NSTX

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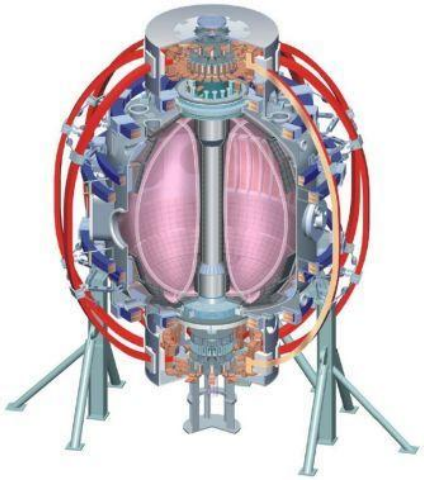
NSTX research collaboration opportunities - part 2

J. Menard, M. Ono

Thanks to all contributors of facility information/plans

B318 - PPPL
October 19, 2011

Columbia U
CompX
General Atomics
FIU
INL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
ORNL
PPPL
Princeton U
Purdue U
SNL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Illinois
U Maryland
U Rochester
U Washington
U Wisconsin



Culham Sci Ctr
U St. Andrews
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
U Tokyo
JAEA
Hebrew U
Ioffe Inst
RRC Kurchatov Inst
TRINITI
NFRI
KAIST
POSTECH
ASIPP
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep

Overview

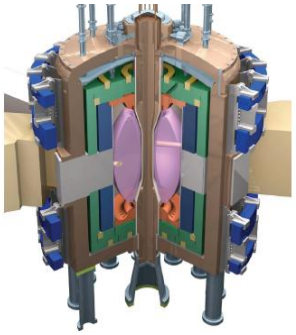
- This is the 2nd collaboration meeting
- First meeting focused on:
  - Collaboration goals and strategy
  - Overview of opportunities on large facilities
- This meeting will focus on:
  - STs, off-site university and smaller-scale experiments
  - PPPL internal/on-site opportunities
  - Targeted DIII-D collaboration opportunities

Outline

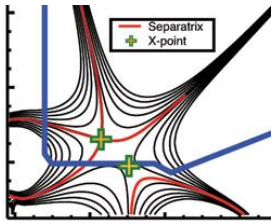
- Reminder RE collaboration goals (NSTX-U)
  - Aim for first author publication from collaborations
  - Maintain scientific productivity of NSTX/PPPL research program. Target: Nature, PRL, NF, PoP, …
- Collaboration opportunities:
  - Japanese STs
  - LTX
  - Off-site Research
  - MST
  - PPPL opportunities
  - ITER diagnostics
  - DIII-D (M. Wade)

Collaboration should aim to support NSTX-Upgrade mission elements

- Advance ST as candidate for Fusion Nuclear Science Facility (FNSF)
  - Advance non-inductive start-up, sustainment
  - Develop predictive capability for confinement, high-beta stability, and control
- Develop solutions for PMI
  - Inform NSTX-U/FNSF decisions on divertor configurations, high-Z PFCs, Li, cryo-pumping
- Advance toroidal confinement physics for ITER and beyond
  - Utilize waves/HHFW, energetic particle, 3D physics expertise in support of ITER, beyond
- Develop ST as fusion energy system
  - Integration + performance extension of above

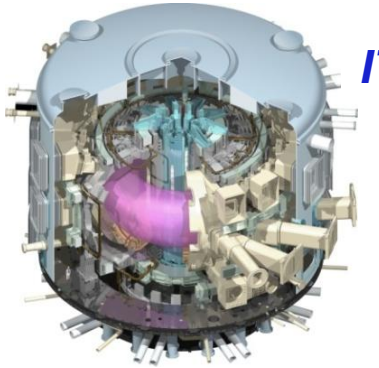


ST-FNSF

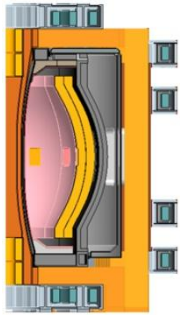


"Snowflake"

Lithium



ITER



ST Pilot Plant

Collaboration opportunities

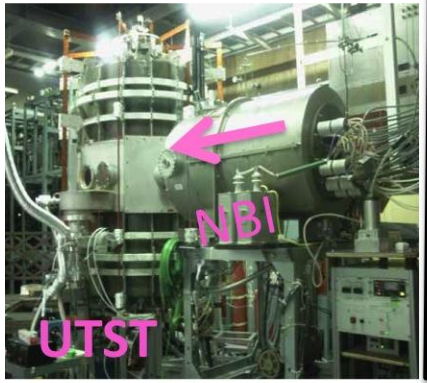
Collaboration opportunities on TST-2

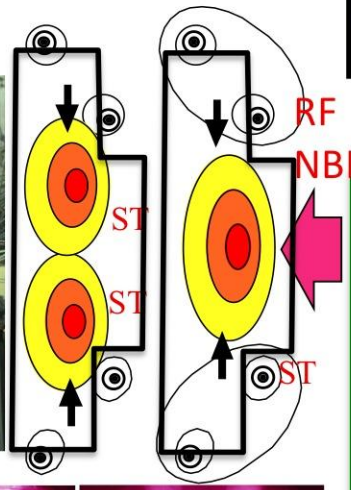
東京大学 THE UNIVERSITY OF TOKYO

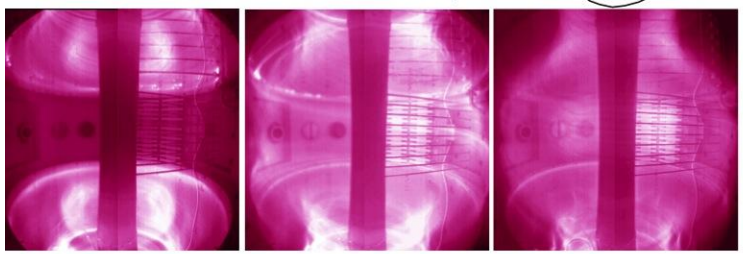
- Typical parameters and capabilities of TST-2
  - R = 0.38 m, a = 0.25 m, B_t = 0.3 T, I_p = 100 kA (up to 15 kA by RF only)
  - 400 kW @ 21 MHz, 400 kW @ 200 MHz, 5 kW @ 2.45 GHz, 10 kW @ 8.2 GHz
- Research focus
  - Solenoidless I_p start-up and ramp-up
  - Wave physics (EC/LH/IC)
  - Turbulence imaging
- Near-term upgrades
  - Improved LHCD antennas
    - Dielectric-loaded waveguide array
    - Traveling-wave slow wave antenna (collaboration with C. Moeller @ GA)
- Possible areas of collaboration
  - Any of the above
  - Collaborations on advanced diagnostics, modeling welcome
- May be possible to arrange a Visiting Professor appointment
  - Duration: 1 month min. 12 months max. (typically 3-6 months)
- Contact: Y. Takase (takase@k.u-tokyo.ac.jp) or M. Ono

US-J Joint Center for Magnetic Self-Organization in Laboratory and Astrophysical Plasmas (CMSO)

1) International COE of Magnetic Reconnection/ Self-Orga -nization and its Kinetic Extension with Beam Dynamics
2) Collaboration of US NSF and Japan JSPS COE Projects
3) Interdisciplinary COE among Lab., Observation, Theory
4) Reconnection Heating/Startup by Double-Null Merging
5) Borderless Exchange of Scientists







COE: US-J Center (CMSO)

US

US-NSF COE Project
US-CMSO
Director: E. Zweibel
Co-director: H. Ji

Core : Princeton Univrsity
Wisconsin University

Japan

ISAS
Observation Solar, Magnetosphere

NAOJ
Solar Observation "HINODE"

AIST etc.
NBI D Development

Chiba Univ.
Num. Simulation

Japan-JSPS Core-to-Core Project
J-CMSO Director: Y. Ono

Core: University of Tokyo
Reconnection Exp. with NBI

Europe

UK
Culham Lab.
Large-scale Exp. of Reconnection

Italy
Padova Lab.
Self-org. exp. with NBI

UTST (Univ. Tokyo) welcomes collaboration on magnetic reconnection or NBI

Collaboration opportunities with Univ. of Hyogo

Ongoing/potential research areas for collaboration

–Transient Coaxial Helicity Injection (CHI) Studies on HIST

Remarks from Collaborator R. Raman

- QUEST at Kyusyu Univ. will conduct a feasibility study of CHI for solenoid-free plasma start-up and transitioning to RF current sustainment.
- HIST is very well positioned to contribute to the QUEST CHI design study through supporting experimental studies. A preliminary experimental test on Oct 1, 2011 on HIST resulted in promising results.
- The collaboration activity on HIST will benefit both the CHI work on the NSTX-Upgrade and support the CHI design study for QUEST.
- This study on HIST would allow the many years of Transient CHI activity on HIT-II and NSTX to be integrated into the Japanese ST program, through a mutually productive and collaborative US-Japan effort.

– Compact toroid (CT) injection on QUEST

- Central fuelling by using the high performance CT injector
- Mitigation, Magnetic reconnection physics

– ELM-like pulse heat load test of W-divertor material for ITER by using the magnetized plasma gun

- High gun pulse heat flux of >2MJ/m^2 leading to melting of W
- Vapor plasma shielding effect, Droplet splashing from melted W

Medium-Term Targets of QUEST Project

AFRC Kyushu Univ.

07	08	09	10	11	12	13	14	15	
Const.	1st Plasma	**10kA 0.8s**	**ECCD/NC 10 kA limiter 37 s**	**ECCD/NC 20 kA divertor 20 s**	**ECCD/NC Several 10kA Divertor SSO**	**EBWCD-POP High density**	**EBWCD/ BS POP High Power**		**SSO Plasma**
		Phased antenna	**Phase control 30-100 kW**	**Phase control 60-200 kW**	**8.5 GHz 250 kW CW**	**28GHz 300kW 1sec**	**8-28 GHz combined POP exp 0.7MW**	**0.8 MW**	**Preparation**
		Flat div. SUS	**Flat div. W**	**Flat div. W**		**Div. Pump**		**Div. Leg Cont.**	**SSO PWI**
			DesignHot wall	**Design Hot wall**		**Install Hot wall**	**Power Supply**		**Preparation**

Collaboration Opportunities on QUEST

- **Potential research areas for collaboration**

- EBWCD start-up and long pulse operation

8.2GHz 400kW CW by phased array antenna at present

8.5GHz 250kW CW in 2012

28GHz 300kW 1 s in 2013

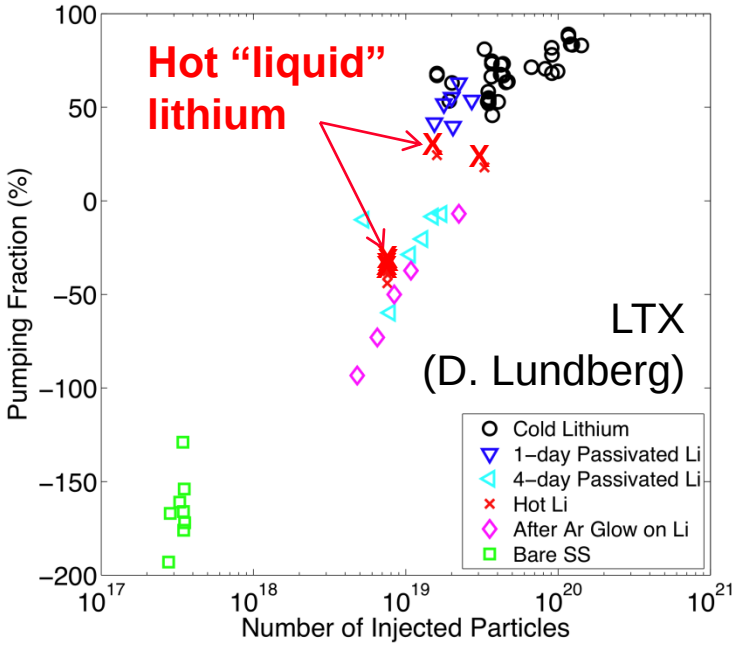
- Closed divertor

Plan to install an closed divertor after investigation and design activities

- Hot wall

Plan to install an hot wall of W in 2013

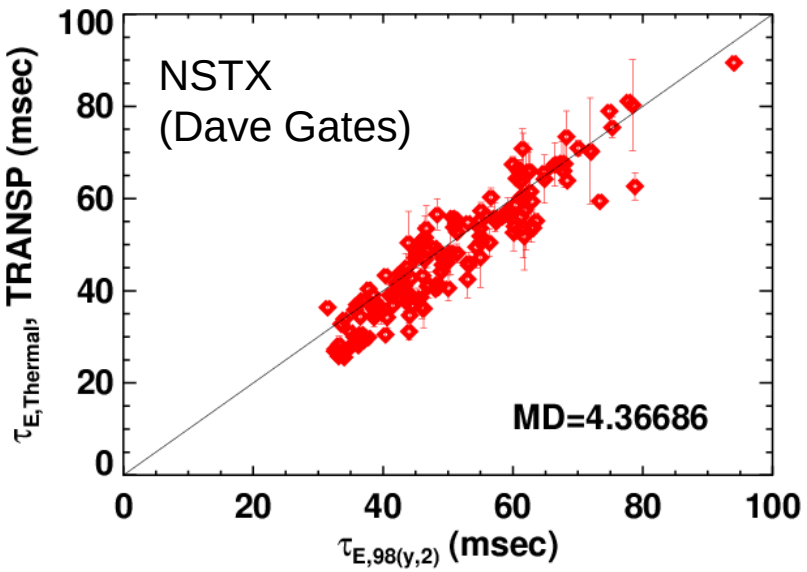
LTX collaboration opportunities: Optimizing a lithium wall

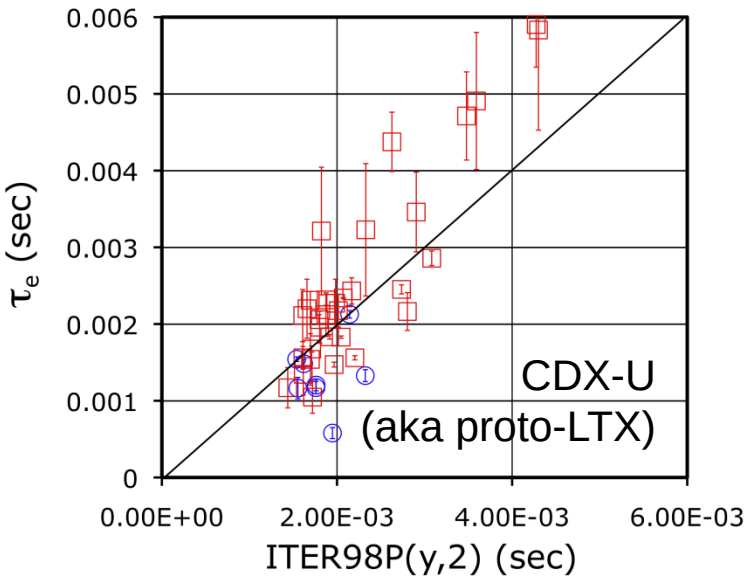


- First test of pumping with hot (300C) lithium wall coatings: modest, short-lived recycling reduction
- Upcoming experiments/additions:
  - More complete bakeout system (including vacuum vessel)
  - Vessel active cooling - hot shell operation
  - Lithium gettering system – prepump water
- Thick, localized lithium coatings
- Liquid lithium lower shell fill, with e-beam stirring, to follow this set of coating experiments

- Opportunities: Recycling measurements and modeling, PMI measurements and modeling, response of the edge plasma to low recycling, edge plasma studies (also with ORNL/Maingi)
- Develop approaches to liquid lithium systems in NSTX-U
- Develop diagnostics for lithium surface conditions
  - Small sample exposure probes. Large probe on the way. Large probe system includes a conflat interface to a double argon glovebox.
- Develop ways to maintain a clean liquid lithium surface in a tokamak

Another collaboration opportunity: Electron confinement with low recycling walls





- Both data sets are vs. ITER98P(y,2)
- But: CDX-U data relevant to electron confinement (Ohmic shots with $\tau_{i\text{-}e} >> \tau_E$)
- Real comparison would require NSTX Ohmic confinement data – opportunity?
- Electron confinement studies in LTX should be of interest to NSTX
  - Global electron confinement + static T_e profiles with Thomson
  - Could study transport with cold pulse – relevant for low recycling?
  - EBW heat pulse system proposed, not ARRA funded. ~100k.
- Other opportunities: plasma control systems (big payoff), high efficiency fueling studies (cluster injector, post-Dan), ORNL CHERs system
  - ➢ LTX neutral beam install, operation

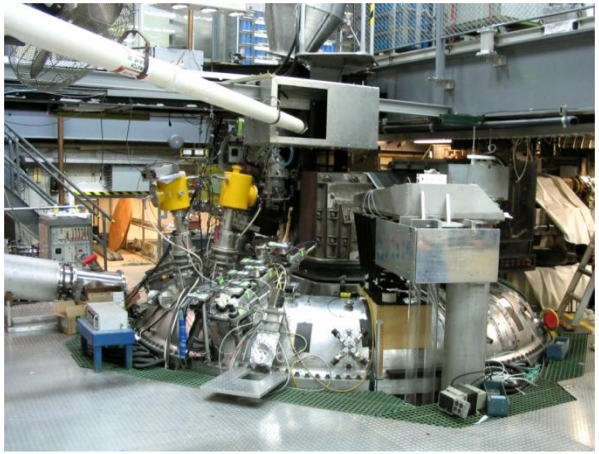
Off-Site University Research Program

- Program provides assistance to plasma science & technology programs at US Universities & Colleges.
- ~ 2 FTE of funding supports PPPL staff, with some modest equipment, to assist universities and colleges. Travel funds are used to closely engage the Universities & Colleges.
- Approximately 27 projects are assisted in areas of plasma science education, engineering support of experiments, theory & computational support, plasma diagnostics, & implementation of good safety practices. Student education is important.
- Recent emphasis on HBCU, HSI, & small undergraduate colleges.
- Approximately 15 – 20 papers are published per year.

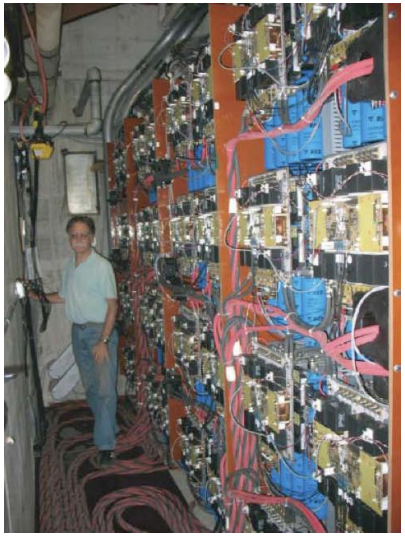
University Support Projects FY 2010

University	U. Collaborator	PPPL Collaborator	Support Topic
Alaska	Otto	Johnson,Kim	Magnetopause transport
Augsburg	Engebretson	Johnson,Kim	Modeling satellite observations
Auburn	Lin	Johnson,Kim	Magnetopause simulations
Auburn	Hansen	Zolfaghari	Eddy current analysis of CTH
Berkeley	Bale, Mozer	Yamada, Ji	Space reconnection
Columbia	Maul	Raftopoulos	Metrology on HBT-EP
Columbia	Keyes	Lee	Computational plasma physics
George Washington	Keidar	Raitses	Nanotube creation in arcs
Howard	Mosleh	Ellis	High vacuum reduced friction parts
Iowa	Daughton	Ji, Yamada	Global reconnection
UC Irvine	Lin	Hahm	Zonal flow theory
UC San Diego	Hinton	Wang	Coulomb collisions with unlike ions
Lehigh	Kritz	Budny	Improving PTRANSP
Maryland	Drake	Yamada	2D structure of reconnection
MIT	Egedal	Ji, Yamada	VTF reconnection
New Hampshire	Lessard	Johnson, Kim	ULF waves from Cluster satellite
Prairie View	Huang	Brunkhorst	Rotamak RF instrumentation
Rochester	Blackman	Ji	Laser produced collisionless shocks
San Marcos	Burin	Zweben	Plasma ball experiment
Texas Austin	Shvets	Kaganovich	Weibel instability theory
Texas A&M	Staack	Raitses	Plasma in liquids
West Virginia	Demidov	Kaganovich	Non-equil. low pressure plasma
Washington	Ennis	Mansfield	Lithium shaker for coating PFCs

MST facility has great capabilities and a lot of run time



- Well-diagnosed plasmas
  - Equilibrium and fluctuations
  - Improved single-shot profiles
- Operates 6 days/week



New programmable BT supply

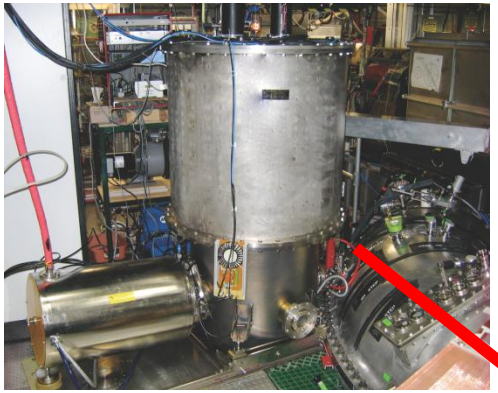
R = 1.5 m , a = 0.5 m

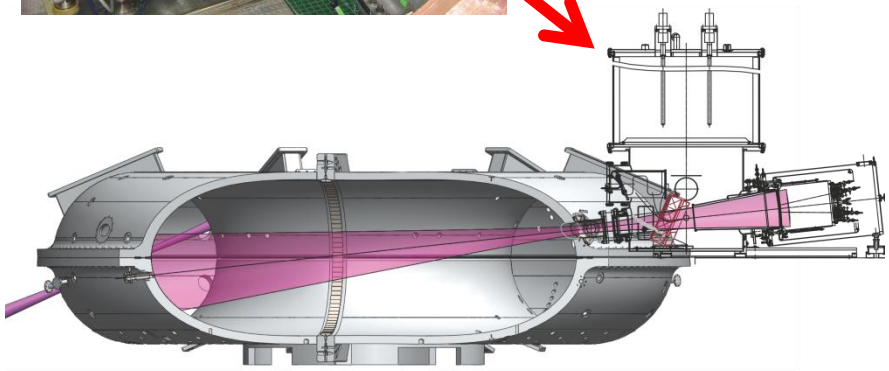
I_P < 0.55 MA τ_{pulse} < 0.12 s

B_P core flux = 2 Wb

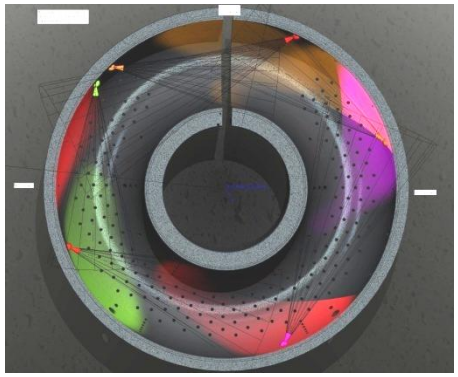
Applied B_T < 0.25 T

1 MW, tangential NBI



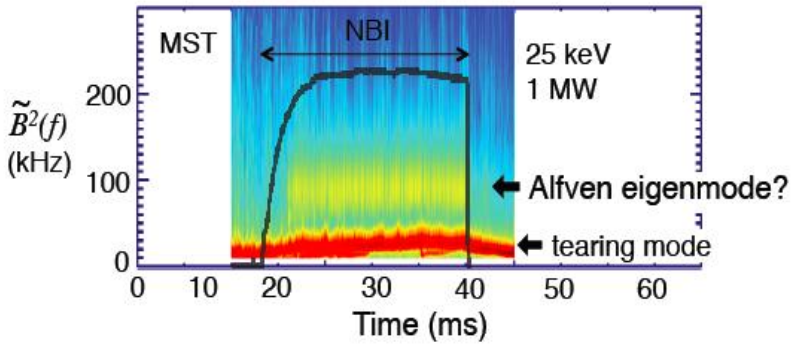


Ports for viewing surface added in 2010

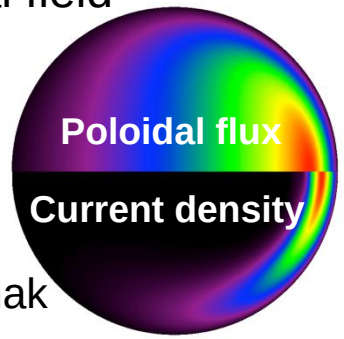


Some opportunities for collaboration with MST

- Neutral beam injection new capability on MST, 1 MW, 25 keV, 20 ms
  - Energetic particle / Alfven eigenmode seen, not understood
  - TRANSP modeling for the energetic ion profile, momentum input, etc
  - Neutral particle diagnostics in development
- 5.5 GHz electron Bernstein wave development
  - 1 MW, 10 ms supply near-ready
  - Improved modeling of wave coupling
  - Fokker-Planck (CQL3D) modeling
  - Improved measurement of electron distribution



- Better diagnosis/understanding/control of the plasma-boundary interface
  - Viewing ports for most of inner surface added in 2010
  - Developing boronization delivered in pulse-discharge plasmas
  - Modeling and field error correction for possible manhole
- Integrated control for new IGBT-based power supply for the toroidal field
  - Multipurpose: advanced inductive control, OFCD, higher BT, …
  - Assessing GA PCS interface
  - Opportunity for unique tokamak physics with close-fitting shell, e.g.,
    - Measure dynamo effects from tearing modes
    - High beta equilibrium stabilized by thick shell?

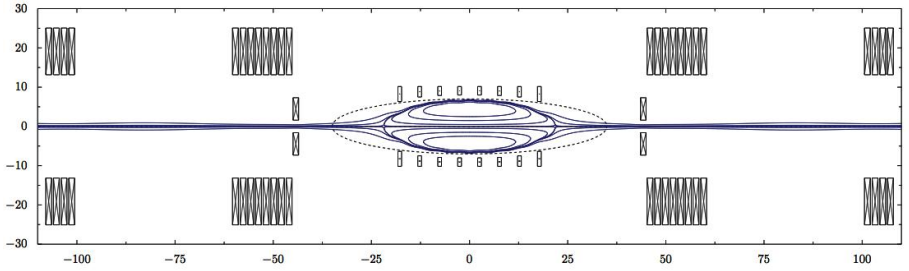


β ~1 tokamak

Opportunities in MRX/MRI/etc

- MRX
  - Diagnostics to measure T_i, T_e and n_e profiles. spectroscopy, Thomson scattering, other imaging techniques?
  - Broader reconnection research topics related to tokamak or general confinement physics
- MRX-U planning and physics design activities
- MRI
  - Diagnostic development: torque measurements, internal current measurements etc.
  - Data analyses: B-dot array data analyses, turbulence imaging analyses etc.
- LMX
  - Diagnostic development: thermal couple arrays, ultrasonic measurements
  - Data analyses: IR camera data analyses for thermal transport
- Swirling gas/plasma experiment
  - Diagnostic development on flow profile measurements

The PFRC-2



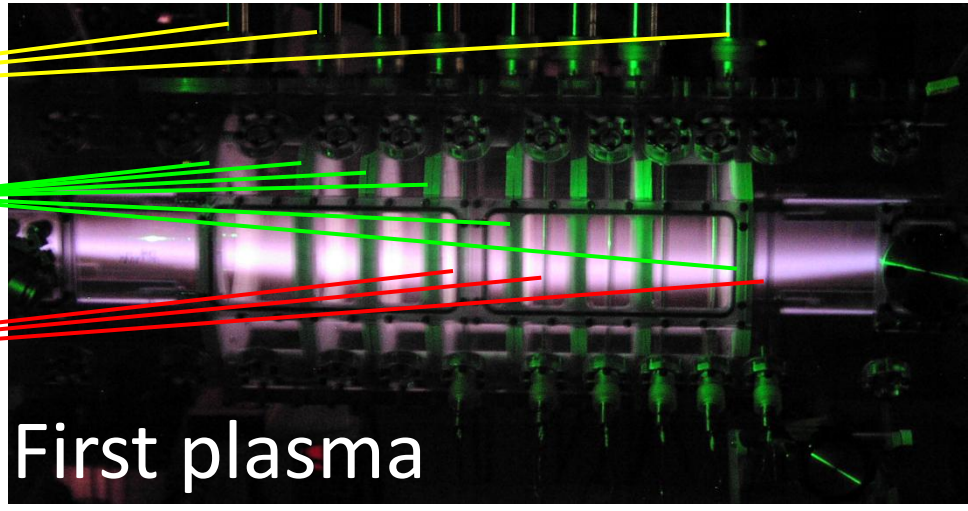
PPPL

Main PFRC-2 research topics: Ion heating, improved energy confinement

Target: $n_e = 10^{13}$ cm^{-3}, $T_e = 1$ keV, $T_i = 1.5$ keV, $\langle\beta\rangle = 0.6$, $r_s = 7$ cm, $B = 1.2$ kG, $t = 0.1$ s, $\tau_E = 70$ μs

General skill

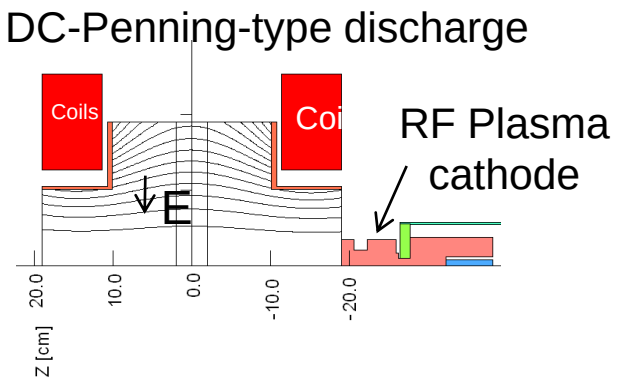
X-ray detection	Time- and energy-resolved emissivity profiles for T_e
Ion temperature	Time-resolved IED by NPA and Ion Doppler spectroscopy
Power & particle control	Heat and particle loads onto walls and into divertors, fueling
Modeling	PIC simulations, reactor design
RF (200kW@ 5 MHz)	RF coupling, power balance, ion & electron heating physics
Magnetics	Profile reconstruction, fluctuations, mode structure
Microwaves	Time-resolved density profiles and fluctuations

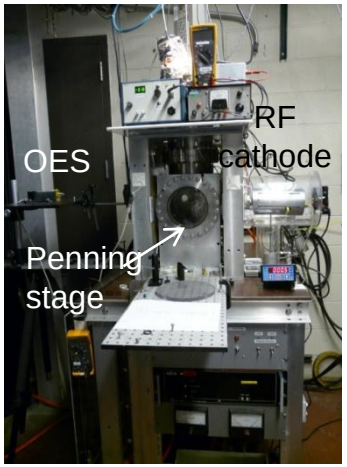


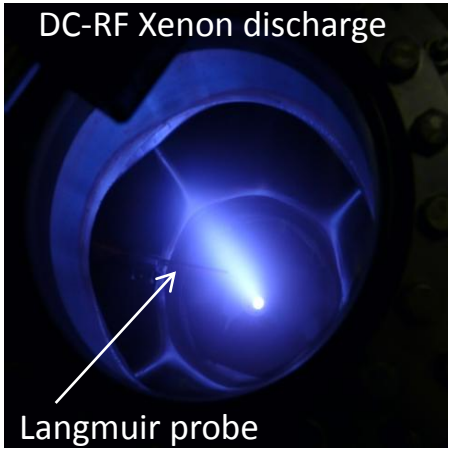
PPPL Low Temperature Plasma Research
(Raitses and Kaganovich)

- This project is a part of the DOE Plasma Science Center on Predictive Control of Plasma Kinetics: Multi-Phase Systems
- More than 20 scientists from 8 universities, PPPL and Sandia collaborate in the Center
- PPPL LTP research is focused on controlling of non-local electron kinetics in a weakly collisional magnetized plasma with active boundaries: emitting and absorbing walls
- Potential applications: neutral beams, plasma sources, negative ions, material processing
- Collaborators: Hershkowitz (Wisconsin), Donnelly (Huston), Koepke and Demidov (West Virginia), Godyak (Michigan)

PPPL LTP Experiment







PPPL PRINCETON PLASMA PHYSICS LABORATORY

Collaboration opportunities on PPPL Low Temperature Plasma Research

- **Studies of plasma-wall interaction in the presence of strong secondary electron emission (SEE)**

  - Measurements of electron energy distribution function in DC-RF Penning discharge using optical emission spectroscopy and Langmuir probes

  -Evaluation of SEE properties of Lithium and micro engineered materials

  - Steady-state and time-dependent infrared measurements of emitting plasma facing surfaces

- **Characterization of ionization instability in magnetized plasma**

  Development of time-dependent laser-induced florescence (LIF) diagnostic and measurements in DC-RF Penning discharge

- **Development of a 1 kW RF plasma cathode**
- **Verification of diagnostics in divertor and PMI**

  Development adequate kinetic codes and their validation

- **Contact: Yevgeny on experiments or Igor on simulations**

ITER Opportunities - Diagnostics

- Michael Walsh has indicated an interest in obtaining short-term assistance of US diagnostic expertise to work with his IO Diagnostics Division Staff
  - to prepare for remaining ITER Diagnostic Conceptual Design Reviews
  - to prepare Procurement Arrangement technical annexes
  - to develop generic tools needed to complete ITER diagnostic designs
    - eg. tools to compute radiant heat loads on aperture facets

- Durations of 3-6 months, starting ASAP
- Some ITER-funded assistance possible
- See D. Johnson

Backup

Collaboration opportunity overview

- The following slides outline facility opportunities and schedules for the next year+, and provide some contacts for additional information

- Names listed are either people already involved in collaboration, or are ideas for potential collaborators
  - These suggestions are not (yet) binding, but are meant to provoke thought, consideration, and discussion
  - If you are a PPPLer and not named, fear not – we will find you
  - If you are not a PPPLer, but are interested in a research area, discuss this with your fellow researchers and inform us too
- Note: In some cases, time is short for your integration into a research team for FY2012 experiments

Goals and expectations for collaboration

- For all researchers, use Upgrade outage as opportunity to:
  - Extend and improve your ongoing and future research on NSTX
  - Learn about other facilities – bring back knowledge, best practices
  - Try or learn something new – new physics, diagnostics, analysis, …
  - Make new contacts (and friends) – national and international
- Should aim to form small teams of NSTX researchers (PPPL + non-PPPL) collaborating on other facilities
  - Coordinate research plans, analysis, travel, and participation
  - Much more efficient and effective than individuals acting alone
- Expectations for (PPPL) researchers:
  - Select 1 primary and 1 secondary/backup collaboration project
  - Aim for first author paper and/or invited presentation based on collaborative research (will be noted on performance appraisal)
  - At very least, be a co-author, and utilize new results/techniques to extend/improve your NSTX research and publications/presentations
  - Present your results periodically to NSTX, PPPL research seminars

Logistics

- Highest priority now is formulating good collaboration ideas
  - Talk about it with your supervisor(s) and with us = NSTX + off-site research divisions
    - Be inclusive in the CC list: Ono, Menard + Wilson, Neilson
  - Discuss with off-site contacts, iterate to mutual agreement
  - For PPPL staff: we will try to find the resources to make collaborations happen through NSTX and/or off-site research departments
    - But, NSTX facility & travel funding very limited during Upgrade outage
  - NSTX will generally provide PPPL researcher salary, provided there is some tie-back to NSTX/toroidal physics – will treat case-by-case
    - Will require researcher discussion with, and concurrence by, NSTX + OSR
- Note for all: some international host institutions may provide housing and/or travel funds
- If you see an opportunity you want to participate in, and it is happening soon, act now. Overall, <u>be pro-active</u>