

PFC Meeting at PPPL, May 9, 2005

# Experimental PMI facilities in the PFC program

## A brief overview

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Livermore, California

### Outline

- Types and purpose
- Facilities:
  - Beam experiments
  - Plasma experiments
  - Integrated experiments
  - Ancillary experiments



# Experimental PMI facilities

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- Four main categories:
  - ion beam experiments
  - plasma simulator experiments
  - integrated experiments
  - ancillary experiments.
- Experiments in each category are needed to effectively address PFC program needs:
  - to characterize PMI effects in PFC materials
  - to help qualify PFC materials
  - to provide data for testing PMI models.



# Ion beam experiments

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**Description:** An ion beam of known energy, flux, and composition bombards a sample and its effects on materials properties are measured.

**Uses:** Study and characterize individual PMI processes

**Key features:**

- provide highest level of control over PMI parameters
- can study basic physical processes
- generate fundamental data
- can be quantitative for calibrating models.



# Plasma simulator experiments

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**Description:** A controlled plasma is formed, contacts a sample, and its effects on materials properties are measured.

**Uses:** Study PMI effects and test materials under a wide variety of conditions

**Key features:**

- provide a high level of control over PMI parameters
- produce conditions that may approximate the fusion reactor environment
- can study PMI and test material performance.



# Integrated experiments

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Description: PFC material samples are exposed to plasmas in operating confinement devices.

Uses: Provide PMI and performance data under actual plasma confinement conditions

Key features:

- Most closely reproduce the conditions experienced by plasma-facing materials in confinement devices
- can study PMI and test material performance.



# Ancillary experiments

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Description: PFC material samples are exposed to particular conditions experienced by PFCs.

Uses: Test material response to high heat fluxes or strong magnetic fields.

Key features:

- provide a high level of control over a single PMI-like parameter
- can generate conditions accompanying PMI over a wide range
- avoid effects caused by energetic ion bombardment.



# PMI experimental facilities

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PMI experiments by category			
Beam	Plasma	Integrated	Other
ARIES (SNL)	DPE (SNL)	CDX-U* (PPPL)	EB-1200 (SNL/NM)
FLiRE (UIUC)	ESP (UIUC)	DiMES (GA)	EBTS (SNL/NM)
IIAX (UIUC)	PEBL (SNL)	LTX*(PPPL)	LIMITS (SNL/NM)
IMPACT (ANL)	PISCES-A (USCD)	NSTX (PPPL)	MTOR (UCLA)
	PISCES-B (UCSD)		
	TPE (INL)	* CDX-U to become LTX	



# PMI experiment descriptions

## ARIES

Angle-Resolved Ion Energy Spectrometer

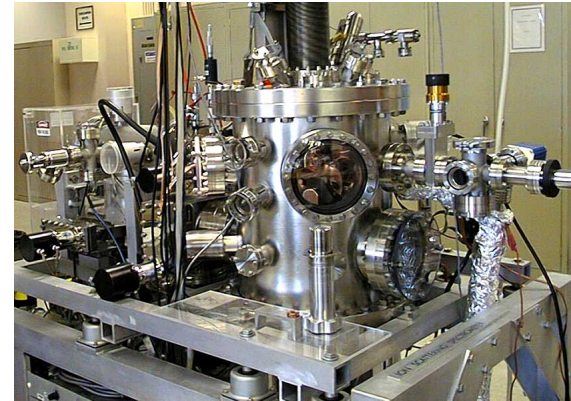
Site: SNL/CA

Staff: R. Bastasz, bastasz@sandia.gov, 925 294-2013

J. Whaley, jawhale@sandia.gov, 925 294-2677

Link: <http://www.ca.sandia.gov/>

Materials&EngineeringSciences/  
facilitiesframe.html



Description: ARIES at SNL/CA is an ion beam experiment that provides PMI data on surface composition, sputtering, implantation, mixing, segregation effects, and hydrogen isotope recycling on solid and liquid materials. ARIES obtains PMI data through energy analysis of ions scattered or recoiled from a sample. The ion beam simulates the particle flux emanating from a plasma as well as functioning as the analytical probe.

Main parameters:

species:  $H^+$ ,  $H_2^+$ ,  $H_3^+$ ,  $D^+$ ,  $D_2^+$ ,  $D_3^+$ ,  $He^+$ ,  $Ne^+$ ,  $Ar^+$  (mass selected)

beam energy: 100–3000 eV, monoenergetic to  $\pm 1$  eV

flux:  $10^{13-15}$  /cm<sup>2</sup>-s

angular ranges: 0–90° beam impact, 15–85° observation, 0–360° azimuth

sample size: up to 2.5 cm diameter

substrate temperature: -100 to 1200 °C





# List of PMI experiments

## Catalog of PMI experiments for the PFC program

### ARIES

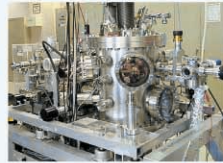
Angle-Resolved Ion Energy Spectrometer

Site: SNL/CA

Staff: Bob Bastasz, bastasz@sandia.gov, 925 294-2013

Josh Whaley, jawhale@sandia.gov, 925 294-2677

Link: <http://www.ca.sandia.gov/Materials&EngineeringSciences/facilitiesframe.html>



*Description:* The Angle-Resolved Ion Energy Spectrometer at SNL/CA is an ion beam experiment that provides PMI data on surface composition, sputtering, mixing, segregation effects, and hydrogen isotope recycling on either solid or liquid materials. ARIES obtains PMI data through energy analysis of ions scattered or recoiled from a sample.

### CDX-U

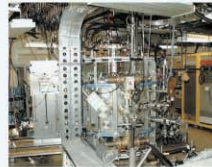
Current Drive eXperiment-Upgrade

Site: PPPL

Staff: Bob Kaita, rkaita@pppl.gov, 609 243-3275

Dick Majeski, majeski@pppl.gov, 609 243-3112

Link: <http://w3.pppl.gov/~cdx/>



*Description:* The Current Drive eXperiment-Upgrade at PPPL provides a small-scale plasma facility in which novel ideas can be tested before they are tried on larger devices. It has recently been used to develop liquid Li technology for MFE. CDX-U will soon be converted to LTX.

### DiMES

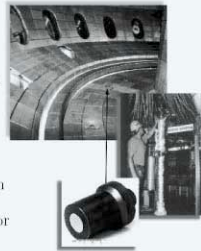
Divertor Materials Evaluation System

Site: GA

Staff: Clement Wong, wongc@fusion.gat.com, 858 455-4258

Dimitry Rudakov, rudakov@fusion.gat.com, 858 455-2895

Link: <http://fusion.gat.com/diag/>



*Description:* The Divertor Materials Evaluation System is an attachment to the DIII-D tokamak at GA that permits materials and diagnostics to be inserted into the divertor floor during machine operation. It provides integrated PMI testing of both solid and liquid materials.

### DPE

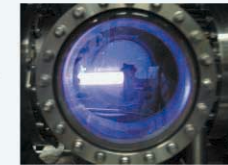
Deuterium Plasma Experiment

Site: SNL/CA

Staff: Rion Causey, causey@sandia.gov, 925 294-3326

Josh Whaley, jawhale@sandia.gov, 925 294-2677

Link: <http://www.ca.sandia.gov/Materials&EngineeringSciences/facilitiesframe.html>



*Description:* The Deuterium Plasma Experiment is a plasma experiment at SNL/CA used to study retention and release of H and He in solid materials and to simulate redeposition. DPE can irradiate samples of various sizes to a high fluence in the sub-keV ion energy range.

### EB-1200

Electron Beam - 1200 kW

Site: SNL/NM

Staff: Dennis Youchison, dlyouch@sandia.gov, 505 845-3138

Link: <http://www.sandia.gov/bus-ops/partnerships/tech-access/facilities/pntf.html>



*Description:* The EB-1200 is a beryllium capable, dual gun, 1.2 MW electron beam HHF facility connected to a high pressure, high temperature water flow loop. It can simulate one-sided plasma heat loads and accommodates medium scale (1 m), actively-cooled PFCs and advanced heat exchangers. It is used to evaluate the thermal response, thermal shock, thermal fatigue and thermallyhydraulic performance of armor materials, joints and heatsinks.

### EBTS

Electron Beam Test System

Site: SNL/NM

Staff: Dennis Youchison, dlyouch@sandia.gov, 505 845-3138

Link: <http://www.sandia.gov/bus-ops/partnerships/tech-access/facilities/pntf.html>



*Description:* The Electron Beam Test System is a 30 kW electron beam HHF facility used to simulate one-sided plasma heat loads to small scale (10 cm), actively-cooled PFCs and advanced heat exchangers. It is used to evaluate the thermal response, thermal shock, thermal fatigue and thermallyhydraulic performance of armor materials, joints and heatsinks. The EBTS is a beryllium capable facility serviced by high temperature, high pressure water, high pressure helium and liquid metal coolant loops.



# List of PMI experiments

## Catalog of PMI experiments for the PFC program

### ARIES

Anglo-Resolved Ion Energy Spectrometer  
 Site: SNL/CA  
 Staff: Bob Bostass, bostass@snl.gov, 925 294 2013  
 Josh Whaley, jwhale@snl.gov, 925 294 2677  
 Link: <http://www.snl.gov/Materials&Engineering/Services/facilities/frame.html>



Description: The Anglo-Resolved Ion Energy Spectrometer at SNL/CA is an ion beam experiment that provides PMI data on surface composition, sputtering, mixing, segregation effects, and hydrogen isotope recycling on either solid or liquid materials. ARIES obtains PMI data through energy analysis of ions scattered or recoiled from a sample.

### CDX-U

Current Drive eXperiment-Upgrade  
 Site: PPTL  
 Staff: Bob Kaita, kaita@pppl.gov, 609 243 3275  
 Dick Majorski, majorsd@pppl.gov, 609 243 3112  
 Link: <http://w3.pppl.gov/~cdx/>



Description: The Current Drive eXperiment-Upgrade at PPTL provides a small-scale plasma facility in which novel ideas can be tested before they are tried on larger devices. It has recently been used to develop liquid Li technology for MFE. CDX-U will soon be converted to LTX.

### DIMES

Divertor Materials Evaluation System  
 Site: GA  
 Staff: Clement Wong, wong@fusion.gat.com, 858 455 4258  
 Dmitry Rudakov, rudakov@fusion.gat.com, 858 452 2905  
 Link: <http://fusion.gat.com/dimg/>



Description: The Divertor Materials Evaluation System is an attachment to the DIB-D tokamak at GA that permits materials and diagnostics to be inserted into the divertor flow during machine operation. It provides integrated PMI testing of both solid and liquid materials.

### IMPACT

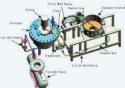
Interaction of Materials with charged-Particles And Components Testing  
 Site: ANL  
 Staff: Jean Paul Abalin, abalin@anl.gov, 630 252 5184  
 Link: <http://www.ornl.gov/sec/ionics/cph/highlights/impact.html>



Description: The Interaction of Materials with charged-Particles And Components Testing facility at ANL is a beam experiment being used to study the properties of thin-film Li coating on various materials. It contains surface analysis components and a quartz microbalance for composition and sputtering measurements.

### LIMITS

Liquid Metal Integration Test System  
 Site: SNL/NM  
 Staff: Tim Tamala, ttamala@snl.gov, 505 844 2981  
 Link: <http://www.snl.gov/lms-ops/partnerships/tech-access/facilities/pnat.html>



Description: LIMITS is a closed liquid metal loop designed to study MHD effects in flows of molten metals in vacuum under the influence of magnetic field gradients as a preliminary study for flowing liquid surfaces inside of magnetic fusion reactors. When the magnets are removed, the free surface of the flowing liquid can be heated by the EBTS, or the liquid metal can be heated inside a tube or heatpipe assembly.

### LTX

Lithium Tokamak eXperiment  
 Site: PPTL  
 Staff: Bob Kaita, kaita@pppl.gov, 609 243 3275  
 Dick Majorski, majorsd@pppl.gov, 609 243 3112  
 Link: <http://w3.pppl.gov/~ltx/>



Description: The Lithium Tokamak eXperiment is a modification of the CDX-U device at PPTL designed to test transport and profile modification in plasmas with fully non-recycling walls. In this integrated experiment, the walls will be coated with a thin film of liquid Li prior to initiating a plasma discharge.

### DPE

Deuterium Plasma Experiment  
 Site: SNL/CA  
 Staff: Ron Consey, conseyr@snl.gov, 925 294 3326  
 Josh Whaley, jwhale@snl.gov, 925 294 2677  
 Link: <http://www.snl.gov/Materials&Engineering/Services/facilities/frame.html>



Description: The Deuterium Plasma Experiment is a plasma experiment at SNL/CA used to study retention and release of H and He in solid materials and to simulate redeposition. DPE can irradiate samples of various sizes to a high fluence in the sub-MeV ion energy range.

### EB-1200

Electron Beam - 1200 kW  
 Site: SNL/NM  
 Staff: Dennis Younison, dyounis@snl.gov, 505 845 3138  
 Link: <http://www.snl.gov/lms-ops/partnerships/tech-access/facilities/pnat.html>



Description: The EB-1200 is a beryllium cathode, dual gun, 1.2 MW electron beam HHP facility connected to a high pressure, high temperature water flow loop. It can simulate one-sided plasma heat loads and accommodates median scale (1 m), actively-cooled PFCs and advanced heat exchangers. It is used to evaluate the thermal response, thermal shock, thermal fatigue and thermohydraulic performance of armor materials, joints and heatinks.

### EBTS

Electron Beam Test System  
 Site: SNL/NM  
 Staff: Dennis Younison, dyounis@snl.gov, 505 845 3138  
 Link: <http://www.snl.gov/lms-ops/partnerships/tech-access/facilities/pnat.html>



Description: The Electron Beam Test System is a 30 kW electron beam HHP facility used to simulate one-sided plasma heat loads to small scale (10 cm), actively-cooled PFCs and advanced heat exchangers. It is used to evaluate the thermal response, thermal shock, thermal fatigue and thermohydraulic performance of armor materials, joints and heatinks. The EBTS is a beryllium cathode facility serviced by high temperature, high pressure water, high pressure helium and liquid metal coolant loops.

### MITOR

Magneto-Thermofluid Omnibus Research laboratory  
 Site: UCLA  
 Staff: Neil Morley, morley@fusion.ucla.edu, 310 206 1230  
 Alice Ying, ying@fusion.ucla.edu, 310 206 8815  
 Link: <http://www.fusion.ucla.edu/>



Description: The Magneto-Thermofluid Omnibus Research laboratory at UCLA is a highly flexible collection of high field, high volume magnet systems including a GT magnet and a 24 coil magnetic test equipped with gallium and lead alloy liquid metal flow loops for studying free surface and closed channel liquid metal MHD and heat transfer phenomena.

### NSTX

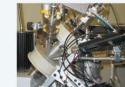
National Spherical Torus eXperiment  
 Site: PPTL  
 Staff: Henry Kugel, hkugel@pppl.gov, 609 243 3146  
 Rajesh Muni, muni@pppl.gov, 609 243 3176  
 Link: <http://www.pppl.gov/projects/ppst/nstx.html>



Description: The National Spherical Torus eXperiment is a major integrated experimental facility at PPTL. It is planned to be used to study boundary and edge-physics effects due to Li pellet injection into the core plasma, Li evaporation onto the walls (ALIST module A) and possibly a flowing Li PFC (ALIST module B).

### PEBL

Plasma Entrained Bubbles in Liquids experiment  
 Site: SNL/CA  
 Staff: Don Cowgill, dcowgill@snl.gov, 925 294 2146  
 Link: <http://www.snl.gov/Materials&Engineering/Services/facilities/frame.html>



Description: The Plasma Entrained Bubbles in Liquids experiment at SNL/CA is designed to study He retention in liquid metals. It is a plasma experiment that uses a <sup>3</sup>He-seeded Penning discharge in conjunction with nuclear reaction analysis (NRA). Retained He is dynamically profiled by NRA.

### ESP

ELM Simulating Plasma  
 Site: UIUC  
 Staff: David Bunk, dbunk@uiuc.edu, 217 333 0332  
 Robert Stablers, stablers@uiuc.edu, 217 333 1750  
 Link: <http://starfire.nsl.uiuc.edu/>



Description: The ELM Simulating Plasma is a plasma experiment at UIUC currently under development. Its purpose is to study erosion and other effects of ELM-like plasma bombardment on PFC materials.

### FLIRE

Flowing Lithium Retention Experiment  
 Site: UIUC  
 Staff: David Bunk, dbunk@uiuc.edu, 217 333 0332  
 Robert Stablers, stablers@uiuc.edu, 217 333 1750  
 Link: <http://starfire.nsl.uiuc.edu/flire/>



Description: The Flowing Lithium Retention Experiment is an ion beam experiment at UIUC used to primarily to study He retention in flowing liquid metals using a mass spectrometer. It has demonstrated the ability to handle liquid Li.

### IAX

InterActive IntraActive eXperiment  
 Site: UIUC  
 Staff: Matt Coventry, coventry@uiuc.edu, 217 333 8385  
 David Bunk, dbunk@uiuc.edu, 217 333 0332  
 Link: <http://starfire.nsl.uiuc.edu/iax/iax.html>



Description: The IntraActive IntraActive eXperiment is an ion beam experiment at UIUC designed to measure the sputtering characteristics of solid and liquid materials. IAX uses a dual quartz crystal microbalance to precisely measure the quantity of atoms sputtered from a sample, providing fundamental PMI data.

### PISCES

Plasma Interaction with Surface and Components Experimental Simulator  
 Site: UCSD  
 Staff: Matt Baldwin, mbaldwin@ucsd.edu, 858 822 4117  
 Russ Doerner, rdoerner@ucsd.edu, 858 534 7820  
 Stan Lockhart, sls@khardt@ucsd.edu, 858 534 9725  
 Link: <http://verle.ucsd.edu/>



Description: The Plasma Interaction with Surface and Components Experimental Simulator is a plasma experiment at UCSD used to study erosion, redeposition, materials mixing, and recycling. Two versions, PISCES-A and PISCES-B, each use a high-flux plasma source and are equipped with both surface and plasma diagnostics. PISCES-B can handle Be sources.

### TPE

Tritium Plasma Experiment  
 Site: INL  
 Staff: Ron Consey, conseyr@snl.gov, 925 294 3326  
 Phil Sharpe, sharpe@inl.gov, 208 526 9830  
 Link: <http://www.inl.gov/fusion-safety/>



Description: The Tritium Plasma Experiment is a plasma experiment being re-commissioned at INL. It is designed to produce high-flux, tritium-seeded plasmas and can provide data on erosion, recycling, and tritium retention in solid materials.



# Status

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- The listing will be available to everyone in the fusion community to provide general information about our PFC facilities.
- The listing is being posted on the PFC (ALPS) website:  
⇒ [http://fusion.anl.gov/ALPS\\_Info\\_Center/](http://fusion.anl.gov/ALPS_Info_Center/)
- Some experiment descriptions are incomplete. In particular, experiment parameters need to be added.
- Please check over your experiment description and send me additions, corrections, and updates.  
⇒ [bastasz@sandia.gov](mailto:bastasz@sandia.gov)

