The Lithium Tokamak eXperiment (LTX) – Status and Plans

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Lithium Tokamak eXperiment - LTX

- Lithium wall technology: static, molten thin (~10 µ) films
  - Heated, conformal wall with small plasma-wall gap (~0.5 cm average)
    » Explosively bonded 1.5 mm SS on 1 cm OFHC nickel plated copper
    » Copper backing for temperature stability
    » Liquefied lithium film on heated metal wall
    » Designed for 550 °C to promote wetting of SS by lithium, 300 – 350 °C during tokamak operation to limit evaporation
  - Second shell (FY11 or 12) - plasma sprayed porous molybdenum inner surface
    » First full 500 °C high Z wall in a tokamak
- Plasma fueling with pulsed gas jets (SGI) and molecular cluster injection
  - NBI in next phase (20 keV, 5 A, full discharge duration in 2011-12)
LTX has a full, 5 m² liquid lithium film coated wall

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CDX-U</th>
<th>LTX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major radius</td>
<td>0.34 m</td>
<td>0.4 m</td>
</tr>
<tr>
<td>Minor radius</td>
<td>0.22 m</td>
<td>0.26 m</td>
</tr>
<tr>
<td>Toroidal field</td>
<td>0.21 T</td>
<td>0.34 T</td>
</tr>
<tr>
<td>Plasma current</td>
<td>100 kA</td>
<td>400 kA</td>
</tr>
<tr>
<td>Current flattop</td>
<td>5 ms</td>
<td>&gt;100 ms</td>
</tr>
<tr>
<td>Ohmic flux</td>
<td>30 mV-s</td>
<td>160 mV-s (centerstack maximum: 225 mV-s)</td>
</tr>
<tr>
<td>Wall temp.</td>
<td>20 °C</td>
<td>400 °C now, ~ 600 °C future</td>
</tr>
</tbody>
</table>
Shell was designed for 500 °C operation to promote wetting, test Li temperature limits

ANSYS modeling (500 °C shell)
- Shell radiating into the vacuum chamber
  - 29 kW heater power required
  - Centerstack, vessel wall fitted with water cooling (still unused)
- Centerstack is fitted with heat shield
- Shell now baked routinely to 300 °C
  - Projected continuous wall temperature limit: 560 °C
- Determine wall temperature limit for lithium
  - CDX-U limiter operated to 450 °C without significant Li impurity
  - Sufficient for testing Sn-Li eutectics

Second shell vacuum plasma sprayed with molybdenum at PPI
Considering option to spray original shell with tungsten and re-install.
Recycling source being replaced by active fueling

- Molecular cluster injector for LTX
  - Precooled (82K) gas condenses through nozzle exhaust
    ➢ Forms clusters
  - Less expansion of jet
  - Fueling capability exceeds 700 T-L/s
  - Millisecond response
- Similar system used for core fueling on HL-2M (China)

![Cluster injector](image)

![Graph](image)
Recycling measurements employs Lyman-α arrays

- Lyman-α array viewing shell high-field (inner) side
- View of shell low-field (outboard) side through tangential port (array developed by K. Tritz, JHU)
- View of lower molybdenum limiter in lower shell
- Mo limiter designed to wick lithium from lower shell reservoir
New lithium coating systems developed for LTX

- LTX will begin with thin coatings of liquid lithium on a hot wall
- Final assembly of the coating systems is taking place now
  - Complete this week
- Final steps are safety systems (backup pumping system, etc)
  - In final preparation now

**Linear motion feedthrough to insert evaporator (two in all)**

- Y$_2$O$_3$ crucible, Ta heater
  - Tested to 700 °C
Lithium operations commence soon

- Multiphase IGBT-based H-bridge supply operating routinely
  - Exploring new flexibility in OH waveform
- Presently operating at ~15 kA plasma currents, <10 msec pulses
  - Using ECH-assisted startup, to minimize OH-induced shell eddy currents
- Lithium will also reduce loop voltage, eddy current effects
  - Pre-lithium discharge development should be completed in ~2 weeks
Copper shell strongly affects PF evolution.
LTX LRDFIT (2D) simulates 3-D shell currents.
Fully 3-D electromagnetic shell model completed

- 3-D model (L. Zakharov, now implemented) includes details of shell, vacuum vessel
  - Triangular solid mesh, NOT a wireframe model
- Integrates PF coils, magnetic sensors, equilibrium reconstruction
- Now being coupled to a discharge development code to predictively design poloidal field evolution
LTX confinement research program for FY11-12

- Introduce lithium - 20g (coatings) => 100-200g (pool in lower shell)
- Spherical tokamak equilibria with a very low recycling coefficient and pulsed gas fueling
  - Fuel with SGI (existing) and a molecular cluster injector (new)
- Employ 140 channel magnetics system, Thomson scattering
  - Global confinement, $T_e$ profile
- Employ 2 channel interferometer, pulsed fueling
  - Particle transport
  - Add digital holography ($\delta n_e$) in FY10-11
- New capabilities to be added in 2010 - 2011
  - Edge Thomson for near-wall $T_e$ gradient
  - Full toroidal field (3.2 kG)
  - 100 kW NBI for ion heating, CHERS
  - Complete full OH power supply
    - 400 kA

Predicted confinement time for LTX from Reference Transport Model (Zakharov, Pereverzev): 20 – 30 msec for Ohmic operation, 50 – 60 msec with NBI
PMI and edge plasma research on LTX

- Phase II SBIR with Ultramet, Inc (with UCLA, Purdue participation) for a sample exposure system
  - System will be based on the transport mechanism for the CDX-U lithium rail limiter, courtesy of UCSD
  - Solids, high recycling LM heated at T>500 °C to eliminate lithium coatings
- Purdue proposes to develop an in-situ liquid surface science station (LS3) for plasma-lithium interactions in LTX
  - Built in part around the sample exposure probe
  - LTX will contribute additional spectroscopy
- ORNL proposes to undertake 2D modeling of the LTX edge with SOLPS
  - Edge CHERS with the Nova Photonics diagnostic beam
    » Edge plasma rotation profile
    » Edge particle, momentum, energy balance
  - Lyman-α analysis, H-α with a filtered CCD camera, filterscopes
- Impurity influx from PMI (also ORNL)
  - Spectroscopic identification of impurity sources
  - Two-color IR imaging of the lithium-coated shell