RESULTS FROM, AND PLANS FOR, LTX

Presented by Dick Majeski

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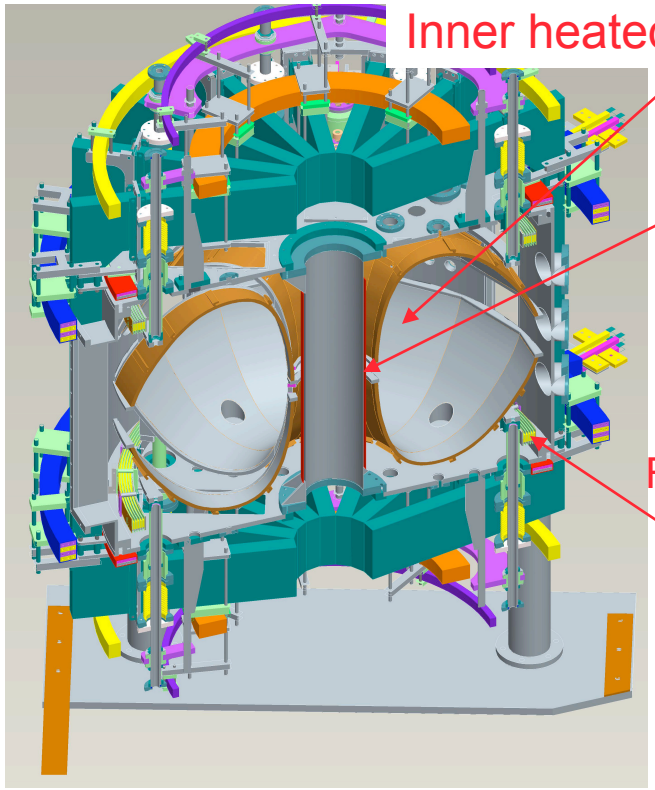
Outline

- LTX overview
  - Fueling and diagnostics
- Evaporator system
- Overview of results with room-temperature (solid) lithium wall coatings
- Results with hot “liquid” lithium walls
- Near term plans
- Summary

LTX –full hot wall with lithium coatings to investigate low recycling operation of a tokamak



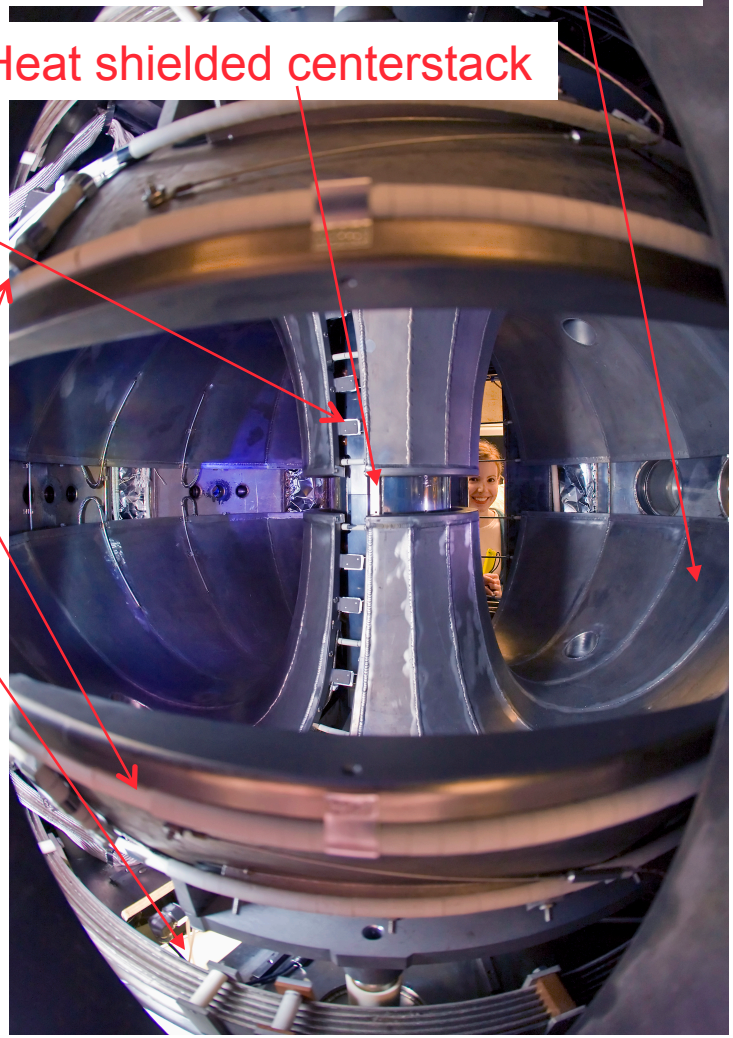
Inner heated shell (explosively bonded SS on copper)

Heat shielded centerstack

2-axis Mirnov coils

Flux loops

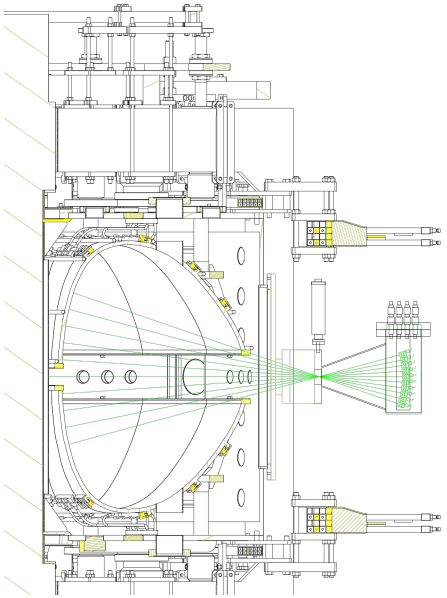
Fast, uncased internal coil

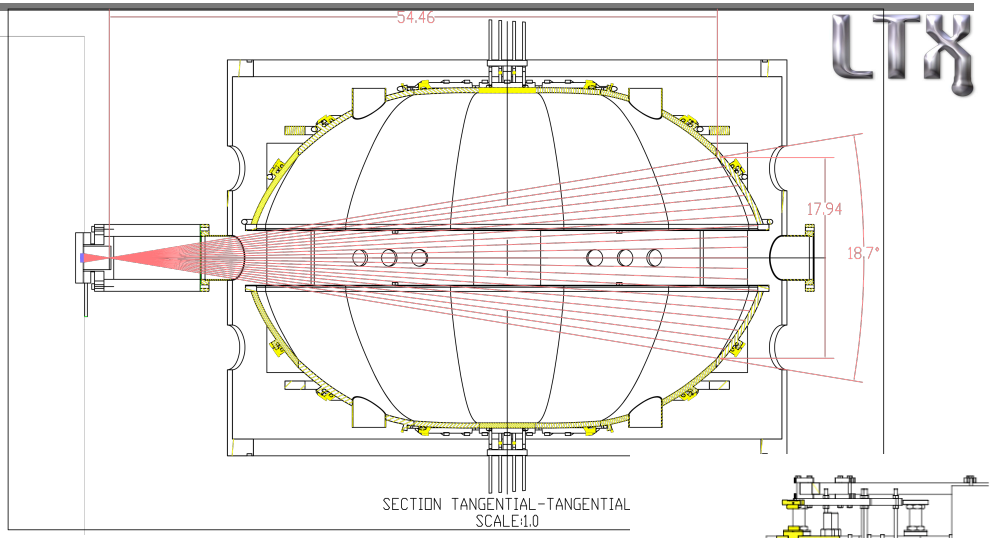


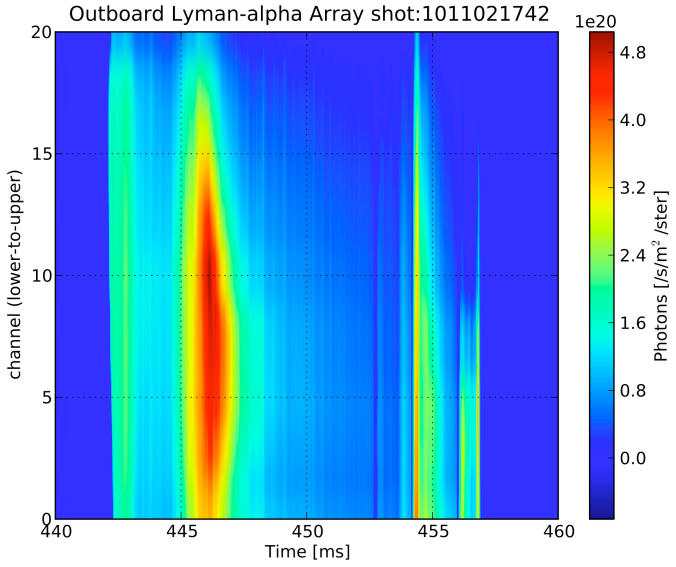
Parameter	LTX (2010)
Major radius	0.4 m
Minor radius	0.26 m
Toroidal field	0.34 T (0.21T)
Plasma current	300 kA (70 kA)
Duration	100 ms (20 ms)
Ohmic flux	160 mV-s (50 mV-s)
Wall temp.	400 °C (300 °C)

Recycling measurements employ Lyman-α arrays

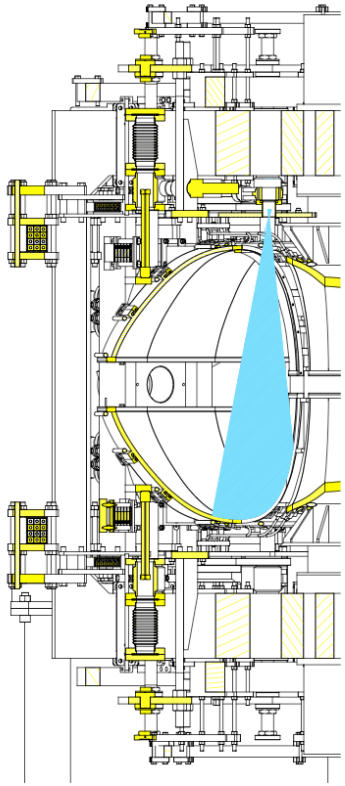
- Lyman-α array viewing shell high-field (inner) side
- Replaced for upcoming run with a JHU-style detector set
  - Lower noise







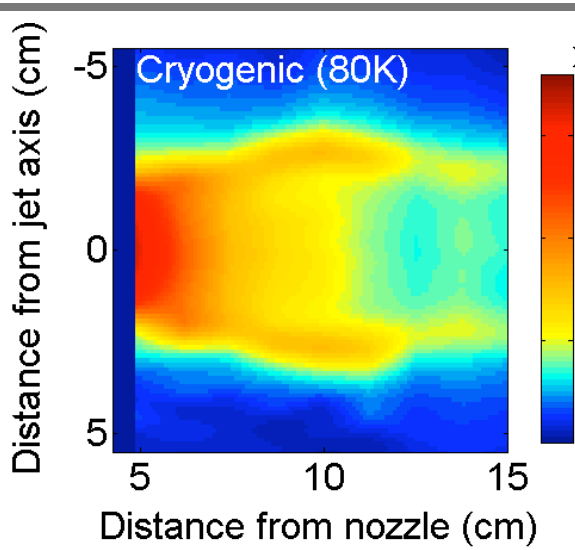
- View of shell low-field (outboard) side through tangential port (array developed by K. Tritz, JHU)



- View of lower molybdenum limiter in lower shell

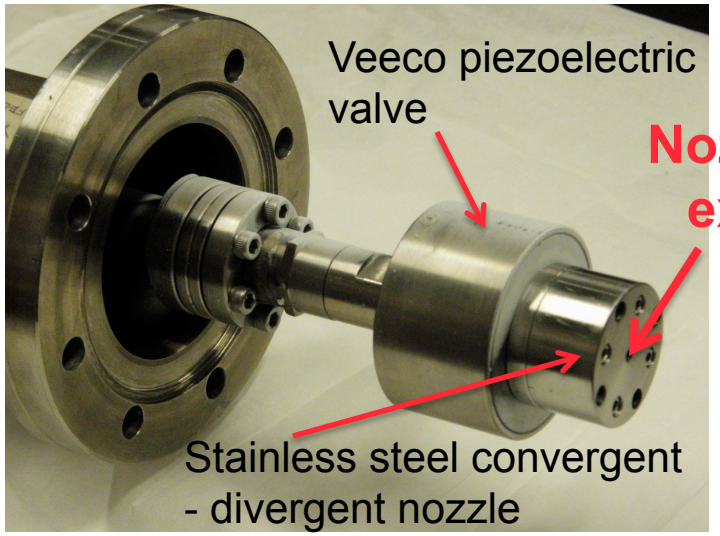
Recycling source being replaced by active fueling

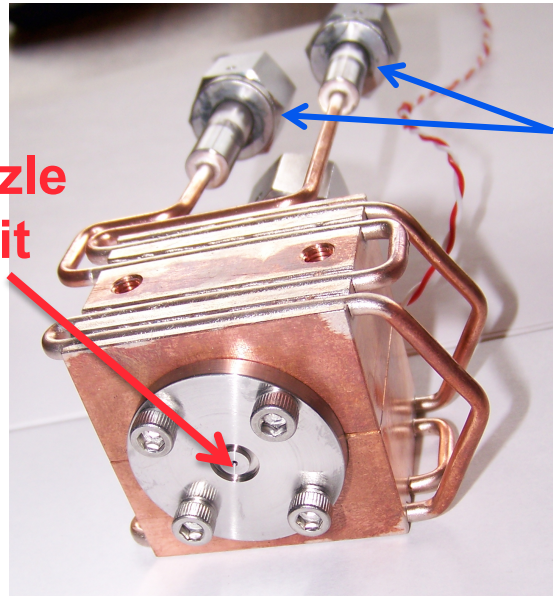
- Molecular cluster injector for LTX
  - Precooled (82K) gas condenses through nozzle exhaust
    - ➢ Forms clusters ~ 10^4 molecules
  - Less expansion of jet
  - High fueling capability
  - Millisecond response
- Combined with existing SGI



Gas density in MCI jet exceeds 10^{22} m^{-3} - between a pellet and conventional gas fueling

Supersonic Gas Injector (SGI)



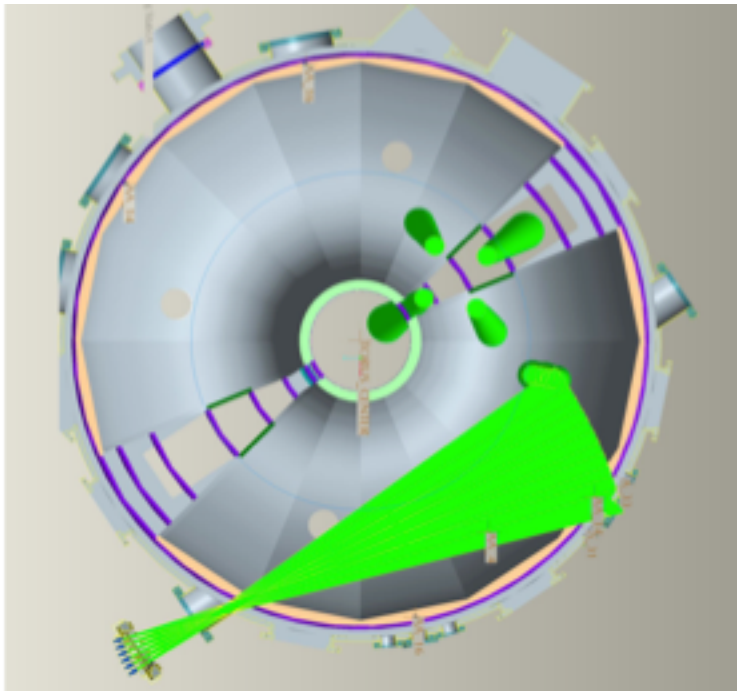


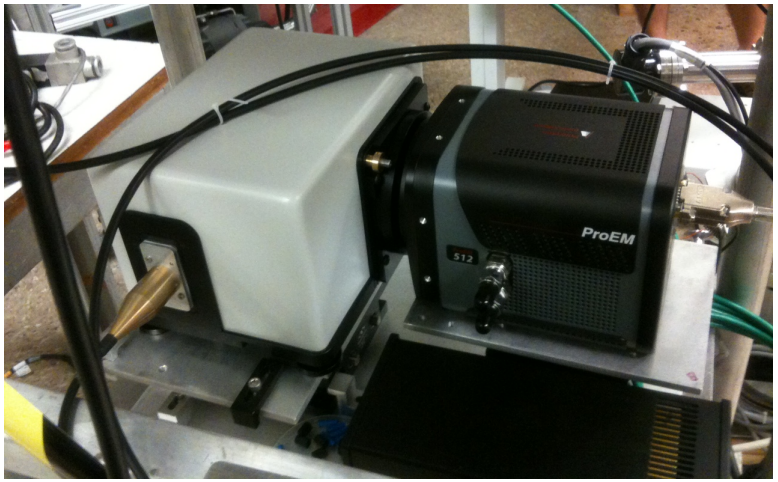
Liquid nitrogen inlet, outlet

Molecular Cluster Injector

Passive CHERS system now installed
Active CHERS next year, with NBI (ORNL)

- Measure Li III and Li II light levels of lithium in LTX
  - 6 toroidal sightlines
  - 8 up-down symmetric poloidal sightlines
- High throughput, short focal length optical spectrometer
  - Coupled to a ProEM 512 Princeton Instruments CCD camera
  - Similar to designs pioneered on NSTX
- These measurements are necessary to estimate lithium charge-exchange light levels once the DNB is installed on LTX





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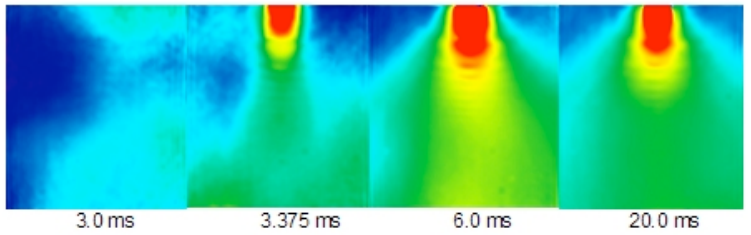
Plasma and Gas density Measurements with Digital Holography

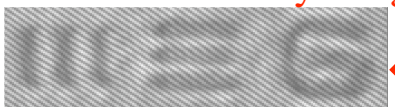
- Angle between reference and object beams creates fringe pattern on detector
- Spatial FFTs and filters extract phase information from sidebands
- High spatial-resolution (~1mm) images of plasma or gas density
- Frame rates of 500Hz (256x256) to 43kHz (64x4)
- AOM allows for 1us snapshots
- Currently working to remove vibration noise from system

ORNL Ar disruption mitigation jet

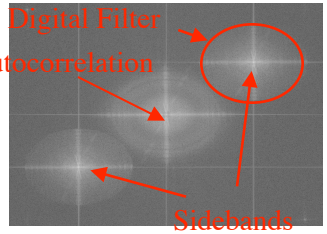


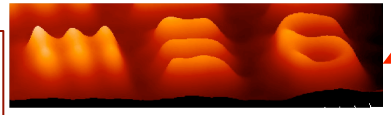
~$4x10^{20}$ cm^{-3}

Air Force Target
Raw Digital Hologram Input
intensity image



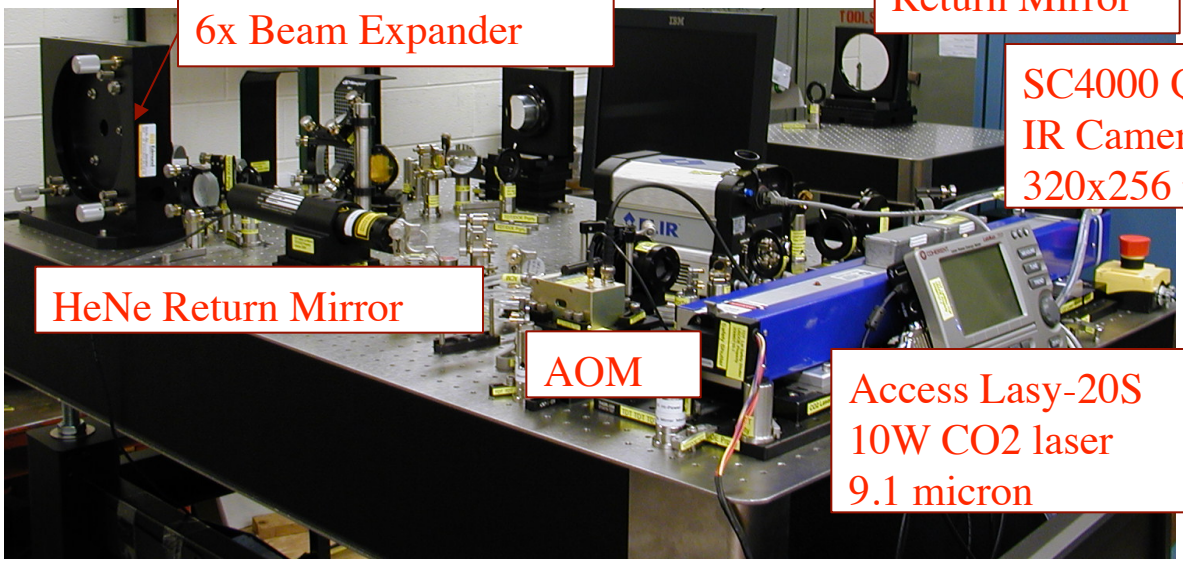
2D FFT



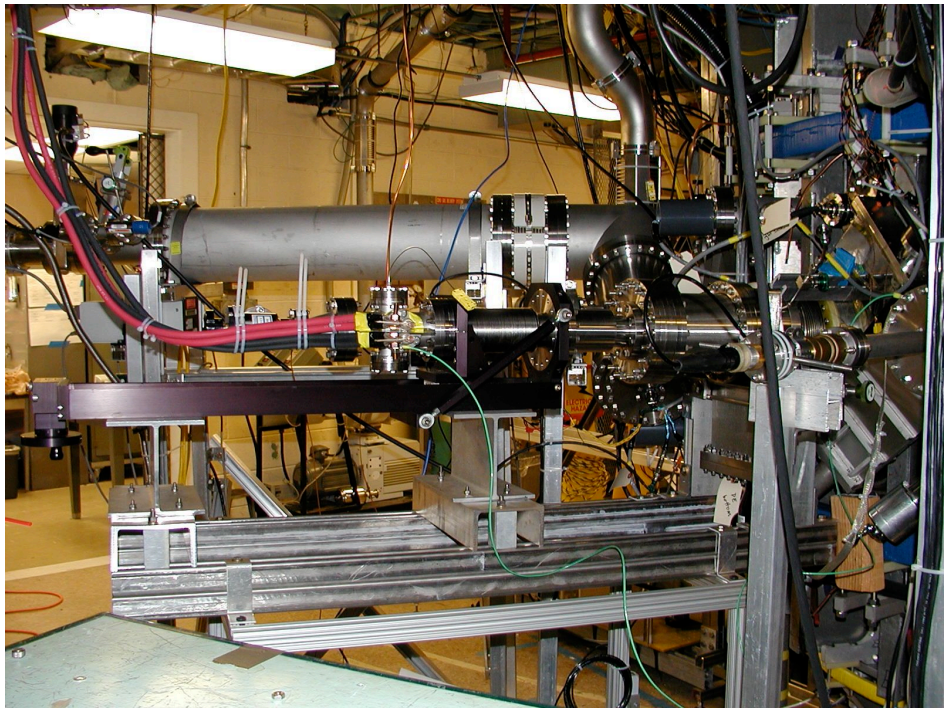


2D IFFT of filtered & Centered sideband

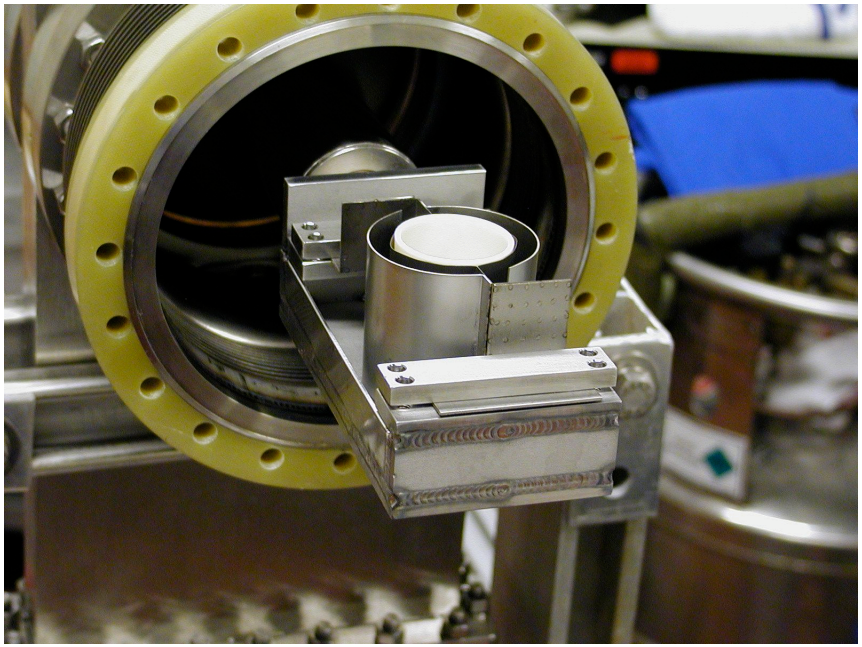
Output phase



New lithium coating systems developed for LTX



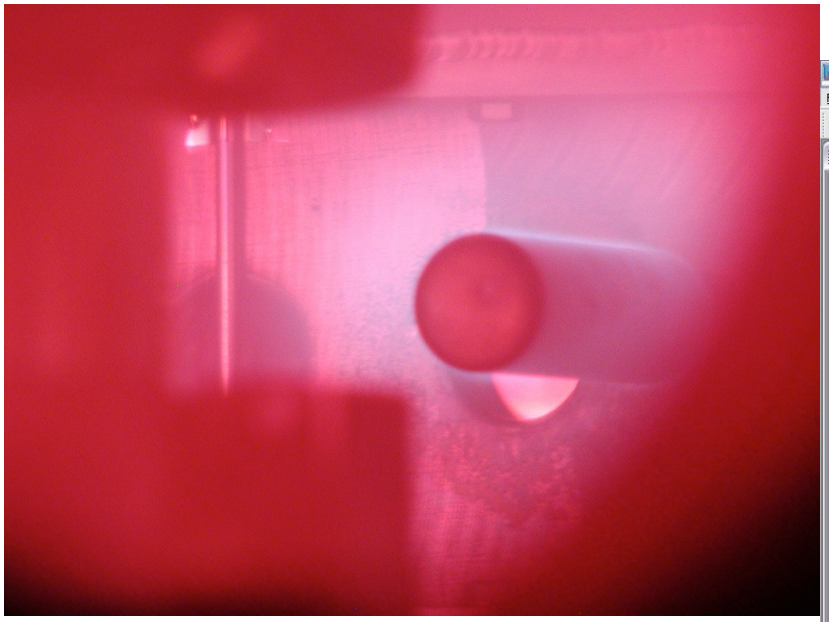
Evaporator (1 of 2) with linear motion stage mounted on LTX



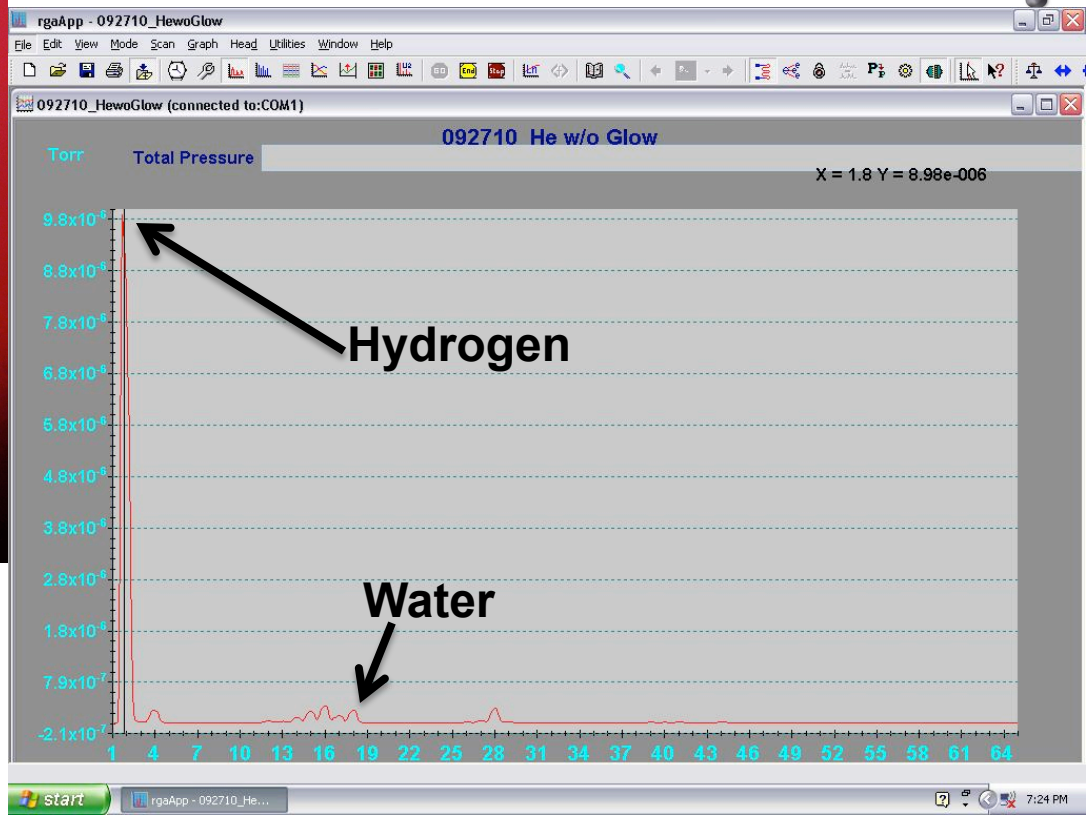
Y_2O_3 crucible, Ta heater
➢Tested to 700 °C

- Two evaporators installed
- 44g total lithium evaporated in 2010
  - Sufficient for a 4 micron coating of the entire shell

Lithium initially evaporated into helium glow



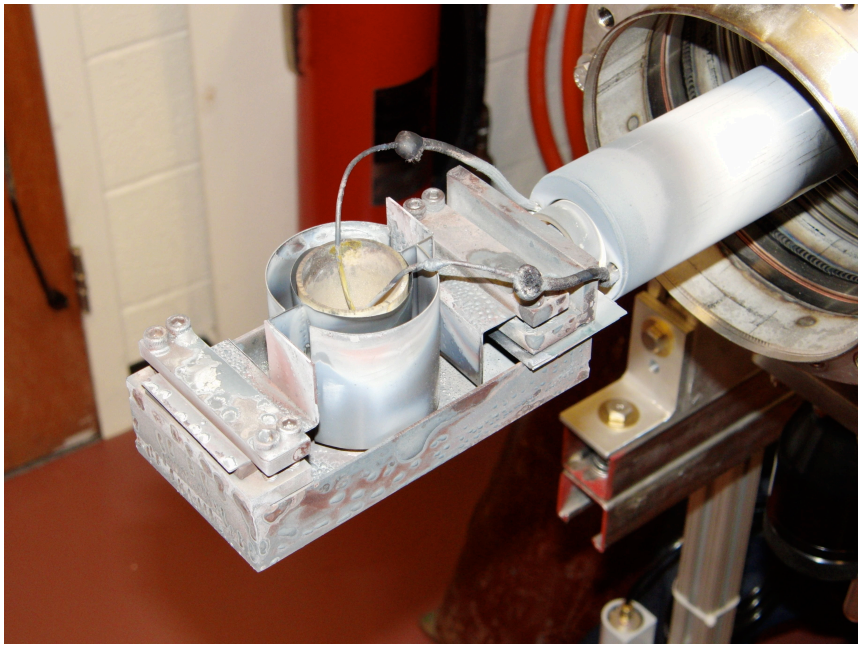
Glow probe head
>Lithium-dominated discharge
>Working gas was helium



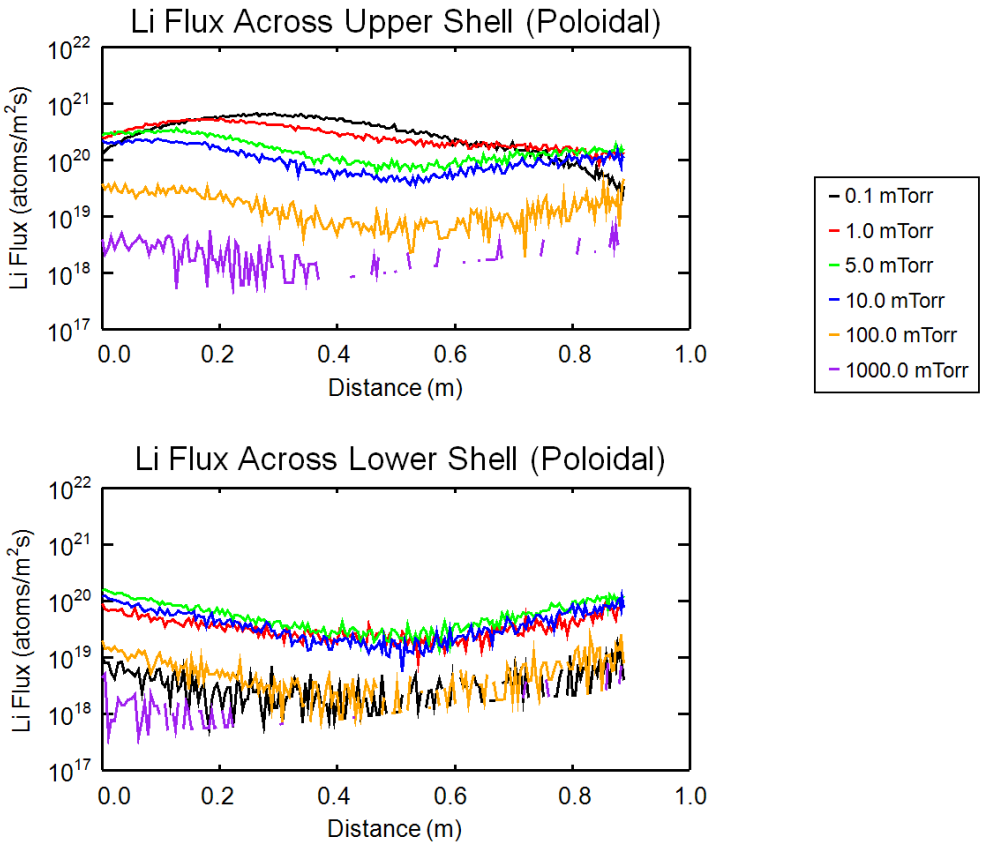
RGA trace indicating lithium gettering of water
>Trace is dominated by liberated hydrogen

- Glow allowed visual evaluation of extent of lithium diffusion from crucible sources

Crucibles and heaters effective, simple, reliable

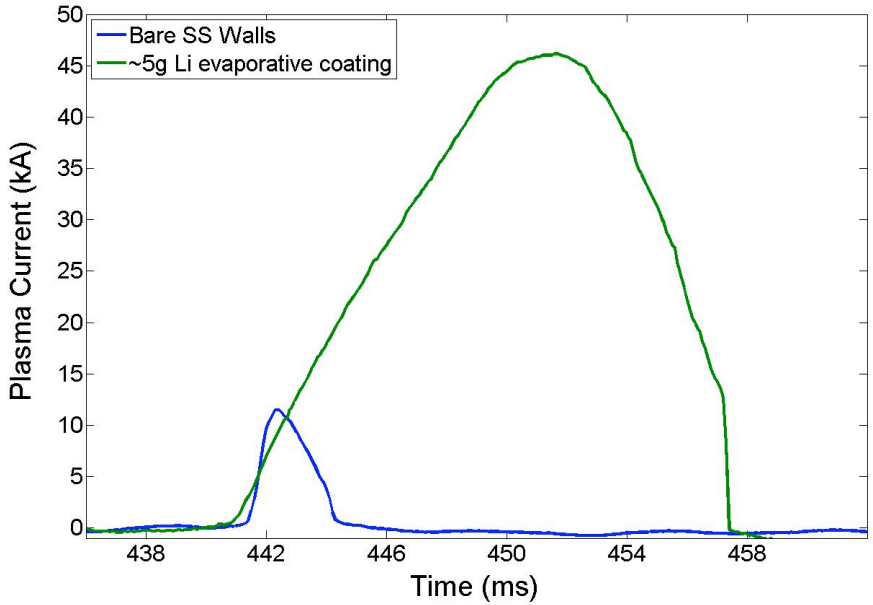


DEGAS2 modeling of lithium distribution over the shell surface

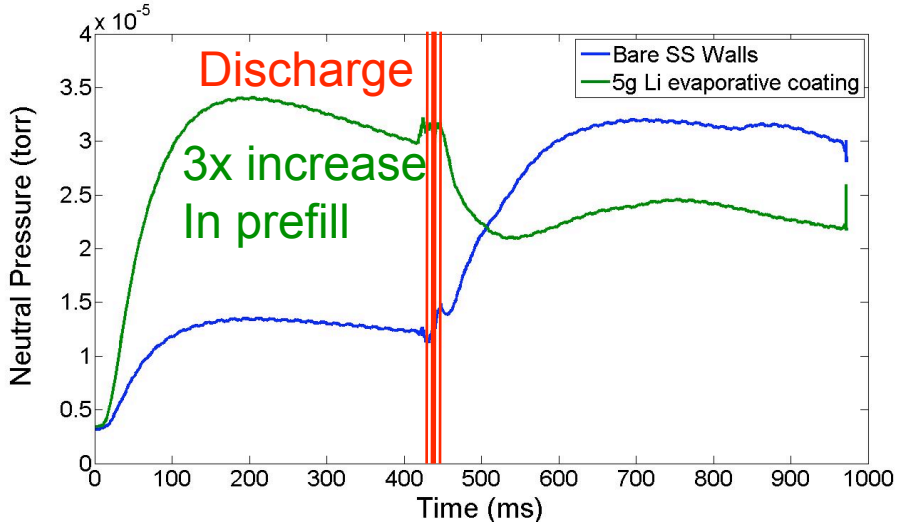


- Helium glow or simple backfill used to disperse lithium
- Coverage moderately uniform for helium fill pressure ~ 10 mTorr

Lithium wall conditioning produced immediate effect on the discharge



Plasma current comparison

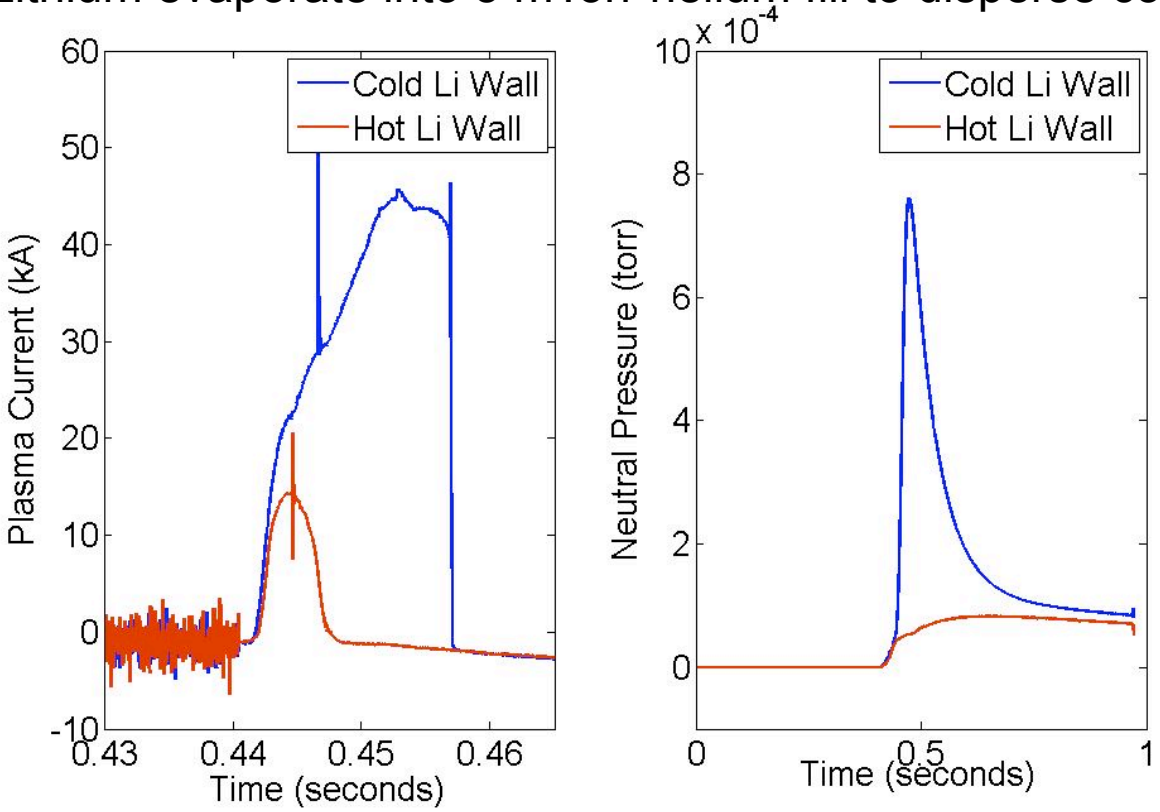


Pressure evolution

- First lithium operation shown – cold shell
- Lithium glow was preceded by helium glow on hot (250C), bare shell for preconditioning
- Discharge current, duration significantly increased following Li glow
- Pressure history shows evidence of reduction in recycling

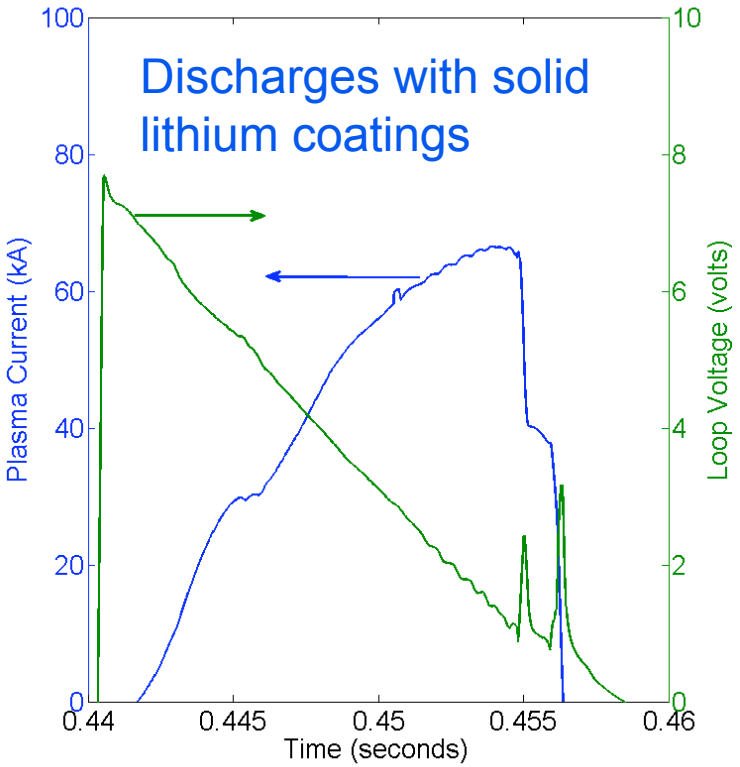
LTX was operated with a lithium-coated 300 °C shell

- First full high temperature, high Z wall operation of a tokamak
  - Lithium evaporate into 5 mTorr helium fill to disperse coating

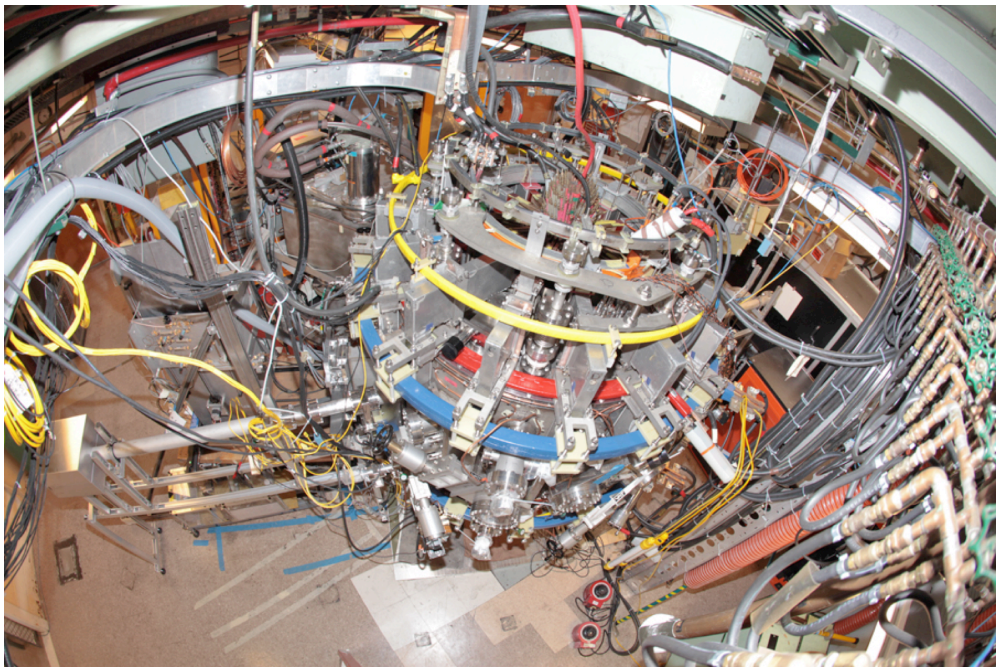


- **Hot (300 °C) shell with thin lithium coatings does *not* exhibit a significant reduction in recycling**
  - Analysis indicates impurities segregate to the surface of hot lithium
  - Relevant to any experiment with lithium on a hot substrate

Current LTX status



- (Almost) overhead fisheye view of LTX

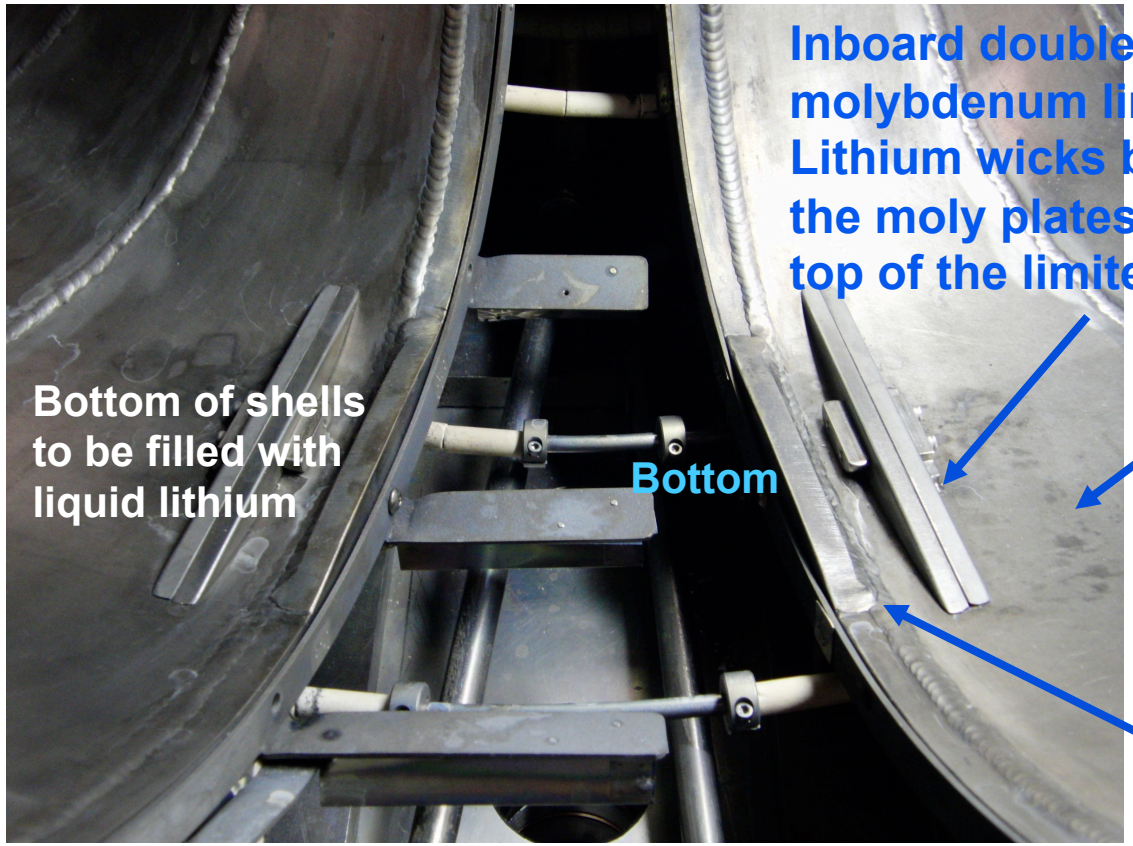


- Plasma current ~70 kA, shot duration ~20 msec
  - Thomson: T_e ~ 150 eV
- Shells routinely heated to 300 C for bakeout (cold for Li deposition)
- Operated with lithium coatings October – December 2010
  - Vented in early 2011 – first vent since 2009
  - Resuming operations now

Research program for 2012

- LTX is now operational after vent for modifications
- New capabilities being added in 2012:
  - Lithium getter pump system nearing completion
  - Vacuum vessel bakeout, cooling systems being installed
  - Expanded Ohmic power supply to be implemented in stages
  - Toroidal field increase to 0.3T (late 2012)
  - High resolution edge Thomson scattering
  - 5A, 20-40 kV, 1 sec neutral beam + CHERS (ORNL)
  - Stirred liquid lithium fill system for lower shell
- Research program:
  - Continued discharge development with lithium wall coatings
  - Revisit hot wall experiments
  - Move to operation with a liquid lithium pool in the lower shell
  - Recycling characterization
  - Confinement determination, as a function of global recycling
    - Begin NBI, beam-based diagnostics

Lower shells designed for liquid lithium pools



- Lower shells have welded stainless steel lips to retain lithium
- Double molybdenum limiters are designed to wick lithium
  - Tested – wicking system works
  - Limiters extend 2 mm above the stainless steel retention lips to reduce plasma contact with the retention lips

Summary

- LTX began operations with lithium walls in October 2010
  - No other low-Z wall conditioning preceded introduction of lithium
- Lithium coatings produced immediate effect on discharge
  - Plasma current: 15 ➔ 70 kA (~CDX-U)
  - Plasma duration: 5 – 20 msec (~CDX-U)
- Observe rapid passivation of hot (300C) lithium films
  - Indications of impurity surface segregation
- Better thermal control of the vacuum vessel in implementation
  - Controlled bakeout + active cooling
- Enhanced pumping being installed with new lithium getter pumps
- Resume operation with lithium coated walls in October
- Liquid lithium fill of lower shells scheduled for later in 2012