Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: **Li pumping and retention in NSTX neutral beam heated plasmas.**

OP-XP-911	Revision:	Effective Date: **4/1/09** Expiration Date: **4/1/11**

PROPOSAL APPROVALS

Responsible Author: C. H. Skinner, et al C Skinner	Date **4/1/09**
ATI – ET Group Leader: Vlad Soukhanovskii (R. Maingi) Rmaingi	Date 4/1/09
RLM - Run Coordinator: Roger Raman Rob Raman	Date 4/2/09
Responsible Division: Experimental Research Operations	

Chit Review Board (designated by Run Coordinator)

Vlad Soukhanovskii; Henry W. Kugel; Dennis Mueller; Michael G. Bell; Daren P. Stotler

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

APPROVED XP #: 911

DATE: 4/2/09

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NSTX EXPERIMENTAL PROPOSAL

TITLE: **Li pumping and retention in NSTX neutral beam heated plasmas.** No. **OP-XP-911**

AUTHORS: C. H. Skinner, H Kugel, L Roquemore, R. Maingi, V. Soukhanovskii, W. Blanchard, J.P. Allain, C. Taylor

DATE: **4/1/09**

1. Overview of planned experiment

- We aim to measure the fraction of the injected deuterium that is retained in the NSTX vessel after ohmic and neutral beam heated plasmas, before- and with-Li conditioning. Ohmic retention will be measured statically with all the TIVs closed. Retention in NB heated plasmas will measured dynamically including tracking of the D inventory on the NB cryopanels. The XP will be run before-Li and with-Li to compare retention in PFCs uncoated and coated with fresh (active) lithium.
- Langmuir probe estimates of the D flux to the divertor will be used to obtain 'physics-based' retention fraction (D flux/D retained).
- ATJ graphite, Pd, and Si samples will be exposed to these plasmas with the Bay J sample probe. One ATJ sample will be analysed by thermal desorption spectroscopy in the evening after exposure. The other samples will be analysed at Purdue U. The data will help understanding of the fundamental processes governing retention.
- A companion XMP has been performed that measured (i) the baseline leak/outgassing rate, (ii) pressure gauge calibration (iii) RGA calibration, (iv) measuring the cold gas influx due to the Neutral Beam and (v) the pumping speed of the NB cryopumps to known gas-only pulses.

2. Theoretical/ empirical justification

XP911 is part of the Joint US tokamak FY 2009 milestone on pumping and retention. It is also important for the NSTX lithium program which aims at density control using lithium pellet injection and lithium evaporation to reduce recycling of hydrogenic species. In 2008 we obtained preliminary data (XP824) on static retention (D pressure rise) in ohmic plasmas before and with-Li. This XP will measure retention of ohmic and NB heated plasmas with data from the new Bay J sample probe, Langmuir probe data, D-alpha array data, new high accuracy baratron, and improved RGA data. It will be run four ½ days devoted to:

1. Static and dynamic measurements of ohmic retention before Li.
2. Dynamic measurements of retention in NB heated plasma before Li
3. Static measurement of ohmic retention with Li
4. Dynamic measurement of NB heated plasma with Li.

Here 'static' refers to measurements with all the pumping valves closed and 'dynamic' means with the NB TIV open. XP911 will be run Fridays as far as possible to allow the measurement of outgassing through Saturday PM. The XP will provide well defined plasma exposure for the new sample probe.

Discharges Developed 3/11/09

- Ohmic Fiducial # 132122: Ohmic 600 kA, outer strike point 0.715 – 1.044. Ip crashes at 200kA with Wtot 5 kJ. Gas input: no cs injection, Bay J PE102 (1732 – 1332)*0.072 = 28.8 torr-l.

- NB Fiducial #132114: NB 2 source. 700 kA, 4MW NB. Modulation used to ramp down beam power. Outer strike point sweeps 0.73 m to 0.96 m. Final disruption @ Ip 455 kA comes after stored energy is down to 10 kJ. IR camera shows no significant heating due to halo currents at this time. Gas injected: 40 torr-l center stack, 9 torr-l Bay J PE102

3. Experimental run plan

Begin after the March 09 maintenance break sample probe installation but before any introduction of lithium. Set up prerequisites per section 4. Start at noon.

B. First day scheduled for 4/3/09: Dynamic retention measurements of NB heated plasmas with sample probe exposure followed by 24 h outgassing through Saturday.

CHECKLIST:

1. Rezero 0.1torr baratron.
2. Set the EPICS Input-Output-Controller (IOC) time for channel archiver by hand (~ 1 sec) to match the NTP.
3. Check EPICS slow digitizer is turned on (nstxpool dwscope -def pressure_d2.scope)
4. IG1 set to 0.1 mA emission
5. MIG gauges on
6. Check RGA tuning, autocalibrate if required.
7. Check Trend RGA and Shot RGA files are being saved.
8. Print out TVPS status
9. VIPS2 set to monitor H alpha / D alpha ratio every few shots.
10. Divertor Langmuir probes operating.
11. IR camera operating.
12. Trend RGA set:
    a. -800 v EM
    b. scan amu 2 to amu 50
    c. 0.1 mA emission.
    d. Auto zero off
    e. 8 pts / amu
    f. 30 msec / pt
    g. display amu=2,4,12,14,18,28,32,44 linked to scan.
13. Shot RGA set:
    a. -800 EM
    b. 0.1 mA emission
    c. auto zero off
    d. 4 pts / amu
    e. 10 msec / pt
    f. display amu=2,4,12,14,18,28,32,44 linked to scan.
14. Neutral Beams
    a. 3 source neutral gas 1.6 s duration
    b. Neutralizer gas for source A,B,C @ 42, 40, 41 torr-l/s (most does not enter torus).
    c. NB calorimeter out for gas-only shots.

15. For each shot check:
    a. Check zero on pe19, rezero if required.
    b. Beams sync'ed with clock ?
    c. IG1 off or on ?
    d. RGA orifice in or out ? Is RGA data saturated ?
    e. For gas-only shots disarm PF, TF, IP.
    f. Is NB TIV open? Is calorimeter out of beam path ?
    g. Appropriate gas injectors armed
    h. TMP TIV's closed
    i. NB TIV to close from t=+10 s until t=60s.
16. Gas-only shot 1: model 132114, NB TVI open with 40 torr-l center stack and 9 torr-l Bay J gas injection. Close NB TIV ~ 10 sec after discharge to measure outgassing for ~ 2 mins after shot. Calculate cryopanel/cold gas contribution. Compare to prior gas-only shots 3 and 4.
    Confirm ~ zero retention.
17. NBI discharge model 132114. Close NB TIV ~ 10 sec after discharge to measure outgassing for ~ 2 mins after shot. At t= + 2 mins open TMP TIVs. Normal ~ 12 min He GDC.
    Calculate cryopanel/cold gas.
    Calculate dynamic retention. If satisfactory proceed with sample probe. Otherwise repeat.
18. Controlled access to open sample probe TIV and raise sample probe into vessel.
19. Rezero 0.1torr barytron.
20. FOUR NBI discharges model 132114 (or until 4:30 PM). Close NB TIV ~ 10 sec after each discharge to measure outgassing for ~ 2 mins after shot.
    Calculate dynamic retention.
    Controlled access to withdraw the sample probe ~ 12" after each shot. Stay in NSTX cell.
    Open TMP TIVs for normal ~ 12 min He GDC.
    Raise sample probe after GDC. Controlled access to leave NSTX cell. Repeat 4x.
21. Rezero 0.1torr barytron.
22. Repeat NBI discharge model 132114. Leave all TIVs closed to measure long term outgassing through Saturday 5:00 PM.
23. Switch shot RGA to calibration shot mode so that it continues to take data.
    IDL> rga_camac_test, 9000200, 15 for 15 min cycle
    with 840 s (14 min) on the scan time in the VB program
    check in rgashotplot that the record lasts 840 sec.
24. When vessel pressure rises to > 1e-5 torr insert RGA orifice and open RGA HVV to avoid RGA non-linearity at higher pressures.
25. Withdraw sample probe, close sample probe TIV.
26. Perform ex-vessel thermal desorption spectroscopy of ATJ sample #1.
27. Remove all samples under argon.

Total 1 gas-only, 6+ plasmas + controlled access.

A. Second day 6 April 2009: Compare static and dynamic gas balance measurements of ohmic plasma. followed by 12 h – 24 h outgassing measurements. Analyse results before embarking on part B. C & D

28. Rezero 0.1torr barytron. NB TIV closed.
29. Gas-only shot 1: Model 129707, Bay J GIS 7.7 torr-l, TMP TIVs closed t = -20 s before shot.
30. Gas-only shot 2: Model 132122 Bay J GIS 28.8 torr-l, TMP TIVs closed t = -20 s before shot
    Compare these shots and confirm static retention is zero.
31. Ohmic plasma shot: Model 132122 all valves closed t = -20 s before shot.
    Compare static retention to 97% - 100% measured in 2008.
    At t= + 2 mins open TMP TIVs, Normal ~ 12 min He GDC.
32. Open NB TIV and close TMP TIVs for simplicity. Rezero 0.1torr barytron.
33. Gas only shot 3: Model 129707, NB TIV open (cold gas pulse but no accel. no NB injection) Bay J GIS 7.7 torr-l. *Check no gas-only retention after cryopanel calculation.*
34. Gas only shot 4: Model 132122 NB TIV open (cold gas pulse but no accel. no NB injection) Bay J GIS 28.8 torr-l. *Check no gas-only retention after cryopanel calculation.*
35. Rezero 0.1torr barytron.
36. Ohmic plasma shot Model 132122 with NB TIV open and NB cold gas injection, TMP TIV closed for simplicity, Bay J GIS 28.8 torr-l. At t= + 5 mins open TMP TIVs. Normal ~ 12 min He GDC. Calculate cryopanel/cold gas.
    Compare dynamic retention to static retention in step 4
37. Controlled access to raise sample probe
38. FOUR Model 132122 shots as above for sample probe exposure.
    Withdraw the probe during intershot He-GDC. Raise sample probe after GDC.
39. Rezero 0.1torr barytron. Repeat Ohmic shot 132122 NB TIV open (but no NB injection), TMP TIVs closed for simplicity.
    Close NB TIV ~ 10 sec after discharge. Leave all TIVs closed to measure 24 h long term outgassing.
40. Switch shot RGA to calibration shot mode so that it continues to take data.
    IDL> Rga_camac_test, 9000200, 15 for 15 min scans, RGASHOTMODE set to 840s (14min)
41. When vessel pressure reaches to ~7e-5 insert RGA orifice and open RGA HVV to avoid RGA non-linearity at higher pressures.
42. Calculate cryopanel/cold gas.
    Compare dynamic retention to static retention in step 5.
43. Do TDS on ATJ sample and retrieve samples under argon in evening.
44. Leave sample holder for HP testing.
45. When released, ship all samples to Purdue

Total 4 gas-only, 7 plasmas + controlled access.

C. Repeat of part A with two LiTERs operating @ 10 mg/min.

D. Repeat of part B with two LiTERs operating @ 10 mg/min.

He-GDC with LiTER at operators discretion. Recommend reviewing 5Jun08 experience with LiTER mg/min rate, GDC or no GDC and successful shot # 129723 to optimize density control.

4. Required machine, NBI, RF, CHI and diagnostic capabilities

PREQUISITES:

1. Measurement of (i) the baseline leak/outgassing rate, (ii) pressure gauge calibration (iii) RGA calibration, (iv) measuring the cold gas influx due to the Neutral Beam and (v) the pumping speed of the NB cryopumps to known gas-only pulses from LDGIS.
2. Spectroscopic H/D should be < few% to avoid confusion with H outgassing.
3. Set the EPICS Input-Output-Controller (IOC) time for channel archiver by hand (~ 1 sec) to match the NTP.
4. Check LiTER interlock removed from ig110 operation.
5. Check ig110 set to 'MV'
6. Disarm PF, TF, IP supplies for gas-only shots.
7. Sample probe available with 2x ATJ, Pd, Si samples installed..
8. LiTER is required for the with-Li part.

DIAGNOSTICS:

9. New 0.1 torr baratron, IG1, IG3A and IG110 ionization gauges, 1 torr baratron,
10. In-vessel micro ion gauges
11. Trend RGA settings: EM=-800 volts emission 0.1 mA, 30 ms dwell time 8 points / amu, (12 sec/scan). Trend data files should be saved on the PC.
12. Shot RGA settings: EM=-800 volts emission 0.1 mA on both RGAs, 30 ms dwell time 8 points / amu, Shot RGA 'Scan' will be OFF to improve time resolution from 12 s to 0.25 s.
    Readout amu= 2, 4, 12, 14, 16, 18, 28, 40, 44.
    RGA data files saved on PC.
13. Shot RGA for 12-24 h outgassing: Shot RGA will be run in 'calibration shot mode' with calibration shot software from Dana M. This will generate a series of data files with calibration shot numbers.
14. VIPS2 to measure H/D ratio
15. D-alpha array (Vlad) to estimate D flux to wall/divertor.
16. Divertor Langmuir probes (Kaita / Josh Kallman).
17. Langmuir probe on sample probe.
18. Reciprocating Langmuir probe if available.
19. Quartz Microbalances
20. IR camera to measure tile temperatures (important for comparing NB to ohmic results)
21. Usual plasma diagnostics (see checklist p.6)

5. Planned analysis

- Send exposed samples to JP Allain's group at Purdue for surface analysis.
- Compare TDS spectra to IMPACT lab results from Purdue. Aim to identify Li/C/D bond energy and 'fundamental processes governing particle balance' (milestone language).
- Use mds scopes to calculate time dependent retention. NB pumping speed needed to track D on cryopanels.
- Track amu=4 levels before shots to get information on potential helium contribution.
- Use idl codes gas_balance_new to calculate static retention
- Plot retention vs. time (seconds) from mds downloaded data – get speed of outgassing.

- Use Bens code (`IDL> ue,129709,times,netotin=netotin,netotou=netotou`) to calculate total electrons in plasma.
- Calculate D flux to divertor/wall from Langmuir probe data (Kallman).
- Calculate D flux to divertor/wall from D-alpha array (Vlad).
- Send data to Pigarov so he can use Wall PSI code to model the retention.
- Send data to Jeff Brooks so he can apply the REDEP code.
- Compare to results from DIII-D and C-mod.

6. Planned publication of results

- Quarterly reports to DoE for Joule milestone.

- Preliminary presentation (including 2008 results) at Div/SOL ITPA mtg in Amsterdam 5-8 May 09 and 12th International Workshop on Plasma Facing Materials and Components for Fusion Applications Juelich on 11-14th May 2009.

PHYSICS OPERATIONS REQUEST

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(use additional sheets and attach waveform diagrams if necessary)

Describe briefly the most important plasma conditions required for the experiment:

1. minimal minor disruptions on rampdown,
2. low triangularity,
3. strike point as close as possible to sample probe,
4. strike point scan over Langmuir probes

Previous shot(s) which can be repeated:

Previous shot(s) which can be modified: **132122 (ohmic), 132114 (NB heated).**

Machine conditions *(specify ranges as appropriate, strike out inapplicable cases)*

I_{TF} (kA): Flattop start/stop (s):

I_p (MA): Flattop start/stop (s):

Configuration: **Limiter / DN / LSN / USN**

Equilibrium Control: **Outer gap / Isoflux** (rtEFIT)

Outer gap (m): Inner gap (m): Z position (m):

Elongation κ: Upper/lower triangularity δ:

Gas Species: Injector(s):

NBI Species: **D** Voltage (kV) **A:** **B:** **C:** Duration (s):

ICRF Power (MW): Phase between straps (°): Duration (s):

CHI: Off / On Bank capacitance (mF):

LITERs: Off / On Total deposition rate (mg/min):

EFC coils: Off/On Configuration: **Odd / Even / Other** *(attach detailed sheet*

DIAGNOSTIC CHECKLIST

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Note special diagnostic requirements in Sec. 4

Diagnostic	Need	Want
Bolometer – tangential array		√
Bolometer – divertor		√
CHERS – toroidal		√
CHERS – poloidal		√
Divertor fast camera		√
Dust detector		√
EBW radiometers		√
Edge deposition monitors		√
Edge neutral density diag.		√
Edge pressure gauges		√
Edge rotation diagnostic		√
Fast ion D_alpha - FIDA		√
Fast lost ion probes - IFLIP		√
Fast lost ion probes - SFLIP		√
Filterscopes		√
FIReTIP		√
Gas puff imaging		√
Hα camera - 1D	√	
High-k scattering		√
Infrared cameras	√	
Interferometer - 1 mm		√
Langmuir probes – divertor	√	
Langmuir probes – BEaP		√
Langmuir probes – RF ant.		√
Magnetics – Diamagnetism		√
Magnetics – Flux loops	√	
Magnetics – Locked modes		√
Magnetics – Pickup coils	√	
Magnetics – Rogowski coils	√	
Magnetics – Halo currents		√
Magnetics – RWM sensors		√
Mirnov coils – high f.		√
Mirnov coils – poloidal array		√
Mirnov coils – toroidal array		√
Mirnov coils – 3-axis proto.		√

Note special diagnostic requirements in Sec. 4

Diagnostic	Need	Want
MSE		√
NPA – EllB scanning		√
NPA – solid state		√
Neutron measurements		√
Plasma TV		√
Reciprocating probe		√
Reflectometer – 65GHz		√
Reflectometer – correlation		√
Reflectometer – FM/CW		√
Reflectometer – fixed f		√
Reflectometer – SOL		√
RF edge probes		√
Spectrometer – SPRED		√
Spectrometer – VIPS		√
SWIFT – 2D flow		√
Thomson scattering	√	
Ultrasoft X-ray arrays		√
Ultrasoft X-rays – bicolor		√
Ultrasoft X-rays – TG spectr.		√
Visible bremsstrahlung det.		√
X-ray crystal spectrom. - H		√
X-ray crystal spectrom. - V		√
X-ray fast pinhole camera		√
X-ray spectrometer - XEUS		√
Shot RGA	√	
Trend RGA	√	
VB – Zeff	√	
VIPS2	√	

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