Importance of Intermediate-scale Experiments in Discovery Plasma Science

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Size Matters

- Many of important plasma physics problems require a threshold size beyond typical sizes of single-PI experiments.
- Intermediate-scale experiments called for by the NRC Plasma 2010 report:

Conclusion: There are important basic plasma problems at intermediate scale that cannot be addressed effectively either by the present national facilities or by single-investigator research.

Recommendation: The plasma community and the relevant federal government agencies should initiate a periodic evaluation and consultation process to assess the need for, and prioritization of, new facilities to address problems in basic plasma science at the intermediate scale.

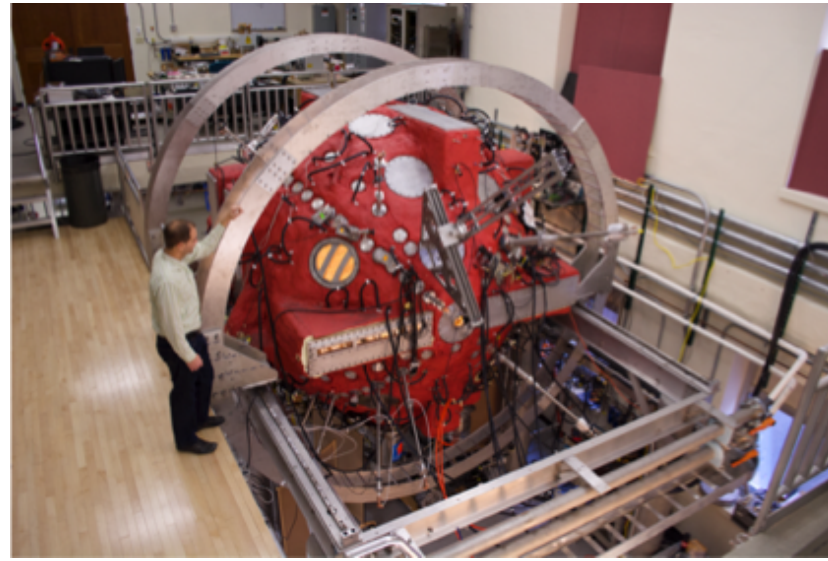
- But currently no programs to support its operation and research

Size Matters - Examples

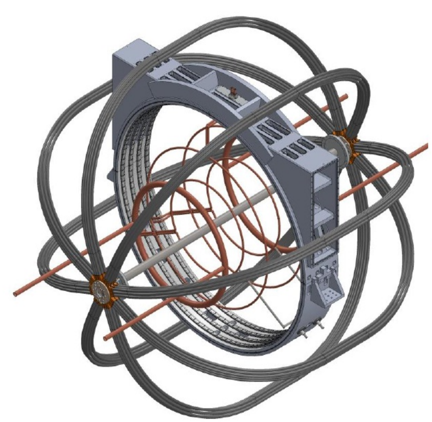
- Dynamo experiments with sufficient magnetic Reynolds numbers;
- Alfven wave experiments with sufficient sizes to accommodate at least one wavelength of Alfven waves;
- Magnetized dusty plasma experiments with sufficient sizes for dust particles to complete cyclotron motions
- Reconnection experiments to access new regimes directly relevant to space and astrophysical plasmas
- …

The Wisconsin Plasma Astrophysics Facility

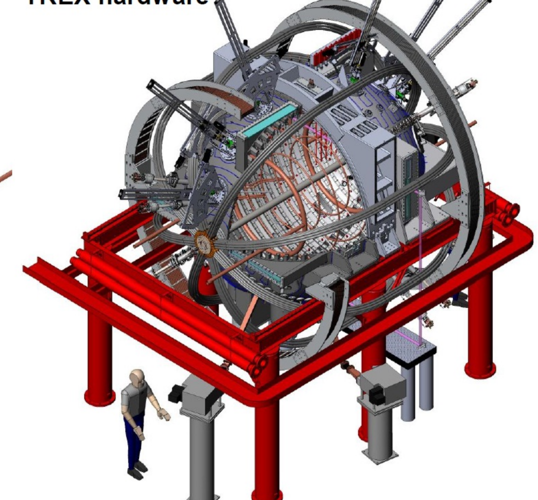
- **Core research team**: C. Forest, J. Egedal, E. Zweibel (U. Wisconsin), major collaborators from NCAR, Princeton, University of Chicago
- **Discovery science:**
  - Extremely flexible, steady-state multidipole confinement of plasma in axisymmetric ring cusp
  - Large, hot, unmagnetized plasma: very high beta physics, target for jets
  - The Madison Plasma Dynamo Experiment (MPDX) uses plasma boundary stirring to allow dynamos and MRI (conversion of kinetic energy to magnetic energy) to be studied at high Rm and Pm
  - Internal rings being added for large, high S reconnection in form of Terrestrial Reconnectior Experiment (TREX)
- **Operation**: a collaborative multi-investigator facility, with very strong connections to solar and astrophysics
- **Support:**
  - Theory/modeling: CMSO
  - Construction: NSF-MRI
  - Operations: DOE, NSF?



TREX insert for reconnection & TF coils

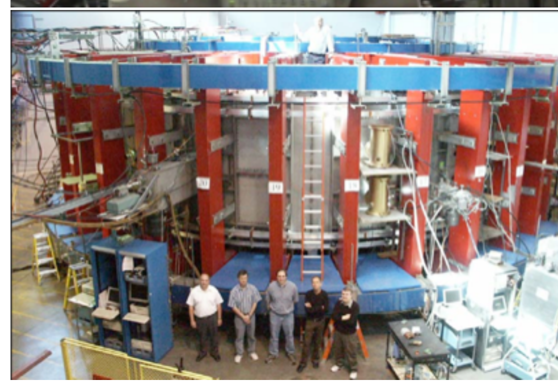


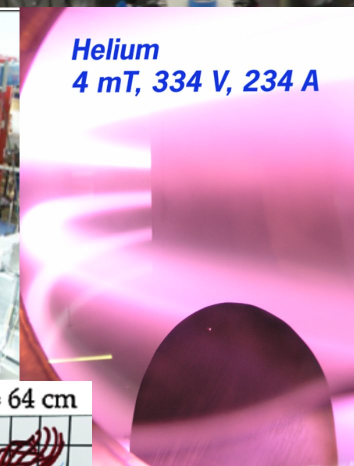
MPDX-facility updated with TREX hardware

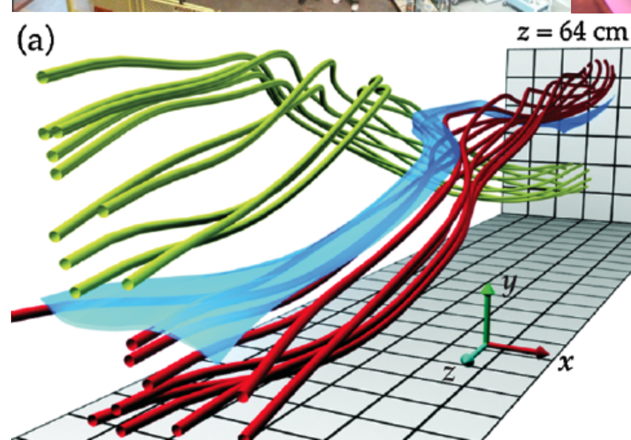


Basic Plasma Science Facility (BAPSF)

- **Core research team**: UCLA Local group: incudes W. Gekelman, T. Carter, G.Morales, J. Maggs, S. Vincena, B. Van Compernolle, S. Tripathi (UCLA); external users from 30+ different institutions
- **Discovery science:**
  – Linear and nonlinear physics of Alfven waves
  - Magnetic flux ropes, reconnection
  - Drift wave turbulence and transport
  - Physics of energetic ion transport
  - Wave-particle interactions
  - …many more areas
- **Operation**: NSF/DOE National User Facility for Basic Plasma Science
- **Support:**
  – Construction: ONR, NSF-MRI
  – Operations: DOE, NSF

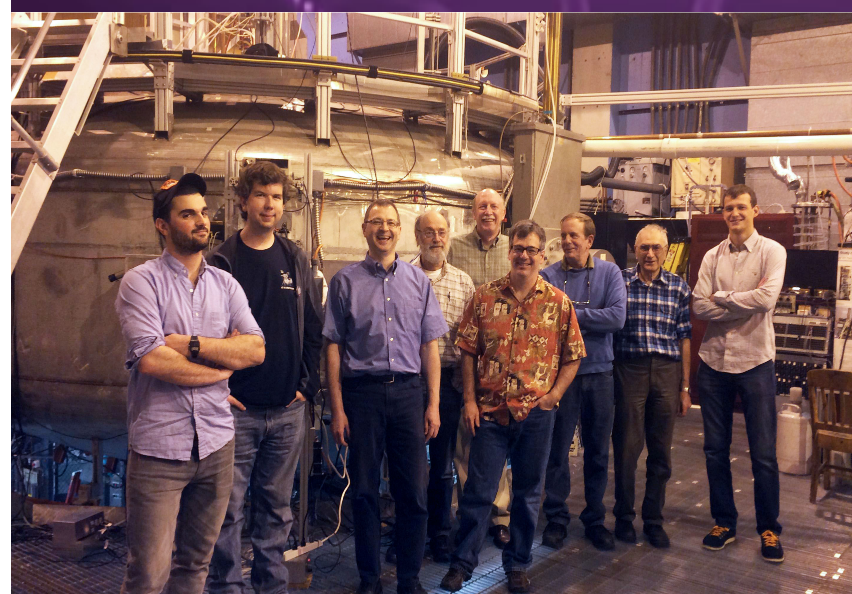






Levitated Dipole Experiment (LDX)

- **Collaborative research team**: M. Mauel, D. Garnier (Columbia), J. Kesner, P. Michael, M. Porkolab (MIT)
- **Discovery science:**
  - New regime of magnetized plasma physics: turbulent self-organization within a high beta plasma torus in dipole geometry
  - Wave-particle interactions and Alfvén dynamics relevant to planetary magnetospheres
  - Validating bounce-averaged gyrokinetics including finite T_i and isotope effects relevant to space weather models .
- **Operation:** Multi-university facility for steady-state plasma science studies
- **Support:**
  - Construction: DOE (~$5M)
  - Current Funding: NSF/DOE ($0.4M/yr)

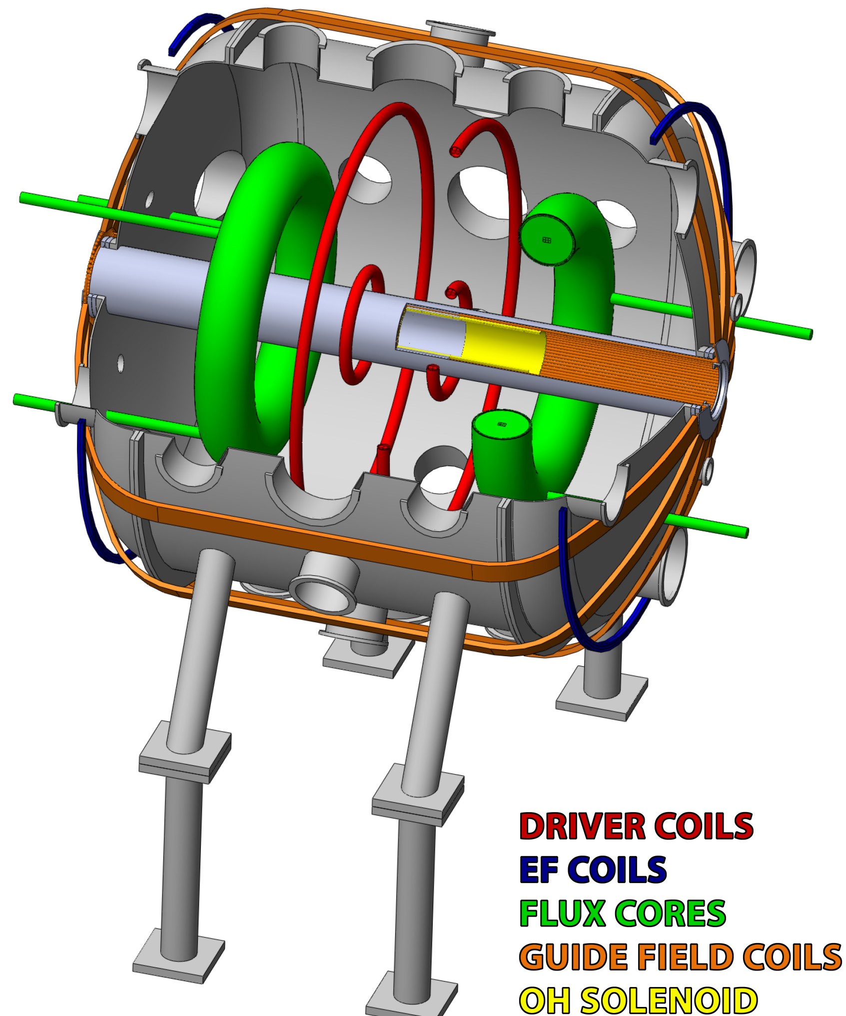


Magnetized Dusty Plasma Experiment (MDPX)

- **Core research team**: E. Thomas, Jr. and U. Konopka (Auburn), R. Merlino (Iowa), M. Rosenberg (UCSD)
- **Partners:** Broad team of US and International researchers [e.g., PPPL, NRL, Baylor, MIT, VA Tech, Wittenberg, Kiel, Giessen, DLR, etc.]
- **Discovery science:**
  - Explore the physics of strongly magnetized plasmas in uniform and non-uniform magnetic fields
  - Develop a fully magnetized dusty plasma
  - Develop flexible, multi-configuration magnetic geometry
- **Operation:** a collaborative multiple-user facility
- **Support:**
  - Construction: NSF-MRI
  - Operations: NSF, DOE

FLARE (Facility for Laboratory Reconnection Experiments)

- **Consortium**: Princeton U., U. Wisconsin, U. Maryland, UCLA, and UC Berkeley, PPPL, LANL
- **Collaborative users from 5 communities**:
  - Basic Plasma
  - Space Physics
  - Solar Physics
  - Astrophysics
  - Fusion Plasma Physics
- **Discovery science:** to explore new regimes of magnetic reconnection directly relevant to space, astrophysical, and fusion plasmas
- **Operation:** a collaborative multi-user facility
- **Support:**
  - Construction: NSF-MRI



Input to the FESAC SP Panel

- To recommend FES take a leadership role to establish a dedicated, coherent program to support intermediate-scale experiments within Discovery Plasma Sciences, possibly jointly with other funding agencies such as NASA and NSF to
  - Enhance opportunity;
  - Improve efficiency;
  - Increase impact.

A Coherent Program Supporting Intermediate-scale Experiment Can:

- <u>Enhance scientific opportunity</u> through the broadened parameter space and the increased variations in geometry from the coordinated multiple intermediate-scale experiments. Examples:
  - Alfven wave experiments in linear and toroidal geometries
  - Turbulence experiments in different regimes, such as low- and high-betas
  - Reconnection experiments in 2D and 3D geometries

A Coherent Program Supporting Intermediate-scale Experiment Can:

- Improve research efficiency through coordination between multiple experiments. Examples:
  - Share advanced diagnostics,
  - Share numerical tools,
  - Share plasma generating and control techniques.
- In addition, these intermediate-scale experiments can offer a shared platform for a variety of experiments to be tried more efficiently.

A Coherent Program Supporting Intermediate-scale Experiment Can:

- Increase broader impact through coordinated operations, shared diagnostics and best practices, and improved interactions with the broader fields of science. Examples:
  - Foster collaborations within a common “collaborative user” community. (Note: plasma experiments are nominally different from a typical user facility often used in other fields, e.g. light sources.)
  - Strengthen Discovery Plasma Science, motivate theory and simulation work, and serve as a mechanism to glue the community together

Summary: Input to the FESAC SP Panel

- To recommend FES take a leadership role to establish a dedicated, coherent program to support intermediate-scale experiments within Discovery Plasma Sciences, possibly jointly with other funding agencies such as NASA and NSF to
    - Enhance opportunity;
    - Improve efficiency;
    - Increase impact.

- But this new program should NOT be at the expense of single-PI projects, rather it should help bridge them to large-scale experiments.