Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: Recycling Measurements Following Repeated Lithium Pellet Injection

OP-XP-515	**Revision:**	Effective Date: 03/21/05 *(Ref. OP-AD-97)* Expiration Date: 03/21/07 *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

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RLM - Run Coordinator: J. Menard (S. Sabbagh)	Date

Responsible Division: Experimental Research Operations

<u>Chit Review Board</u> <u>(designated by Run Coordinator)</u>

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL OP-XP-515

1. Overview of planned experiment

On TFTR it was found that thin lithium films deposited on the graphite tiles of the inner toroidal limiter using lithium pellet injection could significantly reduce recycling and improve the performance of limited circular discharges. This improvement in TFTR performance required special procedures. Brief tests under other conditions on the diverted machines C-Mod, DIII-D, TdeV, and NSTX did not observe similar large benefits following lithium deposition.

The goal of this NSTX XP is to make contact with the TFTR lithium database by performing recycling measurements on inner limited discharges following repeated Lithium Pellet Injection.

This XP involves 3 parts:
1. Inner Limiter Conditioning: On Day-1
Condition the Center Stack (CS) inner toroidal limiter with limited, helium discharges, supported if necessary by low power (2 MW) deuterium NBI heating, until the change in deuterium recycling per discharge is negligible.

2. Preliminary Lithium Pellet Injection Scaling: On Day-1
Using these CS limited, discharges as targets, to briefly characterize the scaling of lithium deposition on the CS as a function of pellet mass, velocity, and timing.

3. Recycling Measurements Following Repeated Lithium Pellet Injection: On Day-2
Using the resultant wall conditioning of the inner limiter and the optimized pellet deposition from the scaling characterization, measure recycling, density and fueling behavior in NBI heated, CS limited, deuterium discharges following repeated Lithium Pellet Injection.

2. Theoretical/ empirical justification

TFTR found that lithium deposition controlled recycling and impurities. Similar effects might benefit NSTX performance.

3. Experimental run plan

3.1 ***Inner Limiter Conditioning: On Day-1***
Condition the Center Stack (CS) inner toroidal limiter with CS limited helium discharges, supported if necessary by low power (2 MW) deuterium NBI heating, until the change in deuterium recycling per discharge is negligible.

3.1.1 At 4.5 kG TF, achieve a suitable helium discharge of Ip = 800-1000 KA (TF= 53 KA) with a flattop of at least 350 ms, free from Internal Reconnection Events (IRE) during the flattop and the ramp-down, supported if necessary by low power (2 MW) deuterium NBI heating. A candidate discharge supported by low power (2 MW) deuterium NBI heating is 111552. Apply with a suitable 30 ms notch in mid flattop for LPI.

3.1.2 Condition the CS inner toroidal limiter using the above (3.1.1) discharges until the change in the ratio of edge Dα to CII per discharge as determined by the cognizant physicist. [3 -30 shots]

First conditioning shot of this sequence: _________________

Last conditioning shot of this sequence: _________________

3.2. ***Preliminary Lithium Pellet Injection Scaling: On Day-1***
Using these limited helium discharges as targets (3.1.1), characterize the scaling of lithium deposition following lithium pellet injection as a function of timing relative to NBI-B, pellet mass, and velocity, as follows.

3.2.1 Measure LPI penetration relative to NBI-B Off /Notch-Start time.

Establish NBI-B to provide 30 ms gap in mid flatop. Use 2.4 mg LPI at **<u>100 m/s</u>** as follows:

Discharge	LPI arrival ms after NBI Off time	Penetration Rp Bay-G Li I Camera	Penetration Rp Bay-B Li I Camera	Penetration Rp Bay-K Li I Camera	MPTS @ ~start @ Rp - SOL	VIPS Li I , Li II SPRED	F/O LiI, CII, BI, Da	
	12							
	10							
	8							
	4							
	2							

Effect of NBI RTAN:

Discharge	LPI arrival ms after NBI-A Off time	Penetration Rp Bay-G Li I Camera	Penetration Rp Bay-B Li I Camera	Penetration Rp Bay-K Li I Camera	MPTS @ ~start @ Rp - SOL	VIPS Li I , Li II SPRED	F/O LiI, CII, BI, Da	
	12							

	10							

Establish NBI-B to provide 30 ms gap in mid flatop. Use 2.4 mg LPI at **200 m/s** as follows:

Discharge	LPI arrival ms after NBI Off time	Penetration Rp Bay-G Li I Camera	Penetration Rp Bay-B Li I Camera	Penetration Rp Bay-K Li I Camera	MPTS @ ~start @ Rp - SOL	VIPS Li I , Li II SPRED	F/O LiI, CII, BI, Da	
	12							
	10							
	8							
	4							
	2							

Establish NBI-B to provide 30 ms gap in mid flatop. Use 2.4 mg LPI at **50 m/s** as follows:

Discharge	LPI arrival ms after NBI Off time	Penetration Rp Bay-G Li I Camera	Penetration Rp Bay-B Li I Camera	Penetration Rp Bay-K Li I Camera	MPTS @ ~start @ Rp - SOL	VIPS Li I , Li II SPRED	F/O LiI, CII, BI, Da	
	12							
	10							
	8							
	4							
	2							

Establish NBI-B to provide 30 ms gap in mid flatop. Use 2.4 mg LPI at **300 m/s** as follows:

Discharge	LPI arrival ms after NBI Off time	Penetration Rp Bay-G Li I Camera	Penetration Rp Bay-B Li I Camera	Penetration Rp Bay-K Li I Camera	MPTS @ ~start @ Rp - SOL	VIPS Li I , Li II SPRED	F/O LiI, CII, BI, Da	
	12							
	10							
	8							
	4							
	2							

3.2.2 Measure mass dependence of LPI penetration

For **100 m/s**, using the timing for full transit time of a 2.4 mg LPI as determined in 3.2.1.

Discharge	LPI arrival ms after NBI Off time	Penetration Rp Bay-G Li I Camera	Penetration Rp Bay-B Li I Camera	Penetration Rp Bay-K Li I Camera	MPTS @ ~start @ Rp - SOL	VIPS Li I , Li II SPRED	F/O LiI, CII, BI, Da	
	4.8							
	7.2							

For **200 m/s**, using the timing for full transit time of a 2.4 mg LPI as determined in 3.2.1.

Discharge	LPI arrival ms after NBI Off time	Penetration Rp Bay-G Li I Camera	Penetration Rp Bay-B Li I Camera	Penetration Rp Bay-K Li I Camera	MPTS @ ~start @ Rp - SOL	VIPS Li I , Li II SPRED	F/O LiI, CII, BI, Da	
	4.8							
	7.2							

For **50 m/s**, using the timing for full transit time of a 2.4 mg LPI as determined in 3.2.1.

Discharge	LPI arrival ms after NBI Off time	Penetration Rp Bay-G Li I Camera	Penetration Rp Bay-B Li I Camera	Penetration Rp Bay-K Li I Camera	MPTS @ ~start @ Rp - SOL	VIPS Li I , Li II SPRED	F/O LiI, CII, BI, Da	
	4.8							
	7.2							

For **300 m/s**, using the timing for full transit time of a 2.4 mg LPI as determined in 3.2.1.

Discharge	LPI arrival ms after NBI Off time	Penetration Rp Bay-G Li I Camera	Penetration Rp Bay-B Li I Camera	Penetration Rp Bay-K Li I Camera	MPTS @ ~start @ Rp - SOL	VIPS Li I , Li II SPRED	F/O LiI, CII, BI, Da	
	4.8							
	7.2							

3.3. *Recycling Measurements Following Repeated Lithium Pellet Injection on Day-2.*
From the above results select the wall conditions yielding the largest decrease in CS D_α/CII and the optimum pellet mass, velocity, and timing yielding the largest increase in deposited Li I on the Center Stack. Use these conditions to measure recycling in 2 NBI heated, limited, deuterium discharges following repeated Lithium pellet Injection as follows:

3.3.1 Condition the CS inner toroidal limiter using the above (3.1.1) discharges until the change in the ratio of edge Dα to CII per discharge as determined by the cognizant physicist. [3 -30 shots]

First conditioning shot of this sequence: _________________

Last conditioning shot of this sequence: _________________

3.3.2 Using the above optimal pellet mass and velocity injection single pellets into 6 discharges

Discharge	LPI arrival ms after NBI Off time	Penetration Rp Bay-G Li I Camera	Penetration Rp Bay-B Li I Camera	Penetration Rp Bay-K Li I Camera	MPTS @ ~start @ Rp - SOL	VIPS Li I , Li II SPRED	F/O LiI, CII, BI, Da	

3.3.3 Use a 2 NBI (4 MW) limited deuterium discharge with approximately the same magnetic equilibrium as the limited He conditioning and deposition discharges used in 3.2 above (e.g. similar to 111552) to measure recycling, density behavior, required fueling.

Note: although it is desirable to maintain the gas puff fueling constant, if necessary to avoid a locked mode, the deuterium gas puff will be increased incrementally as needed. This shall be done in a measured manner and will be accounted for in the recycling analysis.

Discharge	LPI arrival ms after NBI Off time	Penetration Rp Bay-G Li I Camera	Penetration Rp Bay-B Li I Camera	Penetration Rp Bay-K Li I Camera	MPTS @ ~start @ Rp - SOL	VIPS Li I , Li II SPRED	F/O LiI, CII, BI, Da	

3.3.4 If conditions improving inject 2 pellets into 6 more discharges, otherwise one LPI

Discharge	LPI arrival ms after NBI Off time	Penetration Rp Bay-G Li I Camera	Penetration Rp Bay-B Li I Camera	Penetration Rp Bay-K Li I Camera	MPTS @ ~start @ Rp - SOL	VIPS Li I , Li II SPRED	F/O LiI, CII, BI, Da	

3.3.5 Use a 2 NBI (4 MW) limited deuterium discharge with approximately the same magnetic equilibrium as the limited He conditioning and deposition discharges used in 3.2 above (e.g. similar to 111552) to measure recycling, density behavior, required fueling

Discharge	LPI arrival ms after NBI Off time	Penetration Rp Bay-G Li I Camera	Penetration Rp Bay-B Li I Camera	Penetration Rp Bay-K Li I Camera	MPTS @ ~start @ Rp - SOL	VIPS Li I , Li II SPRED	F/O LiI, CII, BI, Da	

3.3.6 Inject LPI into 6 more discharges

Discharge	LPI arrival ms after NBI Off time	Penetration Rp Bay-G Li I Camera	Penetration Rp Bay-B Li I Camera	Penetration Rp Bay-K Li I Camera	MPTS @ ~start @ Rp - SOL	VIPS Li I , Li II SPRED	F/O LiI, CII, BI, Da	
	12							
	10							
	8							
	4							
	2							

3.3.7 Repeat 3.3.5. Use a 2 NBI (4 MW) limited deuterium discharge with approximately the same magnetic equilibrium as the limited He conditioning and deposition discharges used in 3.2 above (e.g. similar to 111552) to measure recycling, density behavior, required fueling.

Discharge	LPI arrival time after NBI Off time	Penetration Rp Bay-K Li II Camera	Penetration Rp Bay-B Li II Camera	MPTS Behavior Rp - SOL	VIPS CS Li I , Li II	F/O Li I, CII, BI, Da	Bay K

Note: although it is desirable to maintain the gas puff fueling constant, if necessary to avoid a locked mode, the deuterium gas puff will be increased incrementally as needed. This shall be done in a measured manner and will be accounted for in the recycling analysis

3.3.8 If a reduction in recycling is measured, continue running plasma described in 3.3.7 to observe any decay of the effect per discharge.

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

1. Limited helium, 800 KA, 0.45T, 1 NBI, discharges similar to 111552.

2. Limited deuterium, 1 MA, 0.45T, 2 NBI, discharges similar to 111552 but at higher current and beam power.

3. Diagnostics listed on pages 14, 15.

5. Planned analysis

The analysis of the data shall include: EFIT, TRANSP, UEDGE.

6. Planned publication of results

The results will be published in J. Nucl. Mater. and/or Nucl Fus.

PHYSICS OPERATIONS REQUEST OP-XP-515

Machine conditions: Example discharge: *

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

I_P (MA): * Flattop start/stop (s): *

Configuration: **Inner Wall / Lower Single Null / Upper SN / Double Null**

Outer gap (m): ____, Inner gap (m): **limited**

Elongation κ: ____, Triangularity δ: *

Z position (m): **0.00**

Gas Species: *, Injector: *

NBI - Species: * Sources: *, Voltage (kV): *, Duration (s): *

ICRF – Power (MW): **0**, Phasing: **Heating / CD**, Duration (s): **0**

CHI: **Off**

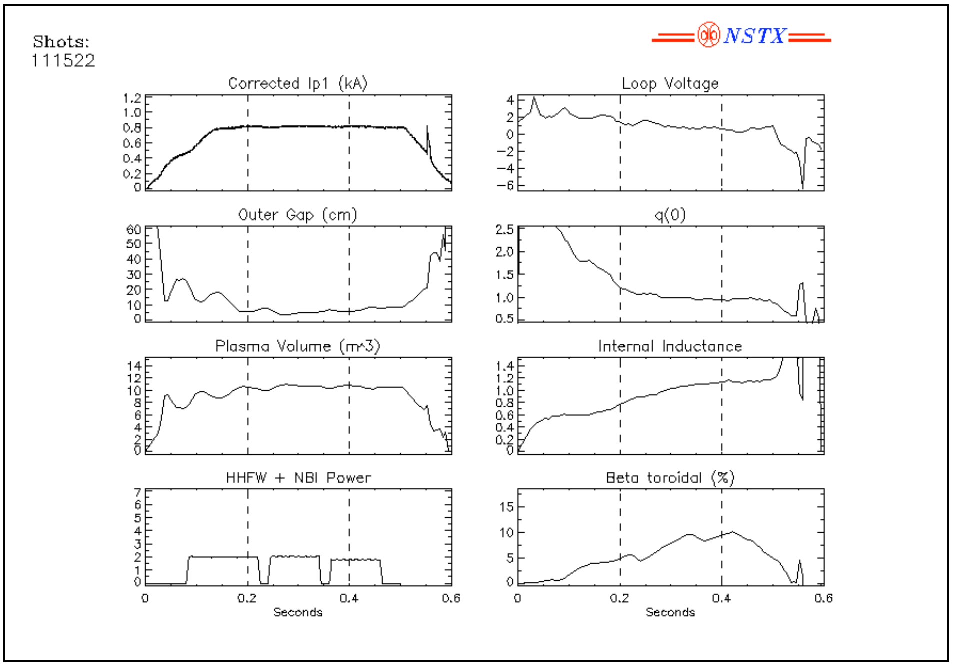
Either: List previous shot numbers for setup: **111522**

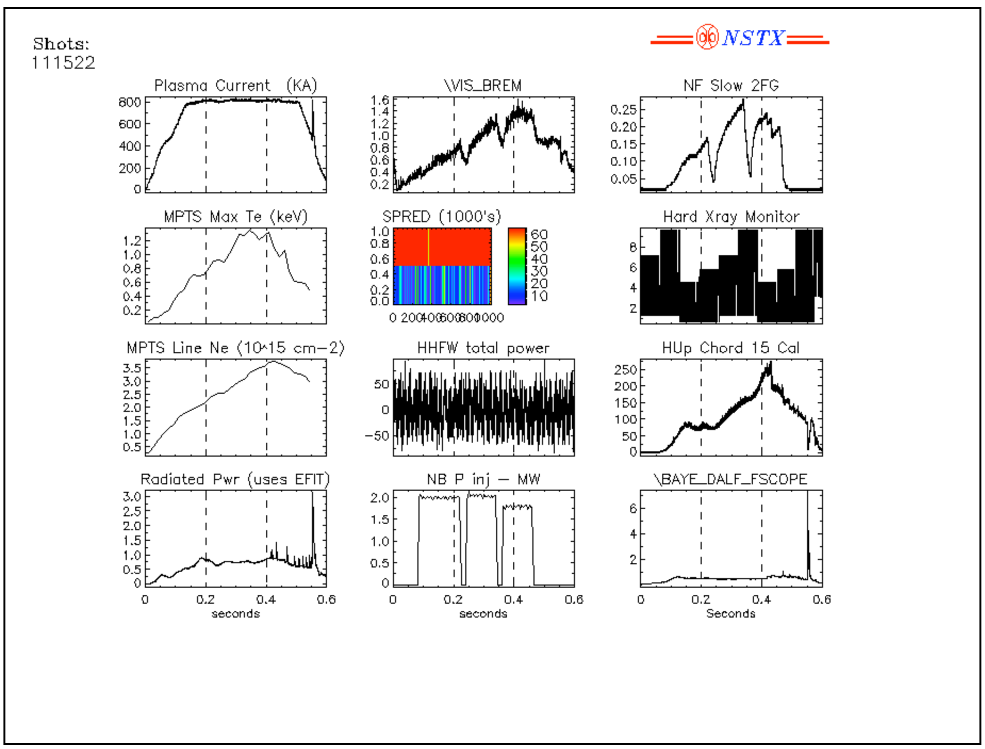
Or: Sketch the desired time profiles, including inner and outer gaps, κ, δ, heating, fuelling, etc. as appropriate. Accurately label the sketch with times and values.

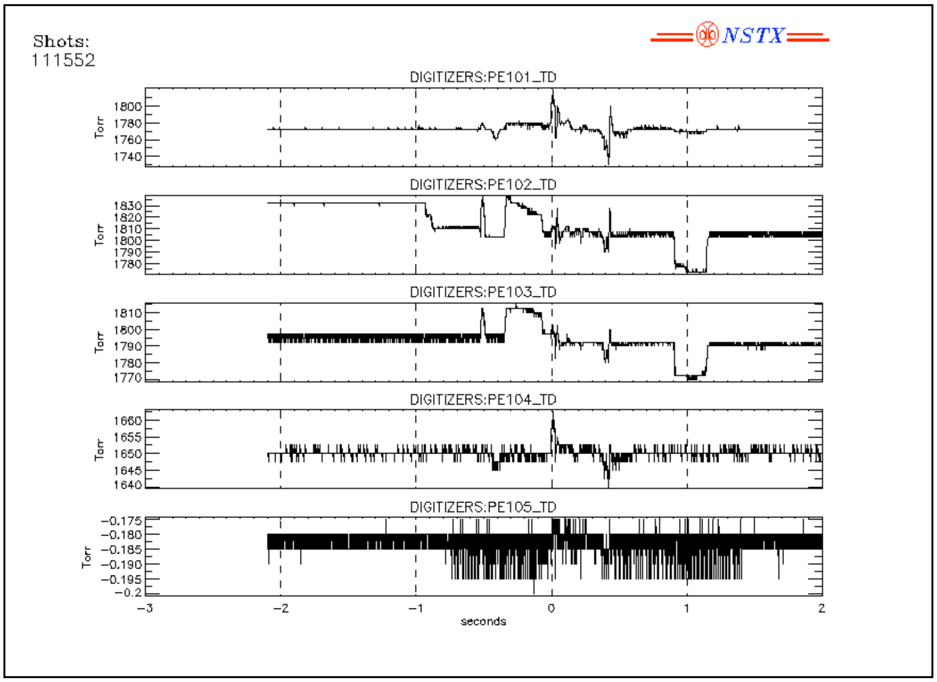
*1) The Helium discharge should be similar to discharge 111552.

2) The 2NBI, 1 MA, deuterium discharge should have an equilibrium similar to 111552.

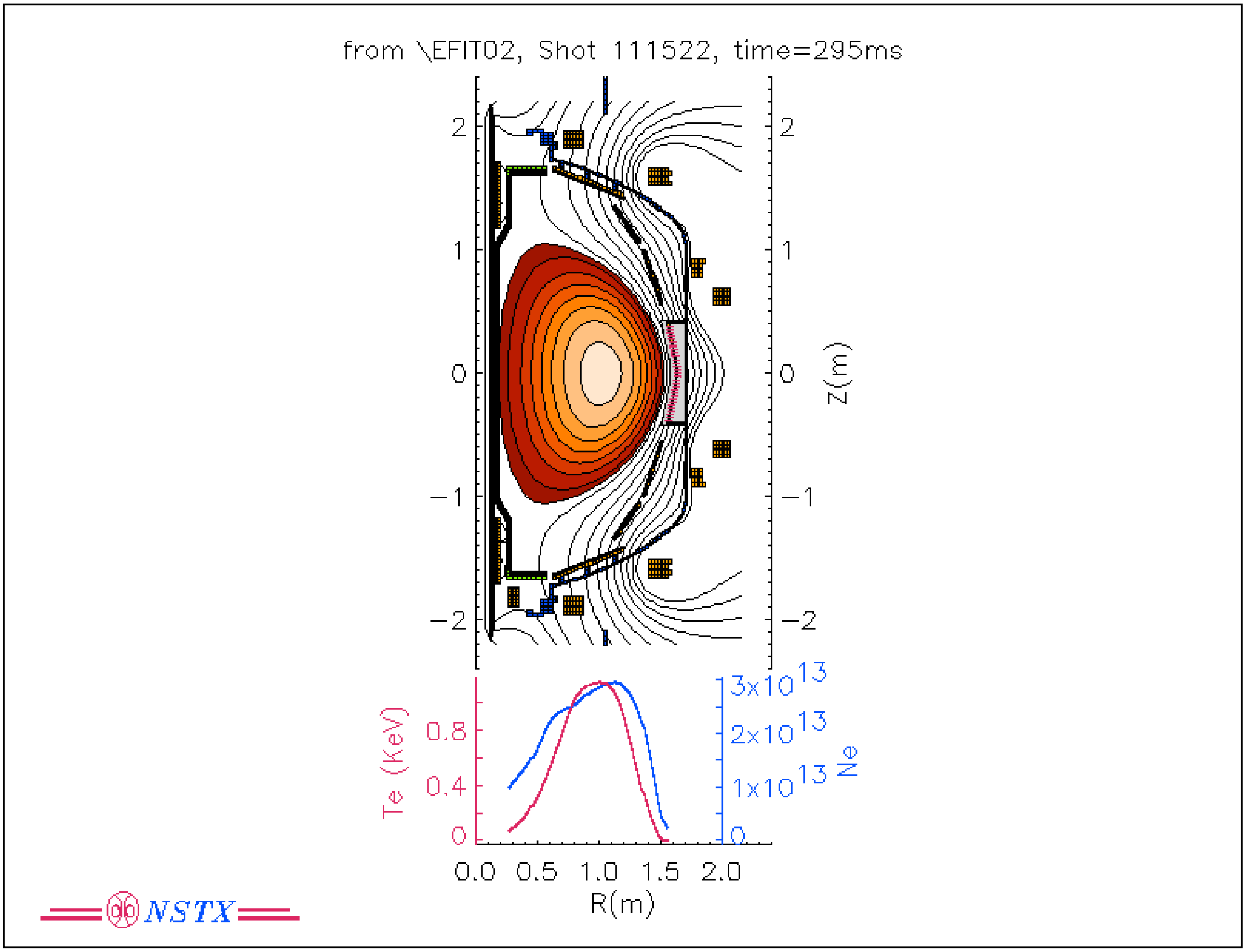
3) Refer to Fig.s 1-4 for 111552 waveforms.


Shots:
111522
NSTX
Corrected Ip1 (kA)
Loop Voltage
Outer Gap (cm)
q(0)
Plasma Volume (m^3)
Internal Inductance
HHFW + NBI Power
Beta toroidal (%)
Seconds
Seconds


Shots:
111522
NSTX
Plasma Current (KA)
\VIS_BREM
NF Slow 2FG
MPTS Max Te (keV)
SPRED (1000's)
Hard Xray Monitor
MPTS Line Ne (10^15 cm−2)
HHFW total power
HUp Chord 15 Cal
Radiated Pwr (uses EFIT)
NB P inj − MW
\BAYE_DALF_FSCOPE
seconds
seconds
Seconds



Shots:
111552
NSTX
DIGITIZERS:PE101_TD
DIGITIZERS:PE102_TD
DIGITIZERS:PE103_TD
DIGITIZERS:PE104_TD
DIGITIZERS:PE105_TD
Torr
seconds



from \EFIT02, Shot 111522, time=295ms
Z(m)
Te (KeV)
Ne
R(m)
NSTX

XP515: DIAGNOSTIC CHECKLIST

Diagnostic	Need	Desire	Instructions
Bolometer – tangential array	X		
Bolometer array - divertor	X		
CHERS	X		
Divertor fast camera	X		
Dust detector			
EBW radiometers			
Edge deposition monitor	X		
Edge pressure gauges	X		
Edge rotation spectroscopy		X	
Fast lost ion probes - IFLIP		X	
Fast lost ion probes - SFLIP		X	
Fast X-ray pinhole camera		X	
Filtered 1D cameras	X		
Filterscopes	X		
FIReTIP	X		
Gas puff imaging	X		
Infrared cameras	X		
Interferometer - 1 mm		X	
Langmuir probe array	X		
Magnetics - Diamagnetism	X		
Magnetics - Flux loops	X		
Magnetics - Locked modes	X		
Magnetics - Pickup coils	X		
Magnetics - Rogowski coils	X		
Magnetics - RWM sensors		X	
Mirnov coils – high frequency	X		
Mirnov coils – poloidal array	X		
Mirnov coils – toroidal array	X		
MSE			
Neutral particle analyzer	X		
Neutron measurements	X		
Optical X-ray		X	
Plasma TV	X		
Reciprocating probe		X	
Reflectometer – core		X	
Reflectometer - SOL		X	
RF antenna camera			
RF antenna probe			
SPRED	X		
Thomson scattering	X		
Ultrasoft X-ray arrays	X		
Visible bremsstrahlung det.	X		
Visible spectrometer (VIPS)	X		
X-ray crystal spectrometer - H	X		
X-ray crystal spectrometer - V	X		

Required Basic Diagnostics for XP515 Characterization and Analysis

1. During the conditioning and deposition phases, monitor CS limited Dα recycling as an indicator of the state of the wall.

This will be done using

1. CS midplane viewing 1 CCD Camera with a Dα filter
2. CS midplane viewing new Filterscope with a Dα filter
3. Upper and lower divertor viewing Dα Filterscopes
4. Midplane tangential viewing Dα Haifa Filterscope
5. Upward viewing new Organ pipe Dα Haifa filterscope

2. During the conditioning and deposition phases, monitor edge C II light for normalizing the limited Dα recycling as an indicator of the state of the wall.

This will be done using

1. Upper and lower C II and C III filterscopes.
2. Occasional Bay B Kodak camera with C II
3. CS midplane viewing new Filterscope with a C II filter

3. During the conditioning and deposition phases, monitor He II light for normalizing the limited Dα recycling as an indicator of the state of the fueling.

This will be done using

1. Midplane tangential He II filterscope

4. During the deposition and evaluation phases, monitor CS limited Li I as an indicator of the relative change in wall coverage.

This will be done using

1. VIPS II spectrometer set for Li I and Li II.
2. Bay B Kodak camera with Li I filter viewing CS and divertors.
3. CS midplane viewing new Filterscope with a Li I filter

5. LPI Radial Penetration will be viewed from

1. Bay G using Phantom-7 fast camera w/Li I filter (R. Maqueda and K. Williams)
2. Bay B Kodak with Li I filter (C.Bush)
3. Bay K tangential window w/RF Kodak camera w/gating & Li I filter (R. Kaita and T. Gray)
4. Bay L Canadian Photonics camera (June), visible, Li I, or Dα filters (R. Kaita and T. Gray)
5. Hiroshima camera on upper Bay D top with He II filter (R. Kaita and S. Paul)