LANL OFES Budget Overview

http://fusionenergy.lanl.gov
http://plasma.lanl.gov
http://wsx.lanl.gov

(This Talk http://wsx.lanl.gov/LANL-BPM-FY05.pdf)

G. A. Wurden

Acting OFES Program Manager
& MFE Team Leader in P-24 Plasma Physics Group

Presented at OFES Budget Planning Meeting,
Gaithersburg, MD
March 19, 2003

LANL Budget Info (pg. 1)

Number	B&R CODE	TITLE	GRP	FY03 Alloc	FY04 Pres Bud	FY04 Rev	FY05 Guidance	FY05 Revised	MANAGER
NEW 05SCP1009	AT5015010	THEORY AND MODELING OF CO-AXIAL HELICITY INJECTION	T-15	0	0	80,000	0	120,000	ECKSTRAND
NEW 05SCP1010	AT5015010	INTENSE DIAGNOSTIC NEUTRAL BEAM FOR BURNING PLASMAS	P-24	0	0	0	0	1,401,000	WILLIS
NEW 05SCP1011	AT5015010	RECONNECTION SCALING EXPERIMENT	P-24	0	0	400,000	0	400,000	MCKNIGHT
05SCPE873	AT5015010	NSTX COLLABORATION	P-24	247,000	276,000	276,000	276,000	289,800	ECKSTRAND
	AT5015010 Total			**247,000**	**276,000**	**756,000**	**276,000**	**2,210,800**	
05SCPE898	AT5015020	OSCILLATING INERTIAL ELECTROSTATIC (POPS)	T-15	274,000	274,000	291,000	274,000	306,000	THIO
05SCPE901	AT5015020	ROTATING MAGNETIC FIELD FRC UNIV. WASH	P-24	178,000	179,000	179,000	179,000	188,000	THIO
05SCPE902	AT5015020	MADISON SYMMETRIC TORUS THEORY	T-15	121,000	120,000	120,000	120,000	126,000	THIO
05SCPE870	AT5015020	MAGNETIZED TARGET FUSION FRX-L EXP.	P-24	1,399,000	1,399,000	1,431,000	1,399,000	2,400,000	THIO
	AT5015020 Total			**1,972,000**	**1,972,000**	**2,021,000**	**1,972,000**	**3,020,000**	

LANL OFES Budget Info (pg. 2)

Number	B&R	TITLE	PROJ LDR	FY03 Alloc	FY04 Pres Bud	FY04 Rev	FY05 Guidance	FY05 Rev	MANAGER
05SCPE894	AT5015034	IFE TARGET FAB & TECHNOLOGY	NOBILE ART	345,000	310,000	345,000	310,000	345,000	NARDELLA
	AT5015034 Total			345,000	**310,000**	**345,000**	**310,000**	**345,000**	
05SCPE70E	AT5020 100	TOROIDAL THEORY	GLASSER ALAN H	869,000	874,000	874,000	874,000	918,000	THIO
	AT5020100 Total			**869,000**	**874,000**	**874,000**	**874,000**	**918,000**	
05SCPE771	AT5020 200	ALTERNATE CONCEPT THEORY	GLASSER ALAN H	137,000	138,000	138,000	138,000	145,000	THIO
05SCPE869	AT5020 200	FRC FUSION THEORY	LAPENTA, GIOVANI	50,000	50,000	50,000	50,000	52,500	THIO
	AT5020200 Total			**187,000**	**188,000**	**188,000**	**188,000**	**197,500**	
NEW 05SCP1012	AT6010 401	FUSION FUEL PROCESSING	WILLMS SCOTT	**0**	**0**	**500,000**	**0**	**500,000**	NARDELLA
	AT6010401 Total (included TSTA in FY03)			**2,917,000**	**0**	**500,000**	**0**	**500,000**	
05SCPE829	AT5010 300	M.I.T. ALCATOR C-MOD COLLABORATION	MAQUEDA, RICARDO	99,000	96,000	96,000	96,000	101,000	DAGAZIAN
	AT5010300 Total			**99,000**	**96,000**	**96,000**	**96,000**	**101,000**	
	Grand Total* ***not including PFXI and Fusion Tech terminated in FY03**			**6,636,000***	**3,716,000**	**4,780,000**	**3,716,000**	**7,292,300**	

MFE Team in P-24 Plasma Physics:

Staff: Glen Wurden, Tom Intrator, Ricky Maqueda, Martin Taccetti, Jeff Wang, and Doug Post*

- Techs: Bill Waganaar, Daniel Begay
- Postdocs: Ivo Furno, Shouyin Zhang, Scott Hsu
- Contractors: Phil Sanchez (engineer), Ed Mignardot (tech)
- Students: Too many to count….. (more on this later)

Existing Projects:

Magnetized Target Fusion (FRX-L at LANL)
Fast Imaging at Spherical Tokamak (NSTX at Princeton)
Rotating Magnetic Field Current Drive on FRC's (U of Washington)
Infrared Heat Loads in Tokamak Divertor (Alcator C-Mod, MIT)
Magnetic Reconnection (RSX at LANL, 4^{th} year LDRD)
Flowing Magnetized Plasma (FMP at LANL, new LDRD)

Funding: OFES $1923k, LDRD & Critical Skills $406k in FY03
+ one Reines Fellow from the Director
*+ one returnee from Management

T-15 Research Staff

- **Group Leader**
  - Alan Glasser
- **Technical Staff Members**
  - Rick Nebel
  - John Finn
  - Leaf Turner
  - Luis Chacon
  - Xianzhu Tang
  - Giovanni Lapenta
  - Michael Murillo
- **Postdocs**
  - Jerome Daligault
  - Dirk Gericke

FY 03 Funding Sources

- OFES
- OFES + Other
- Other

FY 03 OFES Funding of T-15

#	B&R	PC	Description	PI	$K
1	AT5020100	E70E	Toroidal Theory	Glasser	869
2	AT5015020	E898	IEC/INS	Nebel	274
3	AT5020200	E771	Alternate Concepts	Glasser	137
4	AT5015020	E902	RFP Initiative	Finn	121
	Total				1401

T-15 Research Projects:
Innovative Confinement Concepts

- **Reversed Field Pinch (RFP)**
  - **Self-Similar Modeling of Stable RFP Ramp-Down Phase**
    - Nebel
    - Simple numerical model, very fast computation, time-asymptotic limit of simulations, experimental interaction
  - **Numerical Simulation of Single and Multiple Helicity State of the RFP**
    - Nebel, Finn, Bathke (D-3)
    - Numerical simulation with DEBS and NIMROD, statistical analysis. Relaxation to single-helicity states.
  - **Semi-analytical Modeling of RFP Turbulence and Transport**
    - Turner and Glasser
    - Use linear MHD eigenfunctions to reduce nonlinear description to quadratic ODEs.
- **Field Reversed Configuration (FRC)**
  - **FRC Orbits with Rotating Magnetic Field**
    - Glasser, Cohen and Landsman (PPPL)
    - Single-particle motion, Hill vortex, fast and accurate, advanced graphics, nonlinear dynamics.
  - **3D Implicit PIC Code (Proposed)**
    - Lapenta, Delzanno, Brackbill (T-3)
    - Very fast. Magnetic reconnection. Requires conversion from Cartesian to cylindrical for fusion.
- **Inertial Electrostatic Confinement/Intense Neutron Source (IEC/INS)**
  - Nebel, Park (P-24)
  - Experiment + theory, inertial electrostatic confinement, possibly power. Separate presentation.

T-15 Research Projects:
Other Magnetic Fusion Topics

- **SEL Macroscopic Simulation Code**
  - Glasser, Tang
  - Spectral elements, adaptive grid, implicit time step, matrix-free Newton-Krylov, massively parallel.
- **Physics-Based Preconditioning of Newton-Krylov Methods**
  - Chacon, Finn, Knoll (T-3)
  - Simple 2D geometry, resistive and Hall magnetic reconnection. Highly efficient.
- **Coaxial Helicity Injection (CHI) Modeling (NSTX Funding Requested)**
  - Tang
  - 3D implicit, parallel code + Grad-Shafranov equation for open field lines. NSTX.
- **DCON Fast Toroidal MHD Stability Code**
  - Glasser
  - Axisymmetric, fast and accurate. Resistive and neoclassical under development. Widely used. Feedback.
- **Nonlinear Statistical Time Series Analysis of ELMs**
  - Finn, Tracy (William & Mary)
  - Modern statistical methods, identification and comparison of hidden patterns in theory and simulation; control.

Reduced & Slowed Theory Efforts if a 10% Decrease

Additional T-15 Theory Effort For 10% Increase

- **Field Reversed Configuration (FRC)**
  - **3D Implicit PIC Code (Proposed)**
    - Lapenta, Delzanno, Brackbill (T-3)
    - Very fast. Magnetic reconnection. Requires conversion from Cartesian to cylindrical for FRC applications.

- **Coaxial Helicity Injection (CHI) Modeling**

(New project: NSTX Collaboration funding has been Requested)

- Tang
- 3D implicit, parallel code + Grad-Shafranov equation for open field lines. NSTX.

Note: Dan Barnes, X-1 plasma theorist, is retiring in May 2003, and Lapenta will be continuing some related FRC theory efforts

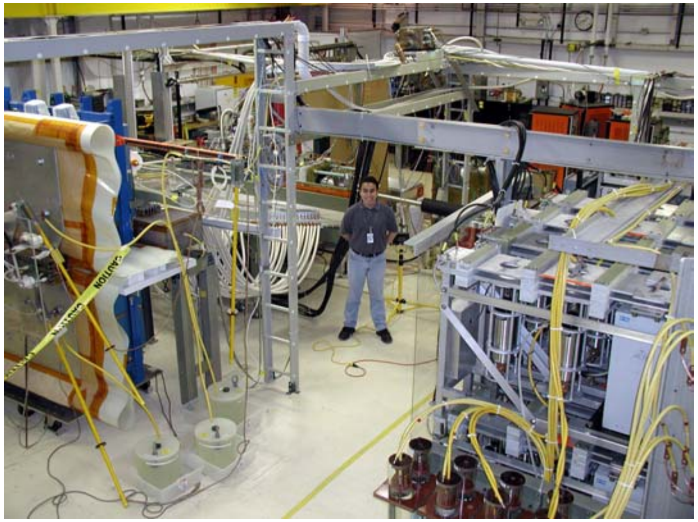
Fusion Technology

IFE TARGET FABRICATION (Art Nobile, ongoing, $310k/year):

The IFE target fabrication team resides in the MST-7 Polymers and Coatings Group. The team consists of three staff (Art Nobile, James Maxwell and Jennifer Young) two postdocs (Kimberly DeFriend and Loren Espada) and two part time technicians (Bernie Cameron and Larry Rodriguez). The team also utilizes the expertise of many personnel in MST-7 who perform target fabrication work directed at near term ICF experiments and development of targets for achieving ignition on NIF.

FUSION FUEL PROCESSING (Scott Willms, new proposal, $500k/year starting in FY04):

- Collaboration with JET on fusion fuel processing topics including water detritiation system design, modeling of AGHS (Active Gas Handling System) isotope separation system data, gas detritiation system operation and development, JET tile tritium deposition modeling, and help with JET concrete characterization and detritiation.
- Contribute to fusion fuel processing needs of the ITER project, as necessary. Only limited development work will be required, but technical input will be essential to the successful construction of the tritium plant. TSTA processing rates were considerably larger than any of the world's other fusion fuel processing experiments and TSTA was the only integrated experiment. ITER will be a considerable extension beyond TSTA (10x in processing rate, 10x in tritium inventory and 10x shorter tritium recycle time). Successfully meeting this challenge will require contributions from the TSTA knowledge base.
- General support for US fusion fuel processing related activities. Examples of such work include participation in the 7th International Conference on Tritium Science and Technology, ITER-relevant cryopump testing, tritiated materials characterization, tritium surface monitor development, APEX/ALPS support, membrane reactor development, fusion committee service and other fusion meeting attendance.



Project/Concept Description: **Magnetized Target Fusion. Develop a suitable plasma injector using a high density FRC**

PI: Tom Intrator, Glen Wurden

Thrust area: Configuration Optimization

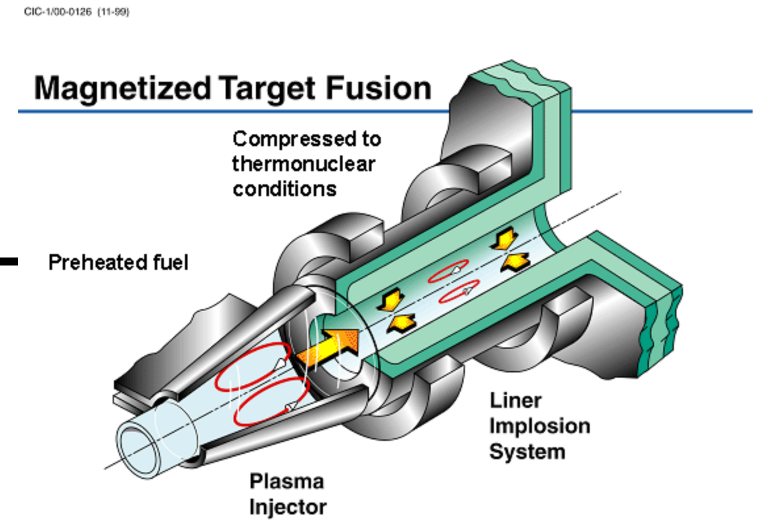
IPPA Goal: 3.2.4.4 Resolve key issues of target formation, translation, and physics for MTF

To make the first physics demonstration of MTF by imploding a field reversed configuration plasma with a metal liner.

Next Review: May 2003

	Base Program					**Impacts**	
FY	**Budget (Guidance)**	**FTE (Staff)**	**FTE (Tech)**	**Students**	**Milestones /Tasks**	**+x%**	**- 10%**
03	1399k	3	2	2.5Postdoc, 6 UGS, 2 GRA	Characterize in-situ FRC. Obtain TS data. Raise fields to increase performance.	+10% keep experiment operating for full FY03. Add Pre-PI	**This year is ½ over. Stop activity in last 2 months of FY03**
04	1385k	2.8 5	1.8 3	2 Postdocs, 6 UGS, 2 GRA	Build "fake liner" for translation experiment. Translate and diagnose FRC in liner at LANL.	+70% (ie, $1M) Start integrated design. Expand theory support. Add university collabs.	**Limp along**
05	1399k	2.7 4	1.7 3	2 Postdocs, 4 UGS, 2 GRA	Fix ringing decompression by adding more crowbar switches. Continue FRC parameter scans and initiate design of integrated experiment.	+70%(ie, $1M) Construct integrated plasma/liner exp. Model implosions	**Give up in disgust.** **Do something else.**

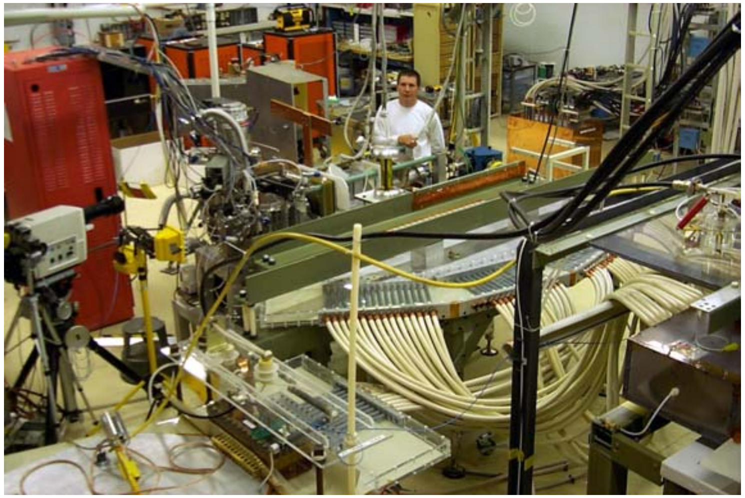
Magnetized Target Fusion:

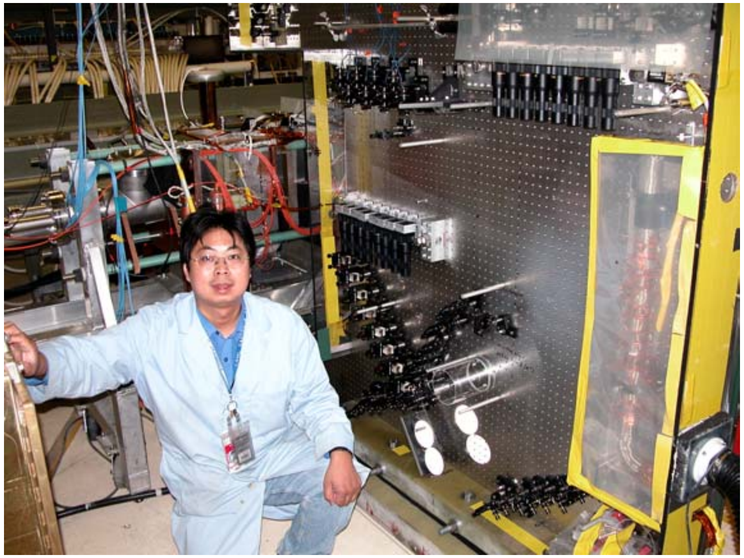


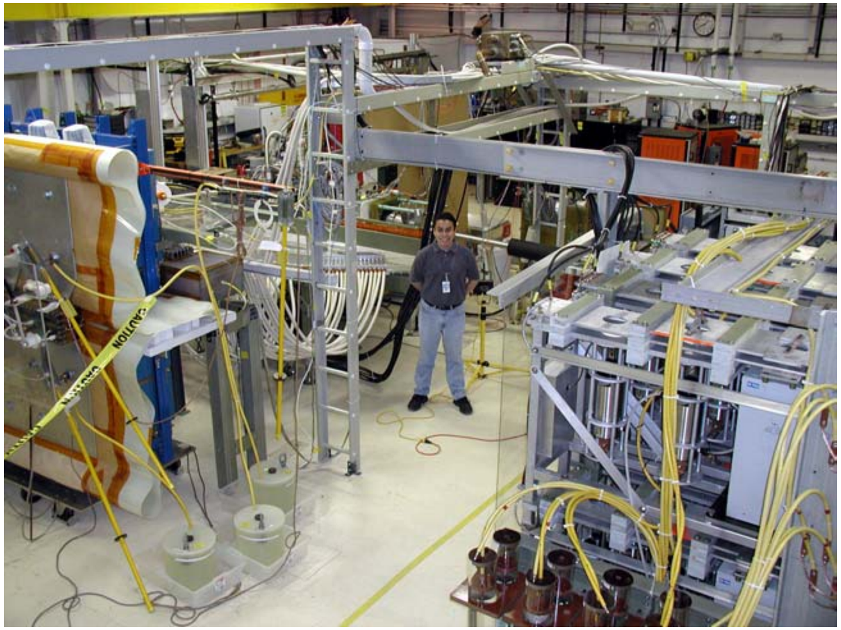
Imagine a fusion concept where:

- The plasma beta ranges from 0.8 to 1
- The heart of the device fits on a modest table-top
- The plasma density is high ~10^{19} cm^{-3}
- The current density can be 1000 MA/m^2
- The magnetic field confining the plasma is 500 Tesla !
- The auxiliary heating power level is ~ 1000 Gigawatts !
- The heating is "slow" adiabatic compression
- Most of the initial physics research can be conducted with existing facilities and technology
- In a reactor, on each pulse the liquid first wall would be fresh
- The repetition rate is ~0.1 Hertz, so that there is time to clear the chamber from the previous event

FRX-L: The Field Reversed Configuration (FRC) Plasma Injector for MTF





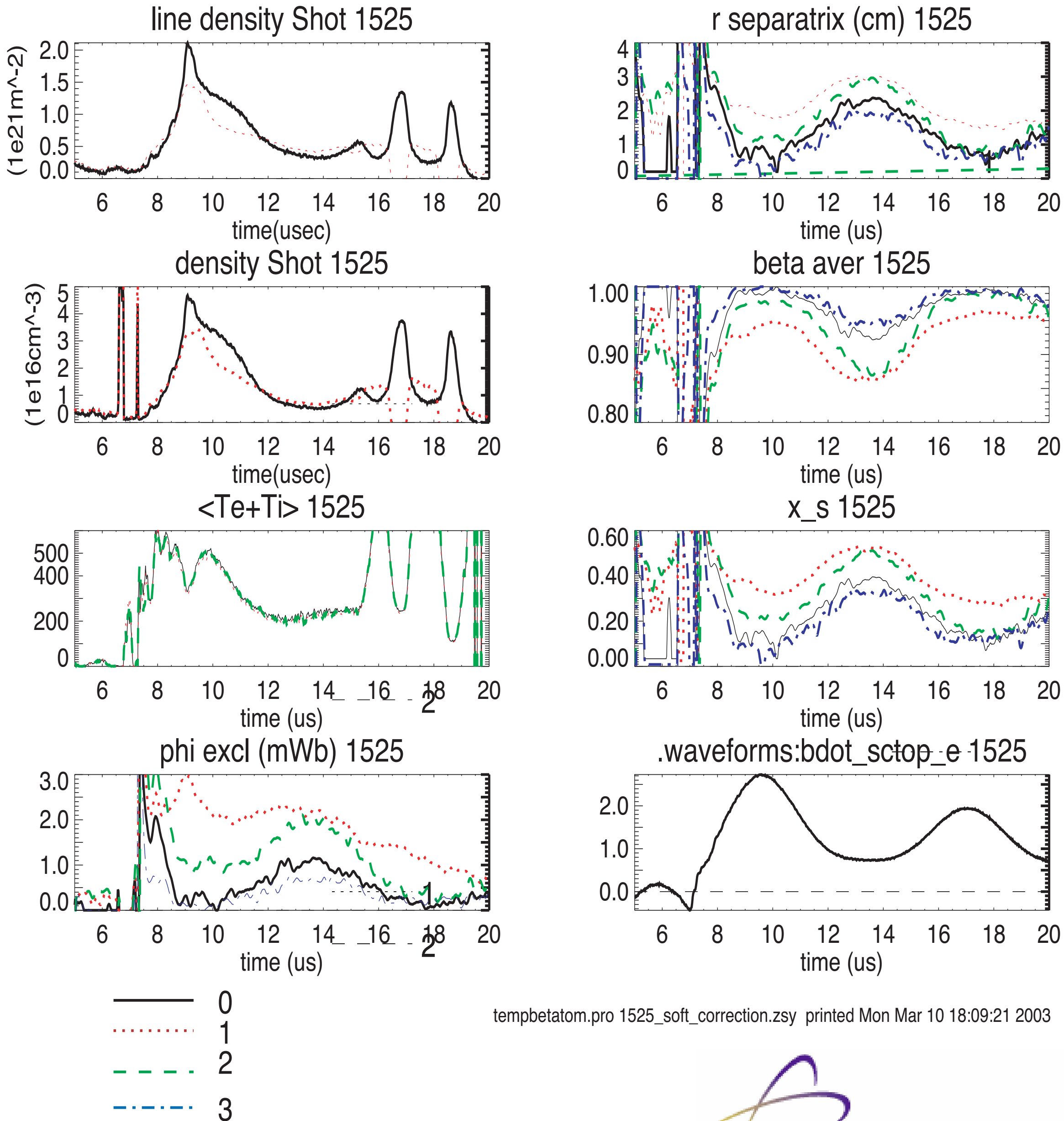


NNSA

Los Alamos

FRX-L FRC plasma data

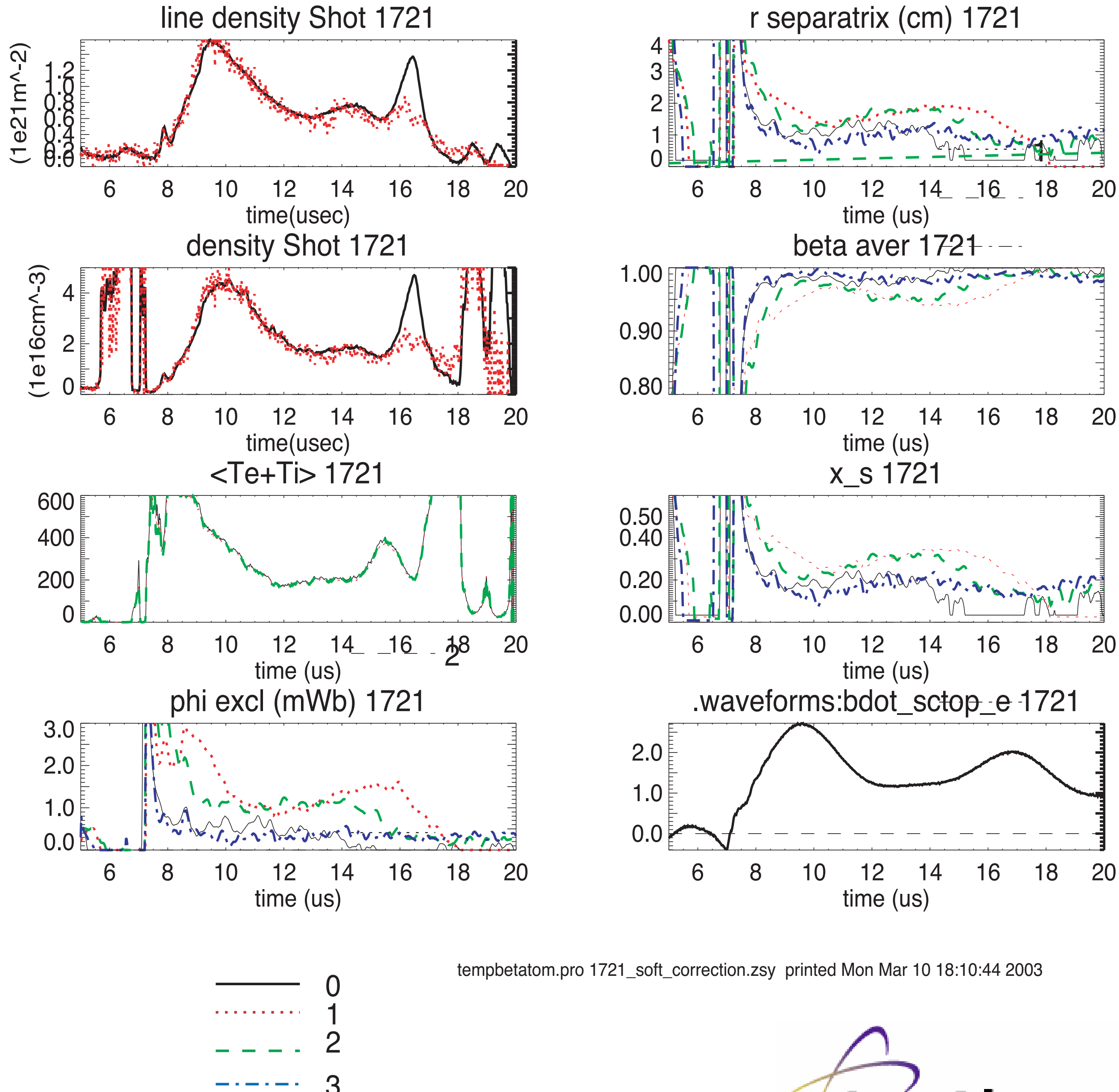
FRX-L makes high density, hot FRC plasmas, which decay a little more quickly (by a factor of 2)* than we want for MTF. However, as we increase the magnetic field parameters, and decrease the main-bank crowbar ringing, we expect the lifetime to improve.
(*Last week, we have doubled the lifetime!)



FRX-L FRC plasma data

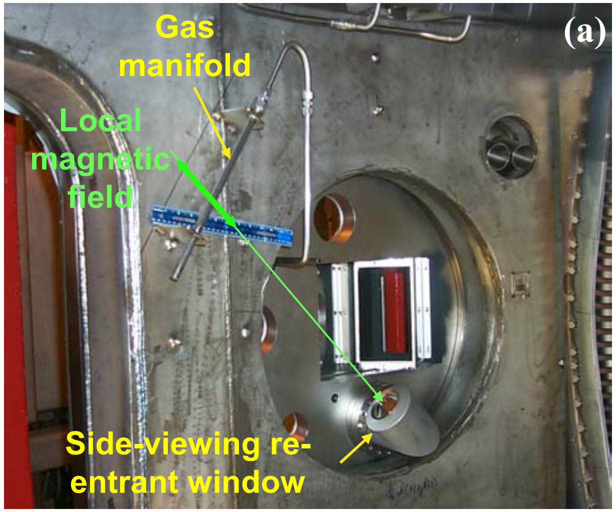
The FRC plasma is much smaller than the 5 cm quartz tube inner radius.

Diagnostics include an 8-chord interferometer, magnetics probes, visible spectroscopy, two optical tomography side-on arrays, and an (almost) operational multi-point Thomson scattering system.



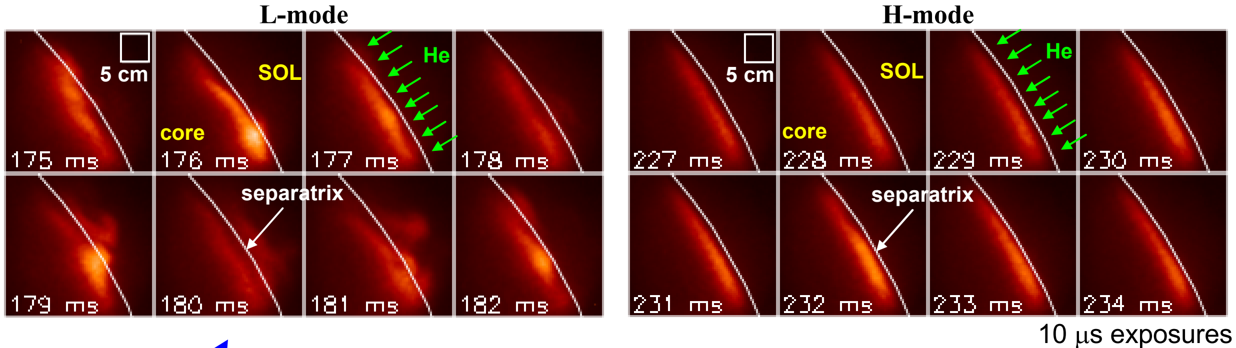
NSTX Collaboration:

Gas Puff Imaging diagnostic & Edge turbulence



PI: Ricky Maqueda

Review upcoming in FY03



National Spherical Torus Experiment In-vessel hardware

Turbulence levels and structures are reduced in H-mode compared with L-mode

Fast framing cameras used to image visible emission from the edge (HeI 587.6 nm):
Phantom v.4: from 512x512 pixels at 1000 fps to 128x32 pixels at 32000 fps
PSI-4: 61x181 pixels at up to 1000000 fps, but only 28 frames!

Plasma "blobs" can be followed in time (~10^5 cm/s)

Invited talk and paper at the Madison High Temperature Plasma Diagnostics Conference in 2002

Periodically Oscillating Plasma Sphere

Project/Concept Description: POPS is an Oscillating Non-neutral Thermal Plasma in an Electrostatic Trap

PIs: Richard Nebel, Jaeyoung Park

Objective of currently funded project: Demonstrate the Scientific Viability of the POPS Concept, Including Stability of the Virtual Cathode, Cathode Uniformity, and Phase Locking of the Plasma Oscillations

Status: Machine has been built and is producing data

Next Review: May 2003

	Base Program					Impacts	
FY	**Budget (Guidance)**	**FTE (Staff)**	**FTE (Tech)**	**Student**	**Milestones /Tasks**	**+ 20 %**	**- 10%**
03	$274k	.9	0	1	Cathode Stability	-------------------	-------------
04	$274k	.8	0	1	Demonstrate POPS	Kinetic Stability	Delay POPS
05	$274k	.8	0	1	Cathode Uniformity	High Voltage	Delay Uniformity

Project/Concept Description: LANL/UW Field Reversed Configuration RMF Collaboration

PI: Glen Wurden

Thrust area: Concept Optimization and Fundamental Understanding

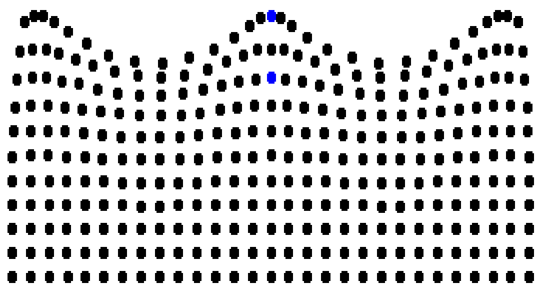
IPPA Goal: Basic physics of FRC formation with rotating magnetic field current drive

LANL is building a 20-channel bolometer system to enable detailed radiation power balance measurements on the new TCS experiment at the Redmond Plasma Physics lab, supporting Thomson scattering design work, and provides engineering support for the LANL RMF power system.

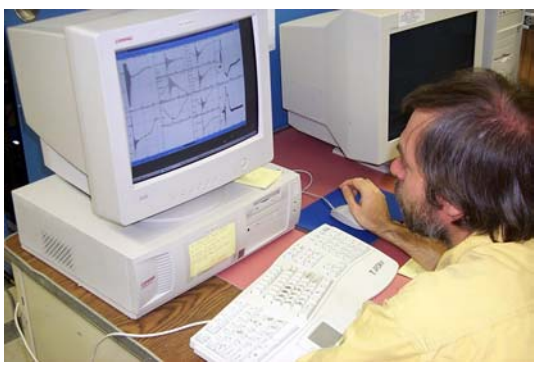
Prior Review: April 2002

	Base Program					Impacts	
FY	**Budget (Guidance)**	**FTE (Staff)**	**FTE (Tech)**	**Students**	**Milestones /Tasks**	**+ x %**	**- 10%**
03	178k	.20	.20	1 UGS	Test 3-channel prototype bolos	0%	Year is ½ over. Slow down pace
04	178k	.20	.20	1 UGS	Build, install, operate 20-channel bolos	+10% buy VME bus digitizers	Slow down pace
05	178k	.20	.20	1 UGS	Conduct radiation balance physics studies in RMF plasmas	+10% install second 20-channel view	Slow down pace

Around the Lab



©1999, Daniel A. Russell



Student Programs

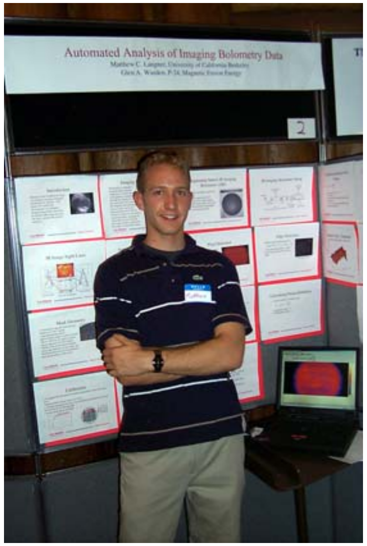
- **Three postdocs work in the MFE Team.** Shouyin Zhang from the HT-7 tokamak in China; Dr. Ivo Furno (from the TCV Tokamak in Switzerland) on RSX (reconnection experiment) and FRX-L; and Dr. Scott Hsu (Reines Fellow at LANL to work on radiation balance in FRX-L, previously at CalTech and PPPL, and an APS Excellence in Plasmas award winner). Tom Intrator recently received an "Outstanding Mentoring" award at the lab, and our team has received a special award from the MIT "UPOP" summer student program. Cameron Bass was quoted in the MIT newspaper as saying "*This summer I was able to have one of those incredible experiences that makes me so excited about a new field of work that I am forced to reconsider every decision I thought I had made about the direction of my life*". He is coming back to work with us again in June 2003. Two MFE team posters won awards for the best physics and engineering displays at the 2003 LANL summer student poster session.

- **MTF and RSX are successful attractors of students from throughout the United States**. We also have a $120k/year "Critical Skills" initiative, supported by DOE to assist our OFES student program. In FY03, FRX-L students are:

  Eric Trask (UCIrvine), Erick Tejero (MIT), David Phillips (Dartmouth), Robert Aragonez (NNM), Richard Renneke (Purdue), Cameron Bass (MIT & Oxford), Erik Hemsing (UNM), Matthew Leonard (UT-Austin, McDermott Scholar), Michelle Pelzer (NASA), Chris Carey (Ohio State, NUF), Sean DeVries (UNM), Rafael Martinez (Michigan), Mike Kozar (Clarkston, NUF), Margaret Harris (Duke, LASS), Dennis Wei (MIT, Canadian Isaac Newton physics winner, Math Olympiad winner), Bill Feinup (MIT, also a possible NUF student in 03), and Richard Kowalczyk (Michigan, DOE Fusion Tech Fellow). We are only constrained by budget (and stamina) as to the number of students who want explicitly to work on MTF. Additionally, we expect two new NUF summer students in 2003.

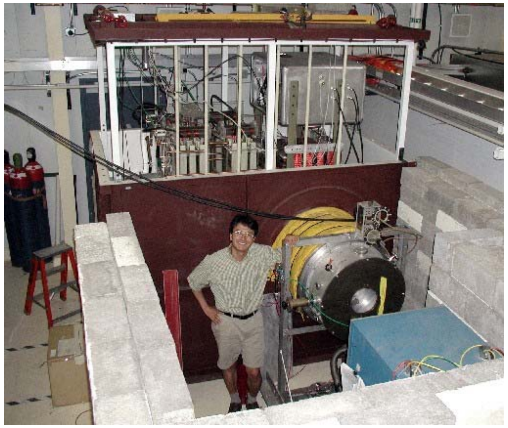
- **Previous students include:** Matthew Langner (UC Berkeley),Phil Assmus (Rhodes Scholar), Kathy Scott (CalTech), Matthew Fisher (North Carolina State), Michelle Cash (NASA), Brooke Lasley (Virginia, NUF), Joanna Liang (MIT), Jesse Hwang (Yale, NUF), Chris Deards (UWashington), Alex Glocer and Jessica Lamb (Dartmouth),Kyle Campbell (NM Tech and UCSD), Emma Torbert (Princeton), Kit Werley (Stanford), Matt Fisher, Laure Vermare (France).

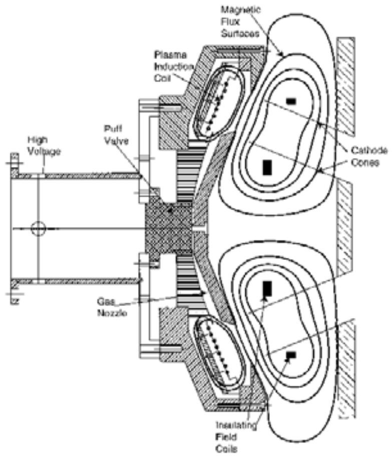
Students in the P-24 Plasma Physics MFE Team



(NEW for FY05) OFES Proposal:
Intense Diagnostic Neutral Beam For Burning Plasmas (ITER)

Pulsed Ion Source - Magnetically Insulated Diode





Proposal Objective:

- FESAC panel on "A Burning Plasma Program Strategy to Advance Fusion Energy": 2nd highest priority " to develop enabling technology that supports the burning plasma research and positions the US to more effectively pursue burning plasma research"
- The highest priority for US contributions to the ITER project: "baseline diagnostics, plasma control, remote research tools, etc."
- Diagnostic neutral beam (IDNB): Critical baseline diagnostics for CHERS and MSE - ion temperature profile, impurity and helium ash measurements, fast alpha distribution., and q profile.
- Intense (~ 50 A/cm^2), pulsed beam: better S/N and cost efficient.
- LANL has hardware, history & expertise (since 90s) and personnel for pulsed IDNB source R&D.

Proposed Technical Approach:

- Intense ion beam source: magnetically insulated diode (MID) with anode plasma for clean, intense (~ 50 A/cm^2) neutral beam
- Repetitive pulse operation: short pulses (1-2 µs) with high rep-rate (~ 30 Hz) to improve S/N ratio with low cost.
- Optimal beam energy of 125 keV/amu for CHERS and MSE.
- Low beam divergence: 1° divergence with modified electrodes and additional electric quadrupole beam shaping.

Task 1: Characterization and optimization of MID

- Operation MID facility (CHAMP) at LANL
- High beam extraction (50-100 times Child-Langmuir limit)
- Modeling of MID (two-fluid and PIC simulation).

Task 2: Deployment of prototype diagnostic beam

- Parallel beam extraction with electrode modification.
- Efficient neutralization and high rep-rate
- Deployment ready at major fusion facility in 4 years

Expected Cost and Schedule:

Task 1: 24 month effort headed up by LANL - P24 (outside collaboration and modeling) ~$1.4 M/yr

Task 2: 24 month effort headed up by LANL - P24 (collaboration with major fusion facility) ~ $1.4M/yr

Total: $5.6 M over 48 months

Deliverables:

Task 1&2: Technical reports on bulleted items and a numerical design tool for IDNB MID.

Task 2: Prototype intense diagnostic neutral beam for deployment.

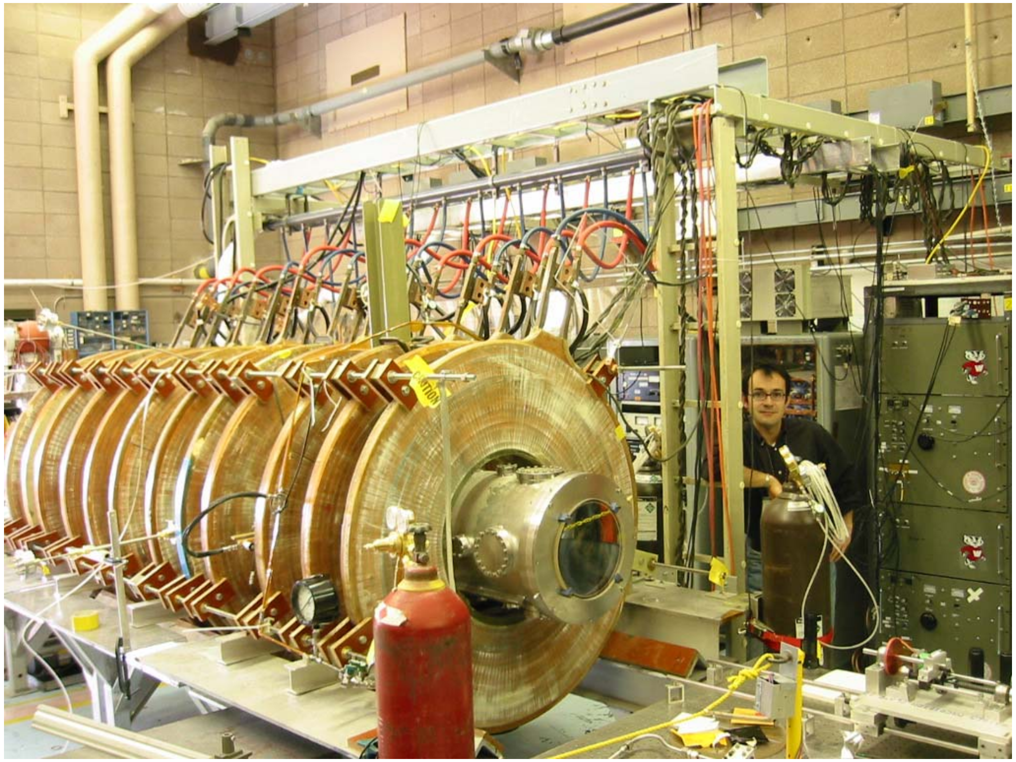
Contact Information:

Dr. Jaeyoung Park, Dr. Glen Wurden, Dr. Doug Post
Plasma Physics Group (P-24), MS E-526
Los Alamos National Laboratory, Los Alamos, NM 87545
Tel) 505-667-8013, e-mail) jypark@lanl.gov and wurden@lanl.gov

Reconnection Scaling Experiment (RSX):

Studying collisionless magnetic reconnection for basic plasma & astrophysics understanding

FWP (now) & will be a new proposal to OFES



Reconnection Scaling Experiment: a new device for three dimensional magnetic reconnection studies. I. Furno, T. Intrator et al. to appear in Review of Scientific Instruments Vol. 4 2003

Magnetic reconnection in the Reconnection Scaling Experiment: Magnetic and visible emission data. T. Intrator, I. Furno, et al., submitted to Physics of Plasmas (March 2003)

A plasma-shielded, miniature Rogowski probe,
E. Torbert, T. Intrator, I. Furno, to be submitted to RSI (student first author paper)

Reconnection Scaling Experiment at LANL: a new device for investigating magnetic reconnection in plasmas. I. Furno, T. Intrator invited talk at 7th Easter Plasma Meeting on OPEN ISSUES IN MAGNETICALLY CONFINED PLASMAS, Turin Italy, 3-5 April 2002

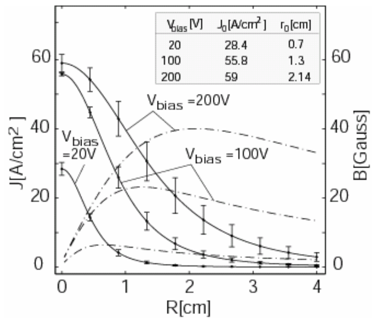
RSX, Reconnection Scaling Experiment
T. Intrator, I. Furno, et al. 43rd Annual Meeting of the APS Division of Plasma Physics, October 23-27, 2001, Long Beach, California

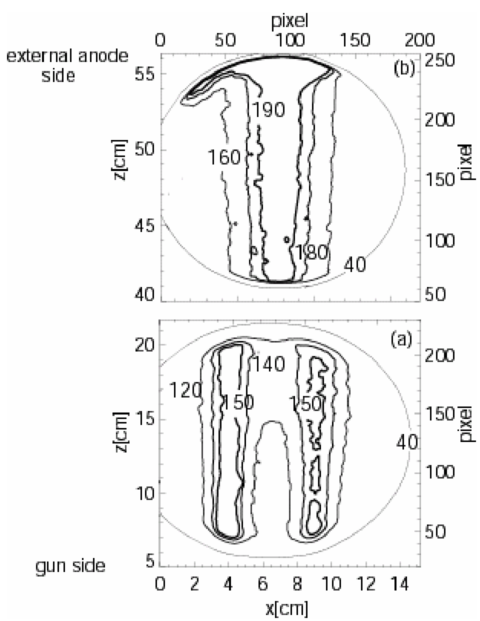
Overview of the Reconnection Scaling Experiment at LANL and first experimental results. I. Furno, T. Intrator , et al.
44th Annual Meeting of the APS Division of Plasma Physics, November 11-15, 2002, Orlando, Florida

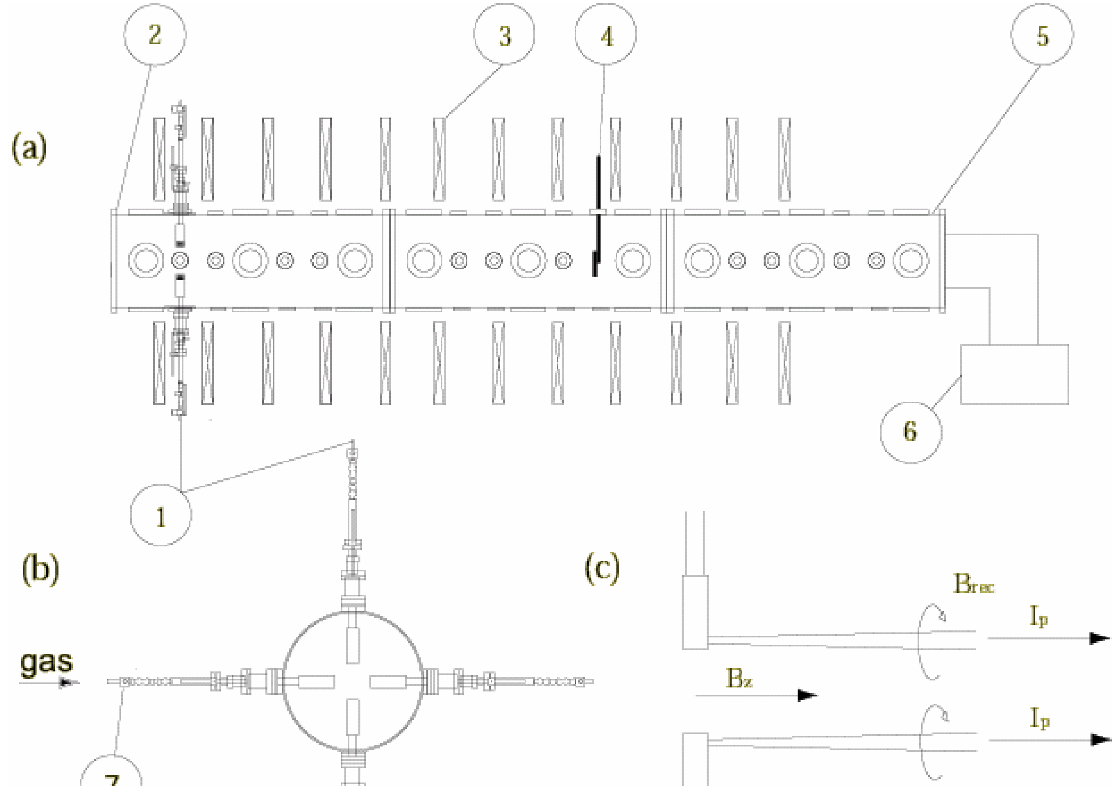
Inverse Problems and multivariate analysis in plasma physics, I. Furno Los Alamos National Laboratory, T-15 seminar series, February 25, 2003, Los Alamos, New Mexico

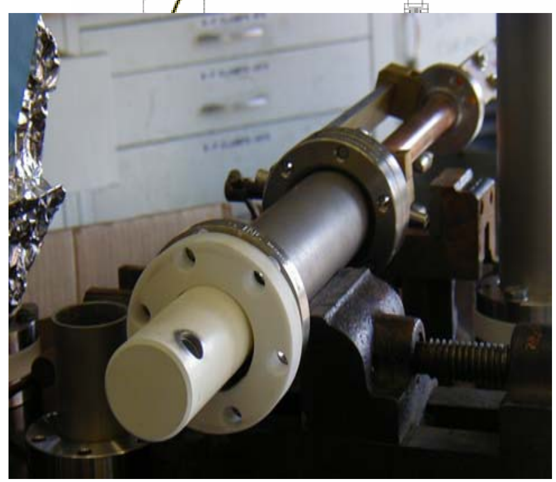
NNSA Los Alamos

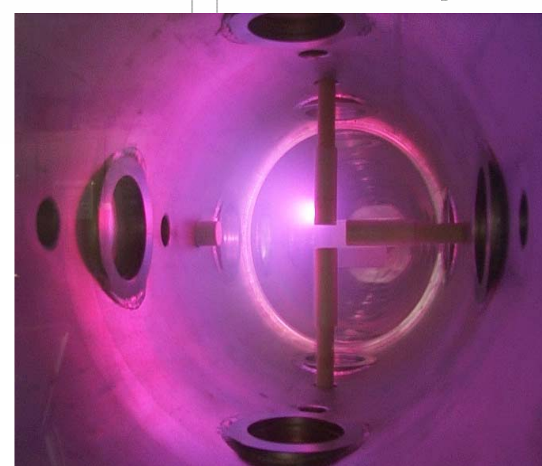
Some RSX Results











Summary

- LANL OFES funding would decrease by 48% in the FY04 President's Budget, compared to FY03.
- LANL has multiple new proposals for FY04 and FY05, ranging from basic plasma science, to plasma theory, to ITER diagnostic R&D and ITER relevant plasma technologies.
- LANL wants to begin the integrated plasma/liner MTF physics CE demonstration, which will require an ICC budget increase.
- All of these proposed increases would still result in a lower LANL OFES budget in FY05, than existed in any prior budget year (back a long ways!).