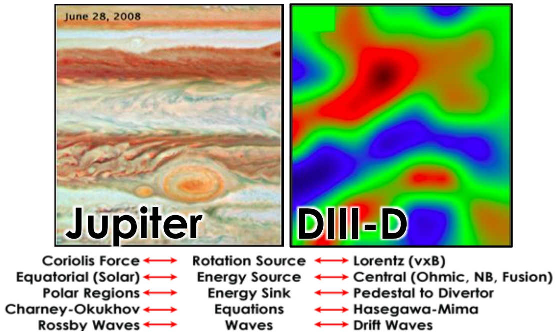
Nov 29th 2023

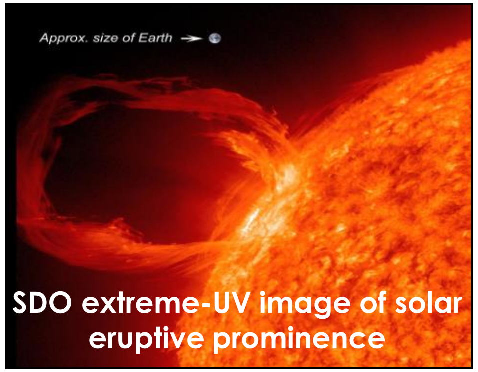
DIII-D NATIONAL FUSION FACILITY

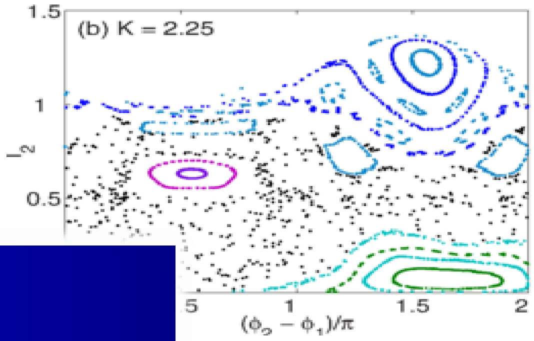
Work supported by US DOE under DE-FC02-04ER54698.

Common Science Foundations of Fusion & Discovery Plasma Science

- **Both require a quantitative understanding of plasma physics**
- **Critical issues :**
  - **Wave-particle interactions** where non-Maxwellian gradients drive modes causing particle redistribution & macro effects
  - **Fundamental turbulence**, its stabilization and interaction with large scale structures and flows
  - **Magnetic reconnection**: processes, explosive instabilities, particle energization and self-organization
  - **Chaotic mechanisms** that can change energy transport
  - **Non-linear interactions** between waves and particles





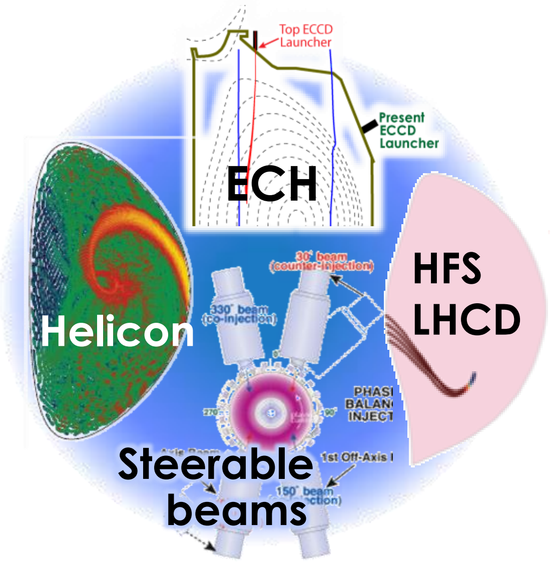


- **Working together we can advance understanding**
  - Complementarity in parameters & capabilities

DIII-D provides a platform to deepen and extend Frontier plasma science understanding

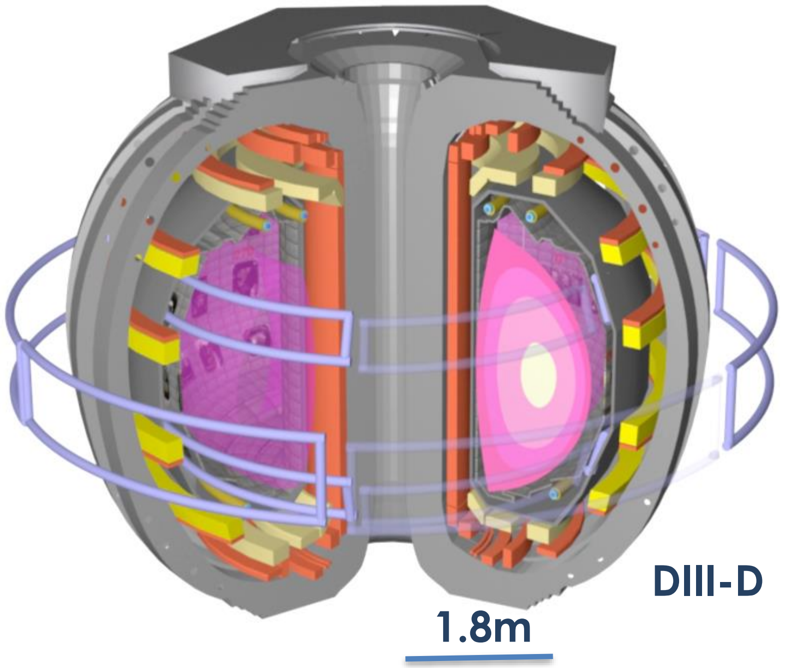
DIII-D NATIONAL FUSION FACILITY

A Highly Flexible Plasma Research Facility to Explore the Frontiers of Plasma Physics



- **Steerable heating and current drive systems**
  - Heat electrons or ions, with variable torque, non-Maxwellian, on/off axis, heating or current drive
- **18 field shaping coils & 3 arrays of 3-D coils**
  - Precise design plasma configurations
  - Probe and control events
- **10s pulses: equilibrated variations**

- **Perturbative materials flexibility & three power handling zones**
  - Precisely study cold plasma interactions & shocks
- **High temperature bake & cryo-pumping with flexible gas and pellet injection**
  - Control particles and plasma purity



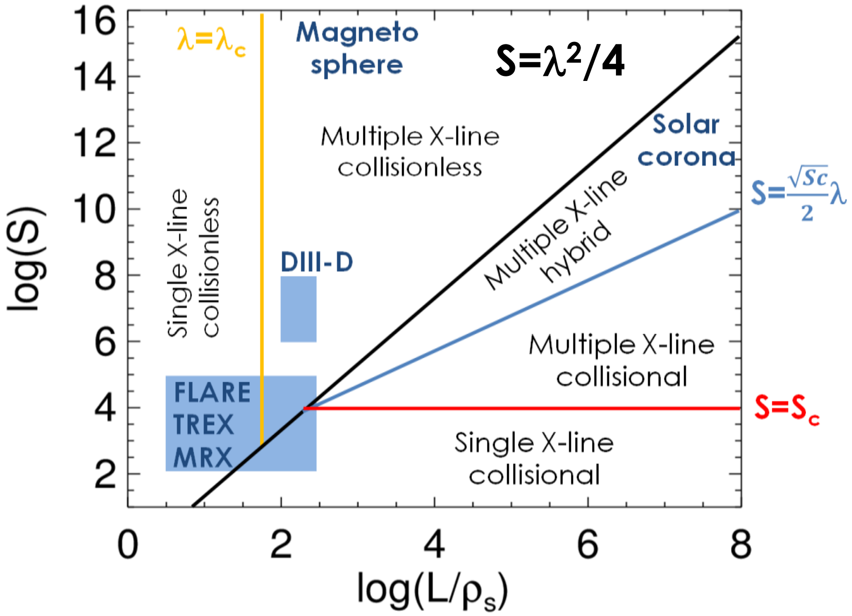
Able to design and vary plasma configuration

DIII-D NATIONAL FUSION FACILITY

DIII-D Provides Complementary Access to Relevant Plasma Physics Regimes

- **Regimes**
  - **High Reynolds**, **collisionless** and **collisional** regimes
  - **High β** to see electromagnetic effects in turbulence
  - **High opacity**, transport defined regimes
  - **Coupled/decoupled electrons**
  - High and low **flow shear**
- **Processes**
  - **Reconnections** – tearing and explosive
  - **Energetic particles** – influence turbulence, MHD and Alfvén eigenmodes
  - **Micro and macro MHD structures**
  - **Self driven and RF driven currents**

Example: Phase diagram for guide-field reconnection



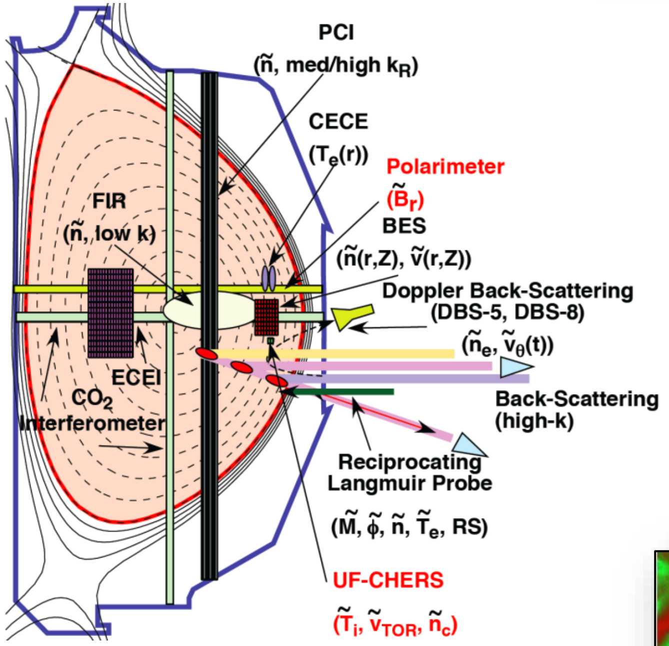
Key parameters:

R=1.7m, a=0.6m, 2T, 2MA,
T~10keV, n~5x10^{19}m^{-3},
S~10^9, ρ^*~.01, ν^*=0.1-4
β=5%, β_P=1, β_{FI}~β_{th}, v_i~$v_{Alfvén}$,

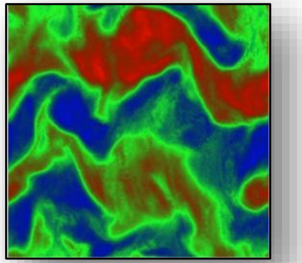
Access to wide range of phenomena

Powerful Diagnostic Set To Test Physics Models of Behavior

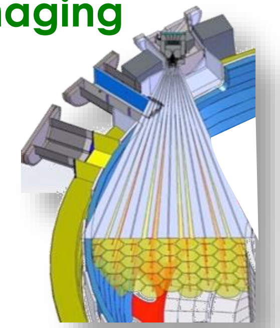
- **Wide range of diagnostics**
  - Profiles: current, rotation, T_i, T_e, n_e
  - Magnetic sensor arrays
  - Turbulence suite k=0.1-100cm^{-1} ➔
  - Fast ion spectra & losses,
  - Neutrons, γ ray imaging, SXR, ICE
  - Bolometry, spectroscopy – UV, visible
  - Infra red, Langmuir probes
- **Pellet injectors:**
  - D_2, A_r, N_e, li/B granules, shattered
- **Material sample exposure facilities**
- **Laser impurity blow off**

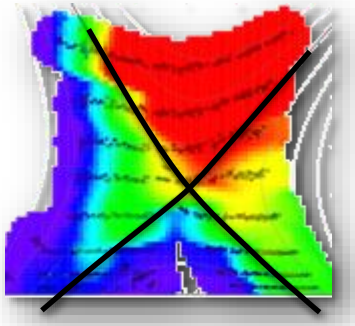


Turbulence Diagnostics



γ imaging





2D Thomson scattering

Remotely observe and measure multiple plasma physics processes

DIII-D values its partnership with Frontiers Science field

Come explore with us to advance the foundations of plasma physics

Call for proposals

https://sites.google.com/view/crfcallforruntimeproposals/

More info at d3dfusion.org

Runtime available from Oct 2024

DIII-D NATIONAL FUSION FACILITY

Princeton Collaborative Low Temperature Plasma Research Facility (PCRF) Report

Yevgeny Raitses on behalf of the PCRF Team

Princeton Plasma Physics Laboratory (PPPL)

&

Princeton University

http://pcrf.pppl.gov

DOE Collaborative Research Facilities Webinar
November 29, 2023

PCRF Team

Theory and simulations ← → **Experiments and diagnostics**

Mikhail Shneider
Co-PI, Princeton
Plasma theory and modeling

Igor Kaganovich
Co-PI, PPPL
Plasma theory and simulations

Sophia Gershman
Plasma sources & diagnostics

Shurik Yatom
Laser-based diagnostics

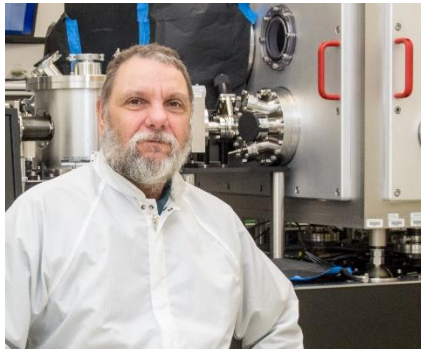
Arthur Dogariu
Ultra fast spectroscopy

Yevgeny Raitses
PCRF PI/Director
Plasma sources and diagnostics

Willca Willafana
PIC simulations

Anatoli Morozov
Ultra fast diagnostics

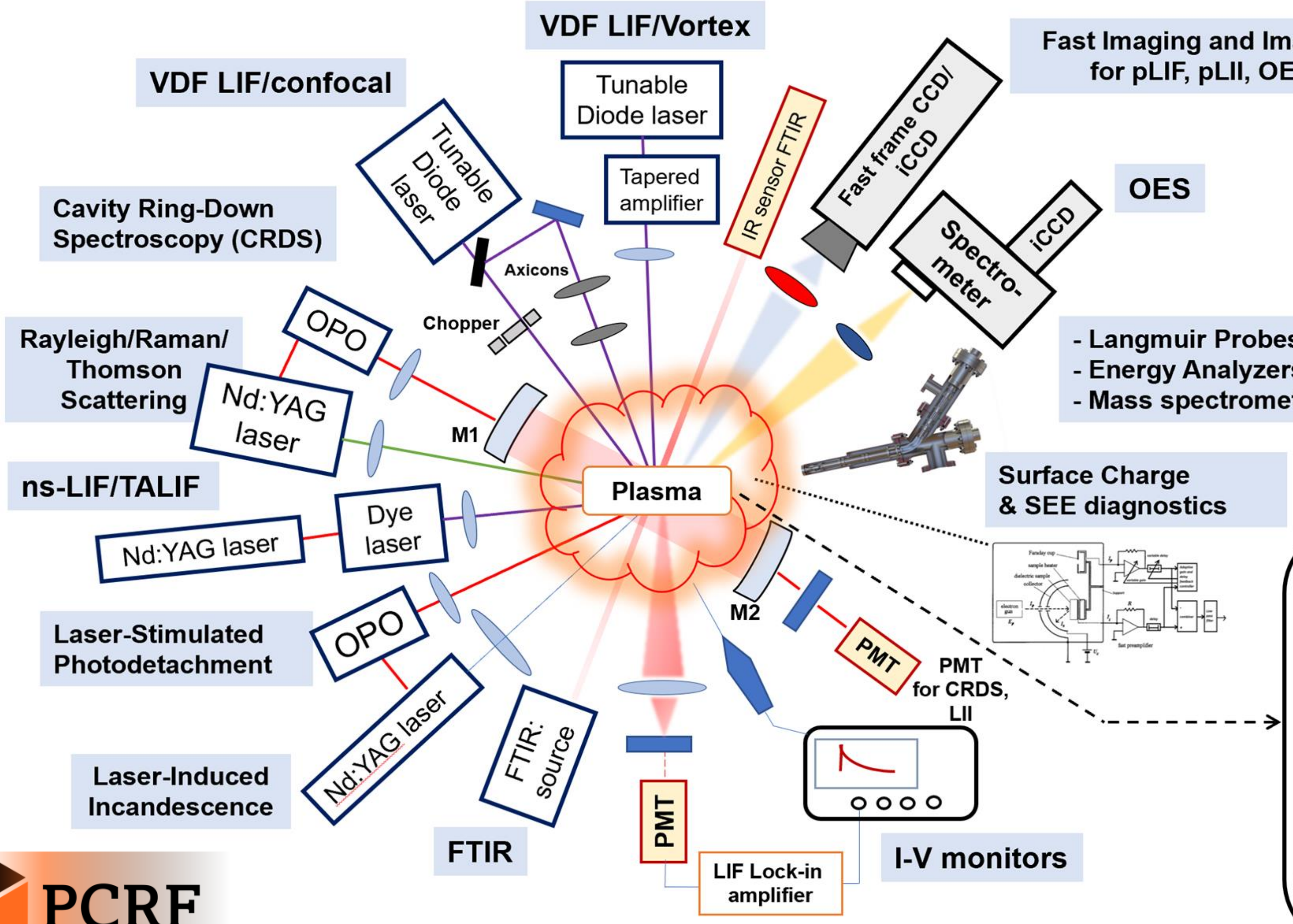
Nirbhav Chopra
Plasma sources

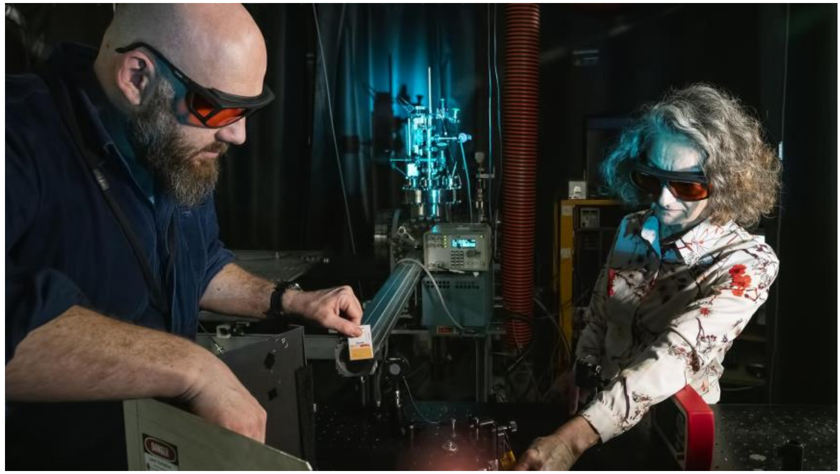


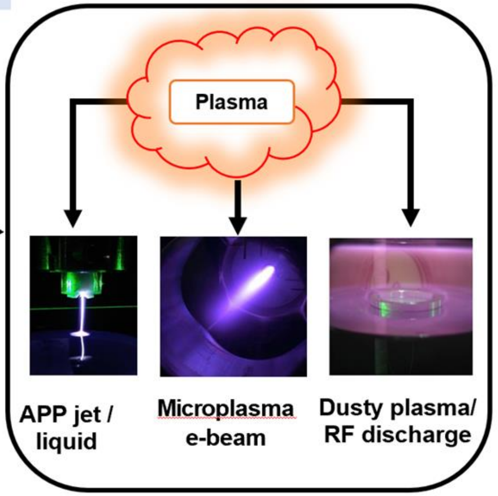
Tim Bennett
Technical Support

PCRF Diagnostics at PPPL and Princeton University

- **Unique combination of ultra fast (fs, ps, ns), cw and stat diagnostics of low to high pressure plasmas, negative ions, nanoparticles and plasma –solid and plasma-liquid interactions**







PCRF

PCRF Computational Tools for LTP Modeling

- **Particle-in-cell codes: 2D EDIPIC, 3D LTP-PIC CPU/GPU**

  Open source

  State-of-the-art collision models and plasma-surface interaction, validated by numerous benchmarks, modern parallelization, complex geometries

- **Fluid codes: customized 3D ANSYS**

  Implemented sheath models, MHD effects, surface interface

- **Quantum Chemistry and Molecular Dynamics**

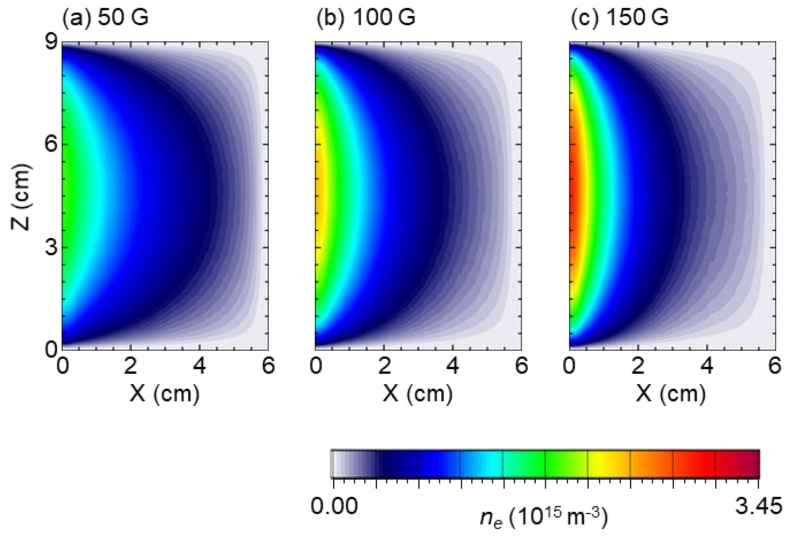
  DFT codes: full and tight binding approximations, CMD (classical potentials), kinetic Monte Carlo, and thermodynamic code for chemical composition

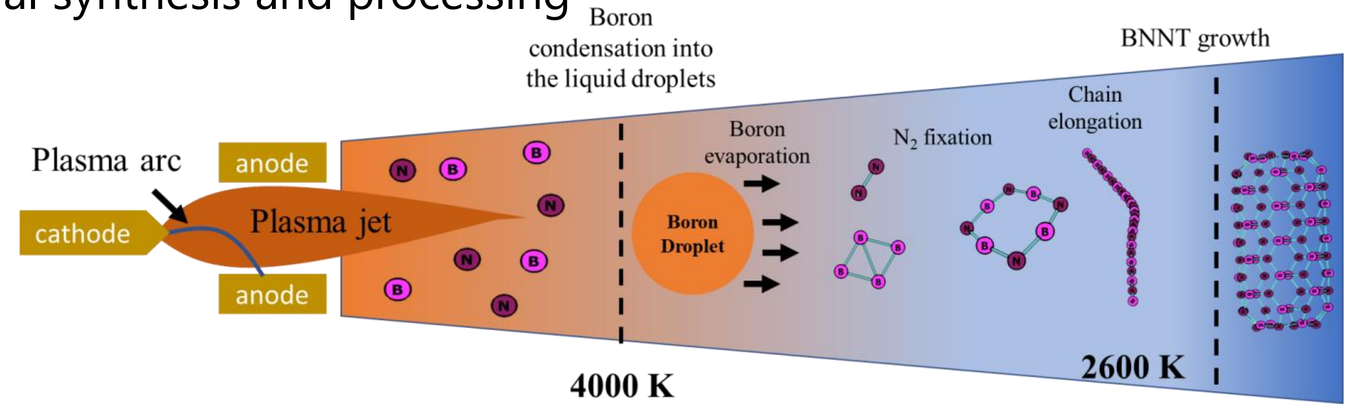
  Gaussian, VASP, DFTB, and CMD used to study material synthesis and processing

- **Gas Chemistry**

  Reaction pathway studies

- Electron-beam generated plasma

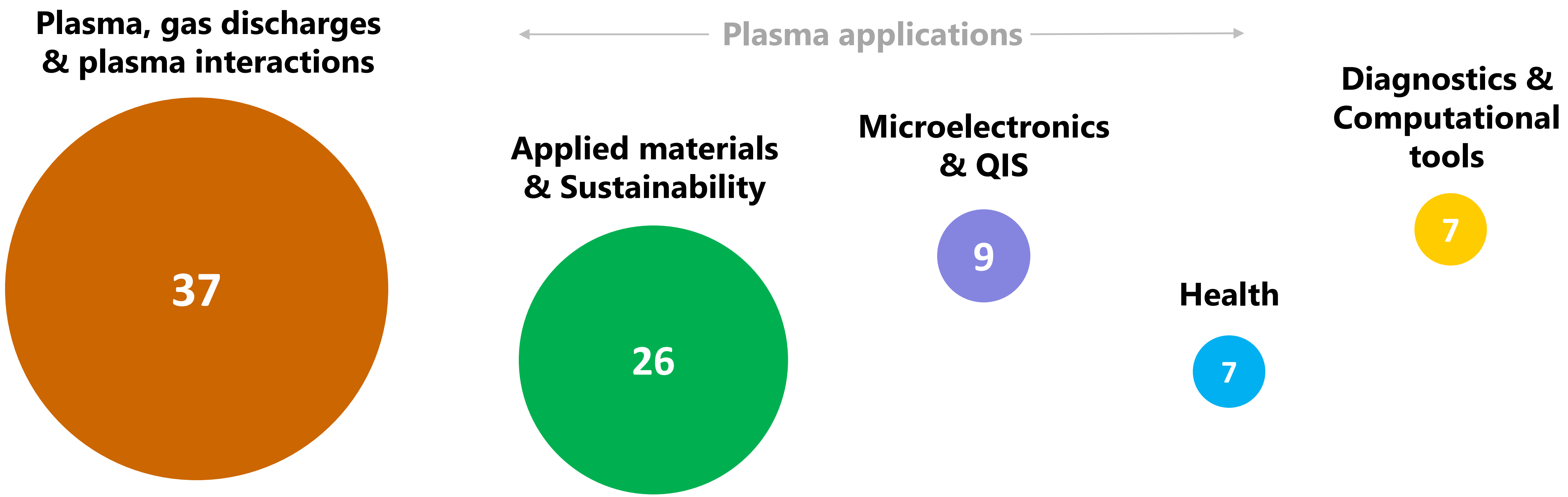




PCRF

User Projects Research Topics

- **Seed projects** to conduct high quality research utilizing PCRF resources and expertise to develop ideas, prepare to apply for direct funding from agencies
- **High risk projects** to test new ideas which would otherwise could not be performed/funded
- **Projects on targeted topics** encouraged in call for proposals (e.g., diagnostics, sustainability, microelectronics)

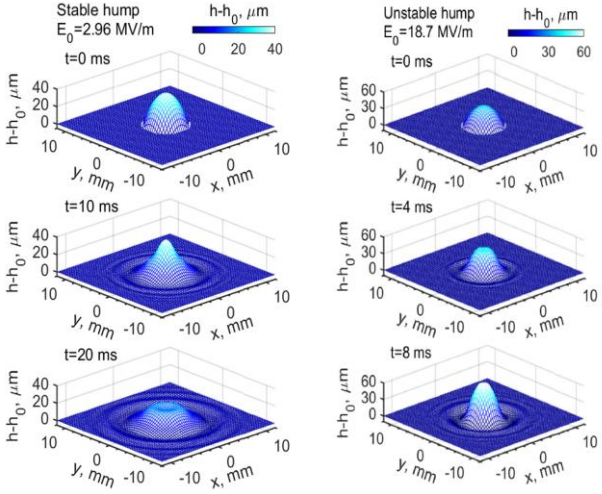


Since FY20, 86 collaborative (user) projects

Examples of PCRF User Research Projects

Electrified liquid metal surface dynamics

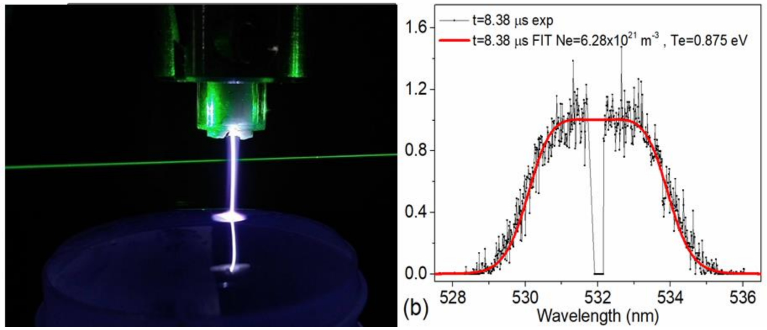
K. Hara (Stanford) and M. Shneider (PCRF)



Plasma jet-liquid interaction

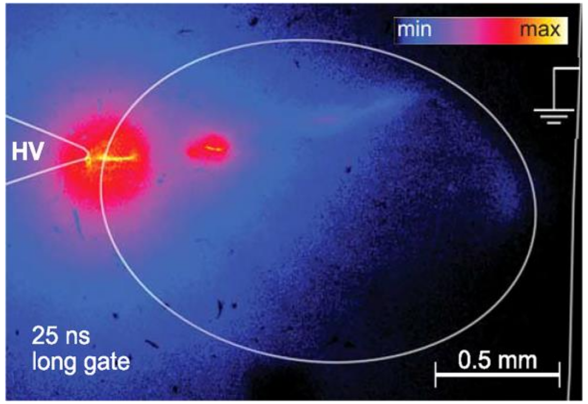
E. Thimsen (WUSTL) and S. Yatom (PCRF)

- Electron density by Thomson scattering



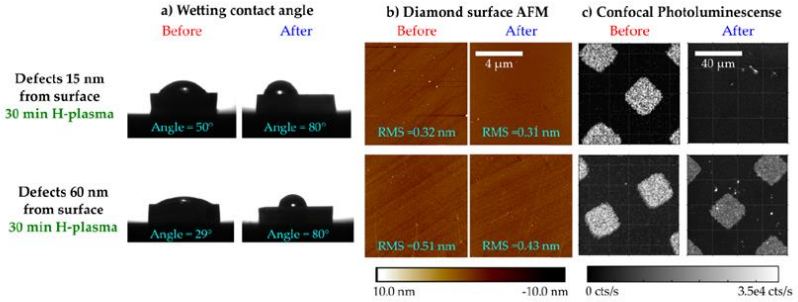
Discharge in a submersed bubble

K. Staplemann (North Carolina State U.) and S. Gershman (PCRF)



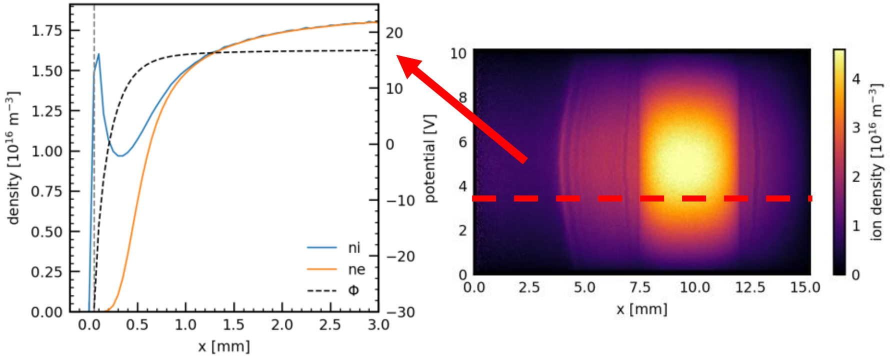
Hydrogen plasma passivation for quantum defect charge control

K-M. Fu (U. Washington) and Y. Raitses (PCRF)



Kinetic modeling of cylindrical probes

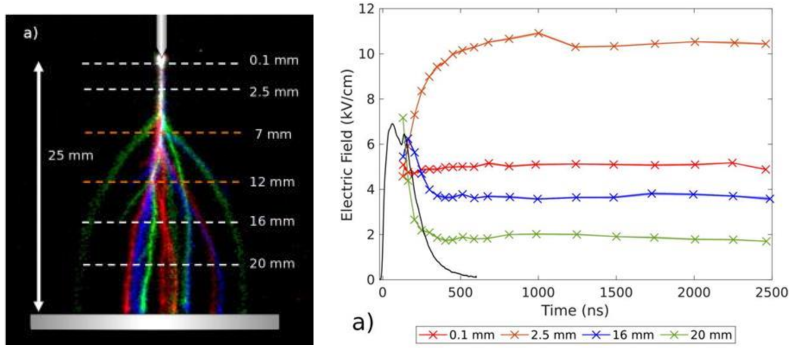
U. Kortshagen (U. Minnesota.) and W. Villafana and I. Kaganovich (PCRF)



Electric field in corona discharge

C. Guerra-Garcia (MIT) and A. Dogariu (PCRF)

- Electric field by E-FISH diagnostic



PCRF

Acknowledgment

PCRF Users: https://pcrf.princeton.edu/research/projects/

PCRF User Group: Bruce Locke, Maria Carreon, Tiernan Casey, Danil Dobrynin, and Albina Tropina

PCRF Advisory Board: Stewart Prager, Uwe Kortshagen, Amy Wendt and Michael Keidar

PCRF External Independent Review Panel

This work was performed under the US Department of Energy, Office of Science, Fusion Energy Sciences, through contract DE-AC02-09CH11466

Program Manager, Nirmol Podder

PCRF

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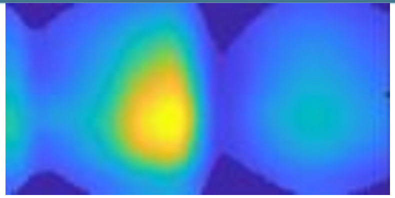
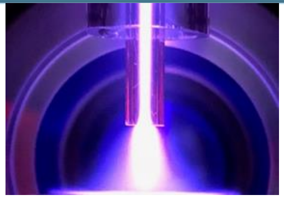
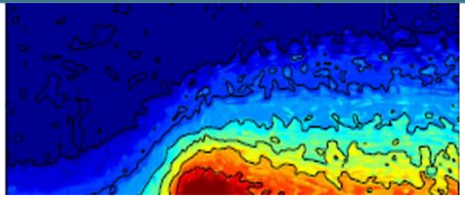
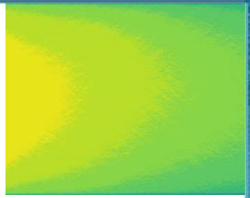
http://pcrf.pppl.gov

Sandia National Laboratories

Sandia National Laboratories Plasma Research Facility (PRF)

Shane Sickafoose, Brian Bentz, Jonathan Frank,
Grant Gorman, Nils Hansen, Matthew Hopkins,
Christopher Kliewer, Sebastian Pfaff, Lucas Beving

29 November 2023

smsicka@sandia.gov

U.S. DEPARTMENT OF ENERGY   NNSA National Nuclear Security Administration

Sandia National Laboratories' Plasma Research Facility is funded by the U.S. Department of Energy's Office of Science, Fusion Energy Sciences.
Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.
SAND2023-13761PE

Plasma Topical Areas – Recent Collaborations

Fundamental Plasma Physics

Electron-Field Instability: Excitation of electron plasma waves by an ambipolar electric field

Understanding the vacuum arc plasma expansion by PIC simulations

Understanding sheath deformation around Langmuir probes in flowing plasmas and presheaths

Photoemission induced plasma breakdown

Plasma-Assisted Chemistry, Catalysis, and Combustion

Upcycling of polyethylene and alkanes in a CO_2 *DBD plasma*

Investigating the Thermal Effect of Nanosecond Repetitively Pulsed Glow Discharges on a Methane-Air Flame by Coherent Anti-Stokes Raman Scattering and Optical Emission Spectroscopy

Kinetics of plasma assisted chemical looping of hydrocarbon fuels with metal oxides

Particle Dynamics in Plasma-Assisted Catalytic Reactions of Ammonia

Microelectronics

Computational and experimental studies of intermediate pressure capacitively coupled plasmas

Particle-in-cell modeling of low pressure (<10 mTorr) high bias (>2000 V) dual-frequency capacitively coupled plasmas

Quantitative 1-D broadband ultrafast coherent Raman imaging of atomic radicals

Reference electron density measurements in a capacitively coupled radiofrequency plasma source

Differentiating Expertise and Capabilities

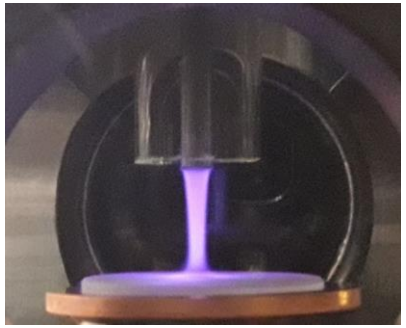
Multiple femtosecond, picosecond, nanosecond and CW lasers for interrogating dynamic plasma and reactive environments

- Neutral species density – LIF, PF-LIF
- Electric Fields (LIF-Dip, EFISH)
- Electron Densities - LCIF
- Multidimensional CARS for gas and surface phase interrogation

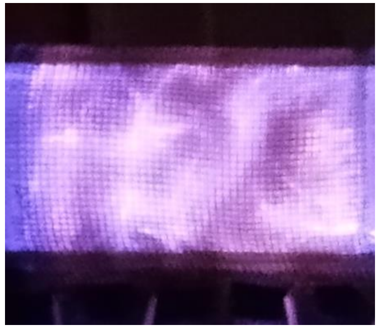
High speed imaging and detectors capabilities

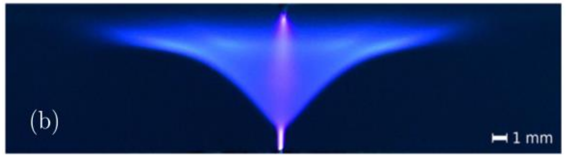
- <200 ps gated cameras, multi-frame framing cameras and high-speed CMOS cameras, streak camera
- VUV to Visible to IR spectrometers

High resolution tandem and molecular beam mass spectroscopy (MBMS) for interrogating gas phase chemistries occurring in multi-atmosphere environments.

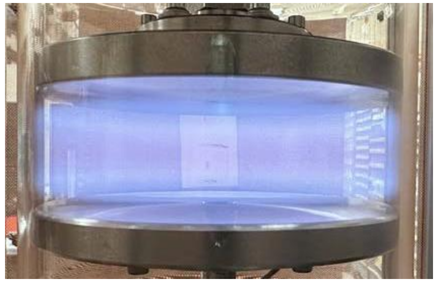

Low-pressure ns pulsed discharge


Plane-to-plane ns pulsed discharge for plasma catalysis


MBMS –flow reactors with DBD



Pulsed Glow Discharge with lean premixed CH4-Air flam


RF-driven CCP


Plasma-assisted combustion in atmospheric pressure narrow channel

Propose a collaboration at: www.sandia.gov/prf

PRF Optical Diagnostics Laboratories

Laser systems

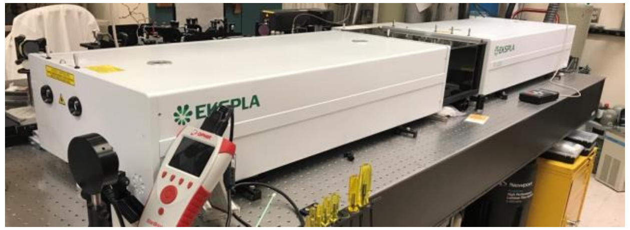
- Nanosecond laser system (50 Hz, 3 ns, 150 mJ)
  - OPA with UV generation (210 nm to 2300 nm)
- Picosecond laser system (50 Hz, 20 ps, 50 mJ)
  - OPA with Deep UV generation (193 nm to 2000 nm)
- Femtosecond laser system (1 kHz, 50 fs, 6 mJ)
  - OPA with DFG and UV modules (200 – 10000 nm)

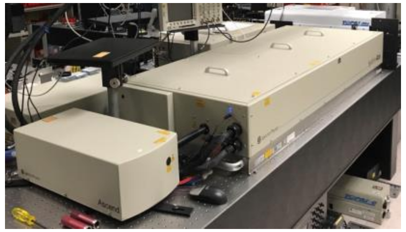
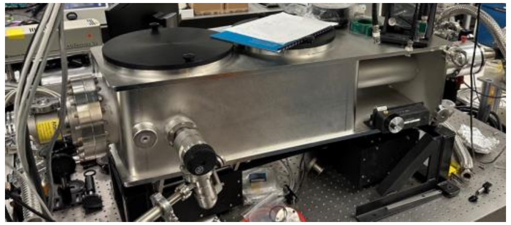
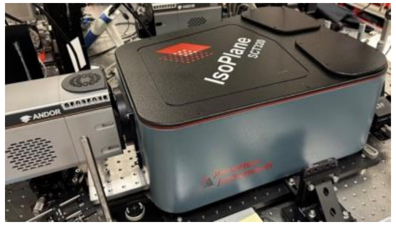
Imaging and spectroscopy

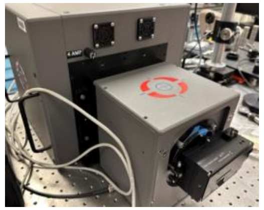
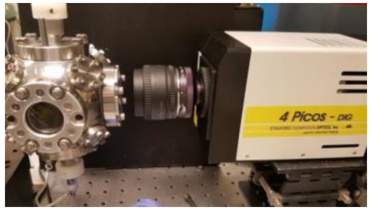
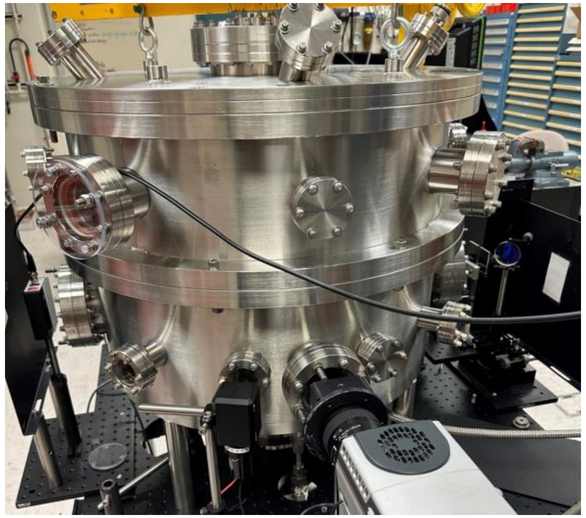
- Intensified cameras (3 ns, 200 ps gate)
- Fast framing camera (8 channels, 5 ns),
- Streak camera (<200 ps)
- Spectrometers (VUV to NIR)

General laboratory capabilities

- High voltage pulses (>100 ns, <20 kV)
- RF amplifiers (<500 W) and matching networks
- Broadband scopes, probes, photo diodes, photomultiplier tubes
- Vacuum systems, gas flow and mixing



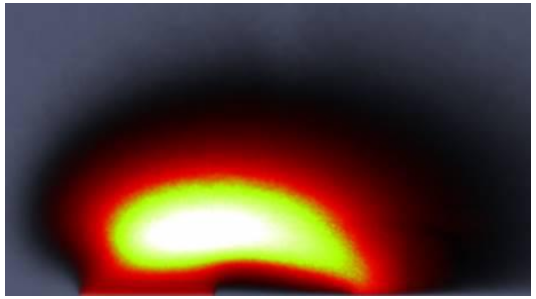





Differentiating Expertise and Capabilities (cont.)

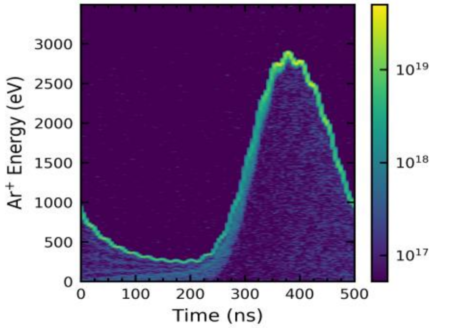
Theoretical/Computational LTP Capabilities

Aleph:

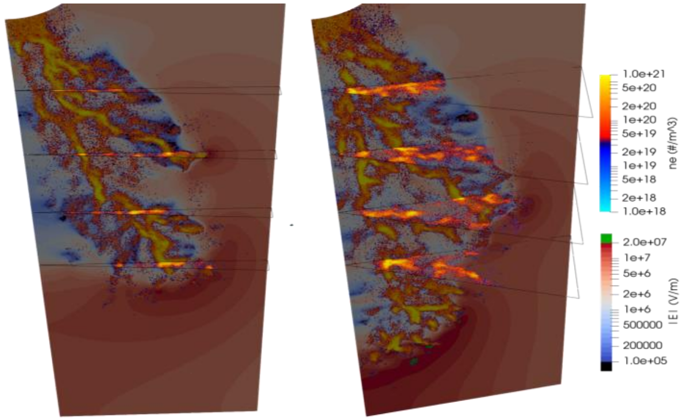
- Massively parallel electrostatic PIC-DSMC – algorithmic development enables simulations on up to ~100,000 cores. Allows for simulations spanning the kinetic-fluid regimes.
- Extensive collision dynamics and interactions:
  - Binary elastic and inelastic collisions between electrons, ions, and neutrals sometimes with ~100 species. Ionization, excitation, dissociation, charge exchange, etc.
  - N-body rate-based chemistry.
  - Photonic processes (photoexcitation, photoionization). Can generate mod spectra.
- Multiple boundary models for plasma-surface interactions. Secondary emission processes. Angle and energy distributions. Circuit models. Photoemission. Dielectric charging. Thermal energy deposition.
- Unstructured mesh and/or CAD geometry to model complex structures.



3D image e- density cathode plasma



IED dual frequency RF in high aspect ratio etching. 27 reactions, 8 species. 1D PIC-DSMC.

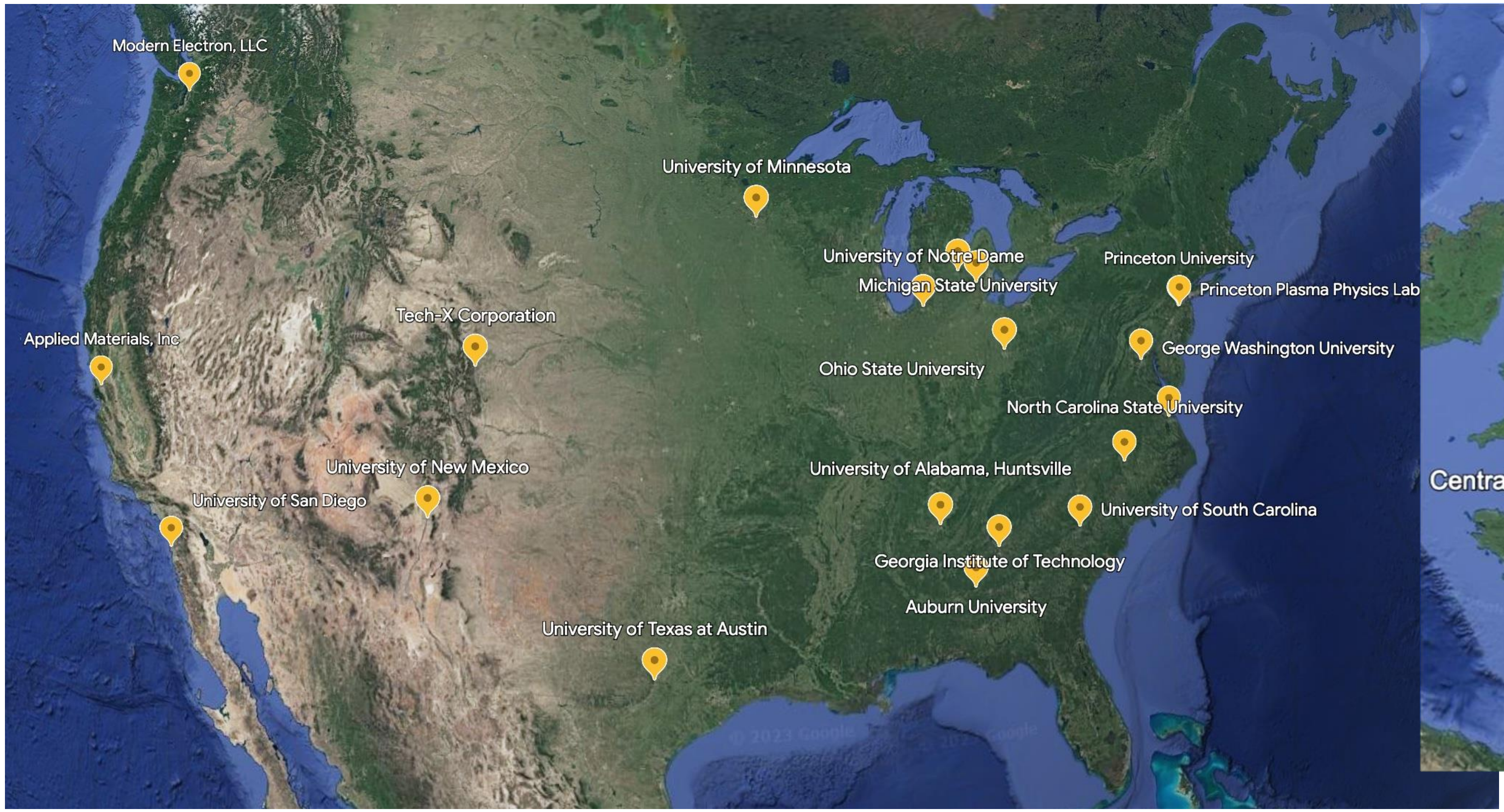


Other capabilities under development include:

- 0D global modeling (PlasMod0)
- Electromagnetic PIC-DSMC (EMPIRE) using heterogeneous architectures (e.g., GPUs)

Propose a collaboration at: www.sandia.gov/prf

Accepted Proposals – International



Proposals submitted – 69

Proposals accepted – 38

Institutions Proposing – 32

PI's proposing – 43

Experimental – 30 accepted

Computational – 8 accepted

Sandia Plasma Research Facility – Principal Investigators

Brian Bentz – Multi-dimensional interrogation of atomic species, electron densities and electric fields using linear and non-linear spectroscopies (bzbentz@sandia.gov)

Jonathan Frank – Imaging and gas-phase spectroscopy for high-speed, multi-dimensional measurements in plasmas and plasma-assisted reacting flows (jhfrank@sandia.gov)

Grant Gorman - Computational modeling and simulation of non-equilibrium plasma phenomena in ultracold and discharge plasmas (gmgorma@sandia.gov)

Nils Hansen – Interrogation of chemistries in reactive environments using high resolution mass spectrometry (nhansen@sandia.gov)

Matt Hopkins – Computational modeling and simulation of non-equilibrium plasma phenomena (mmhopki@sandia.gov)

Chris Kliewer – Ultrafast non-linear gas and surface phase spectroscopies (cjkliew@sandia.gov)

Acknowledgements

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U.S. DEPARTMENT OF ENERGY

Call Opens: October 9th, 2023

Call Closes: December 15th, 2023

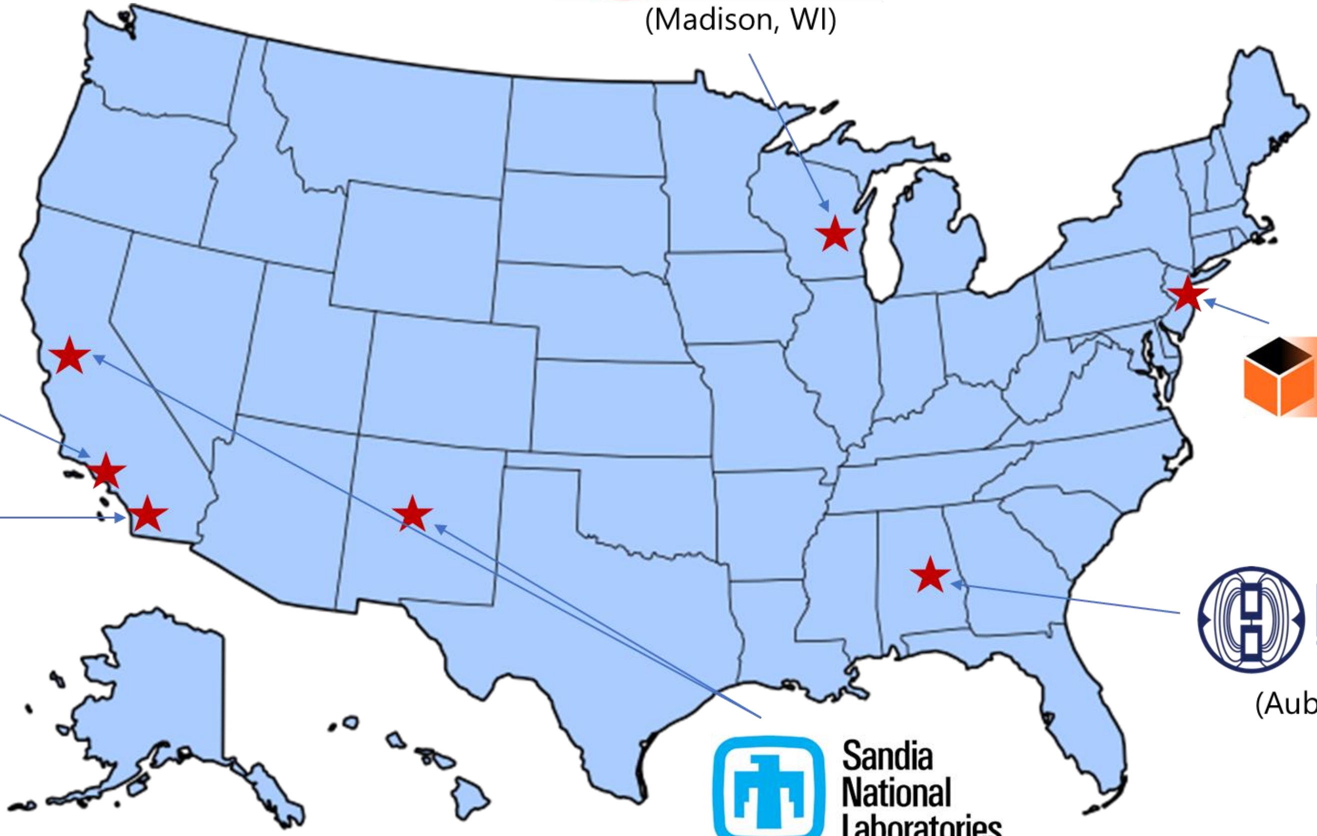
Notification of Principal Investigators: 5 February 2024

https://www.sandia.gov/prf/plasma-research-facility/proposals/

smsicka@sandia.gov

Thank you!

Q&A



For the webinar recording please contact:

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