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Planning for Toroidal Lithium Divertor Target for NSTX and Supporting Experiments on CDX-U/LTX

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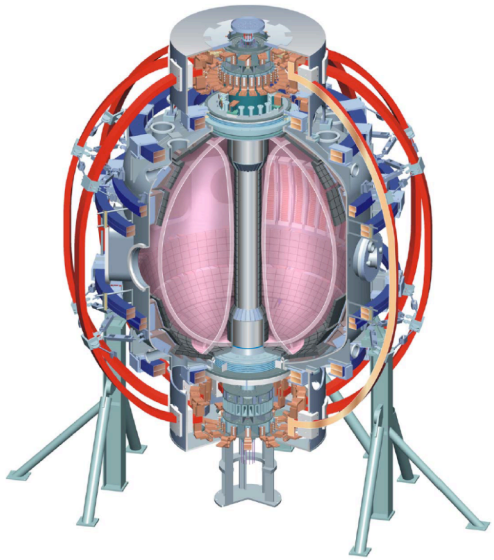
R. Kaita

Boundary Physics Science Focus Group Meeting

July 15, 2005

Princeton Plasma Physics Laboratory



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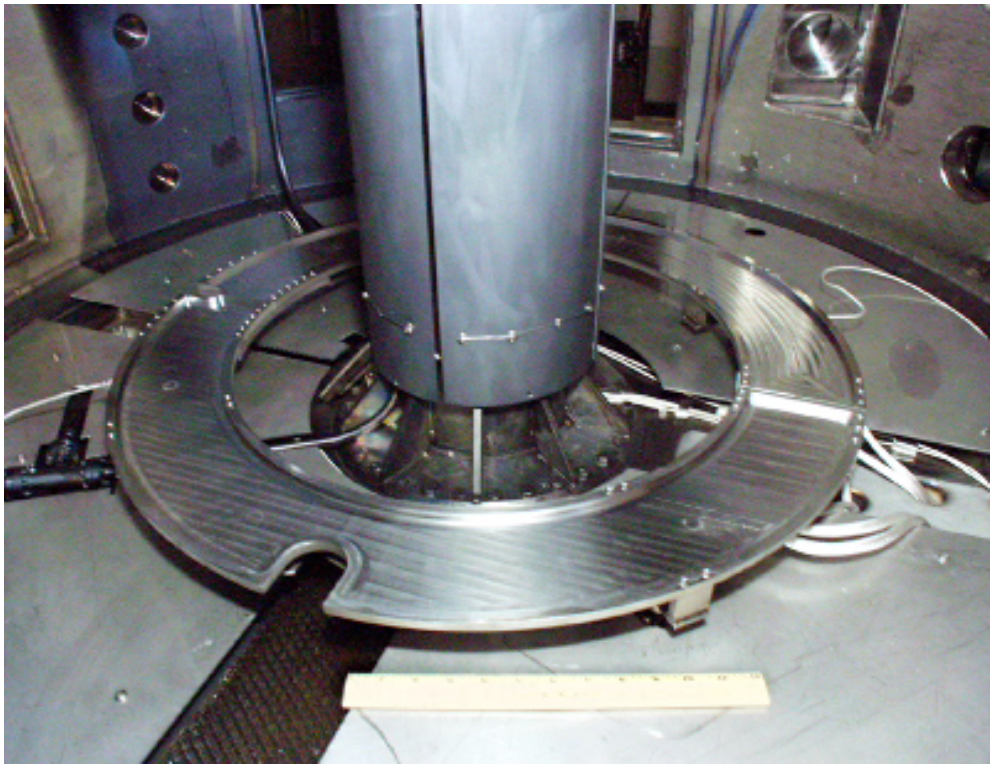
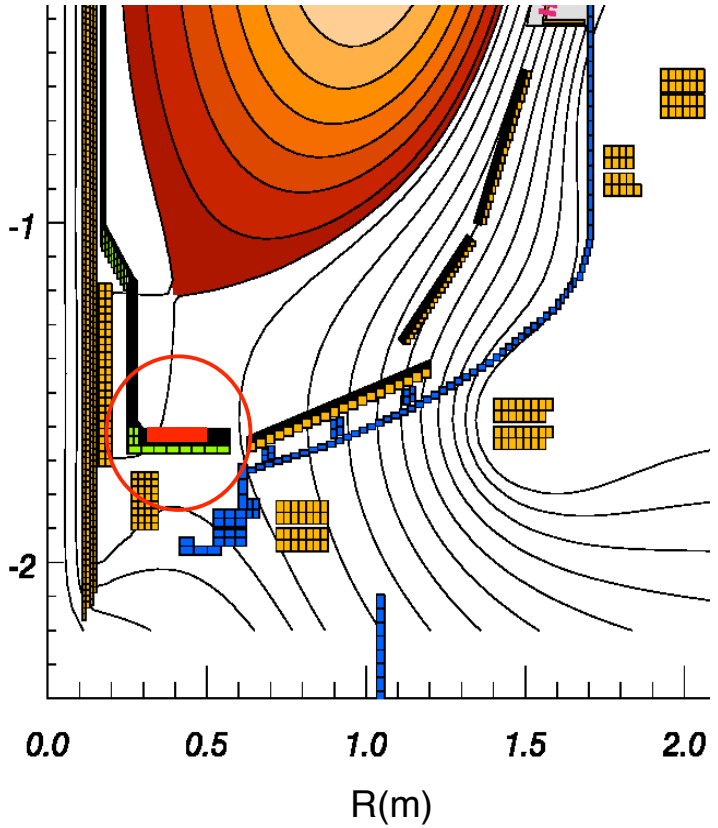
A Fully Toroidal Liquid Lithium Divertor Target is under consideration for NSTX





Concept based on CDX-U liquid lithium limiter tray

- Recent electron beam heating experiments suggests that flowing lithium target may not be necessary
- Marangoni effect induces strong convection that results in efficient heat transport

NSTX design, fabrication, and safety issues can be addressed based on experience from CDX-U

Materials

- Bare stainless steel tray withstood months of exposure to lithium
- Plasma sprayed alternatives under investigation by Plasma Processing, Inc.

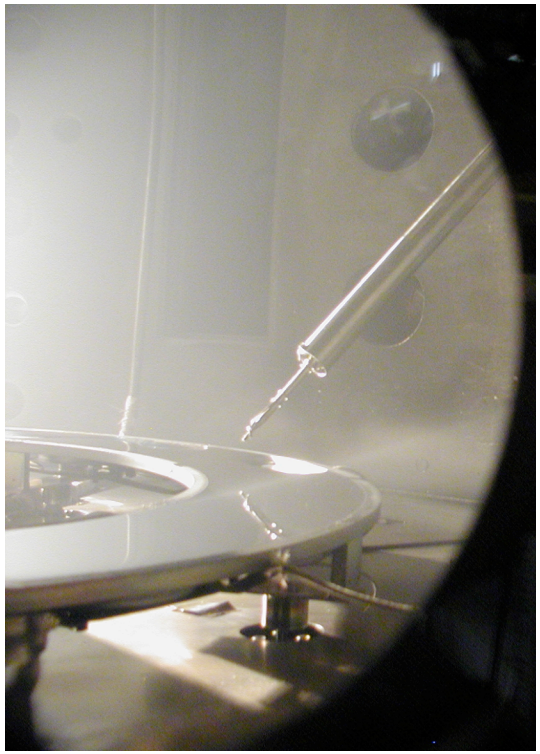
Design

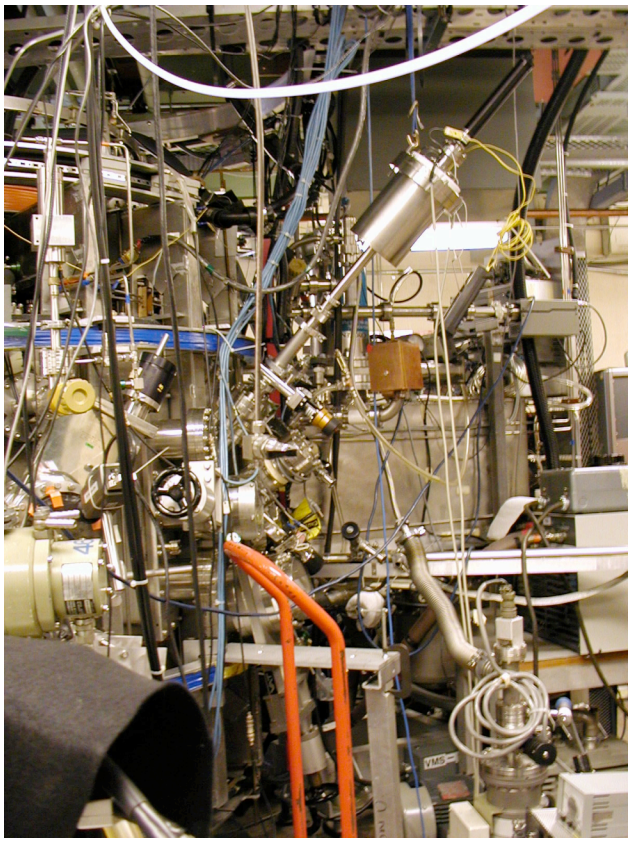
- CDX-U tray fabricated in two halves with toroidal break to eliminate *jxB* forces on lithium
- Need for toroidal break in liquid lithium divertor target is an issue for NSTX

Safety

- Several cycles of lithium loading, machine venting, and tray removal for cleaning performed safely

Loading of NSTX liquid lithium divertor target can use concept developed for CDX-U





Loader

- Developed by collaborators at University of California at San Diego
- Successfully used for several safe loadings of liquid lithium into CDX-U tray
- Available for NSTX if desired - further offline development may be required

Effect of vertical field on lithium motion can be investigated on CDX-U

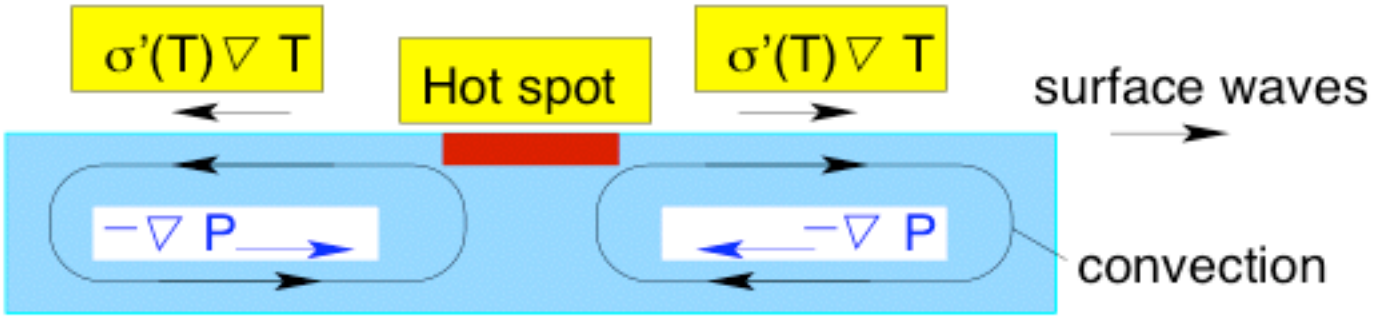
NSTX

Marangoni Effect

- Appears to be responsible for efficient heat transport by convection
- Vertical field on CDX-U can be ramped to maximum strength in steps to look for suppression of flow
- Need modeling to determine magnitude of vertical field required to observe effect

Surface tension gradient generates a viscous fbw inside liquid lithium

$$\frac{\partial \vec{V}}{\partial n} = \frac{\sigma'(T)}{\nu}\nabla_s T_s, \quad \vec{V} \simeq \frac{\sigma'(T)}{\nu}\nabla_s T_s d \simeq 0.12\nabla_s T_s d, \quad (d \text{ is the thickness of fbw})$$



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Effect of Lithium Divertor Target on plasma performance cannot be tested currently on CDX-U

Experience to date

- Most conspicuous effect of lithium on reduction of recycling observed in *limiter* experiments
  - T-11: Mesh limiter
  - TFTR: Limiter coatings with various techniques
  - CDX-U: Toroidal liquid lithium limiter
  - NSTX: Center stack coating with lithium pellet injection

Experiments in progress

- Initial pellet injection experiments have shown effect of lithium on density in NSTX lower single null plasmas
- Divertor plasmas not possible with present coil configuration on CDX-U

Effect of divertor plasmas on Lithium Divertor Target cannot be tested currently on CDX-U

DiMES experiments on DIII-D

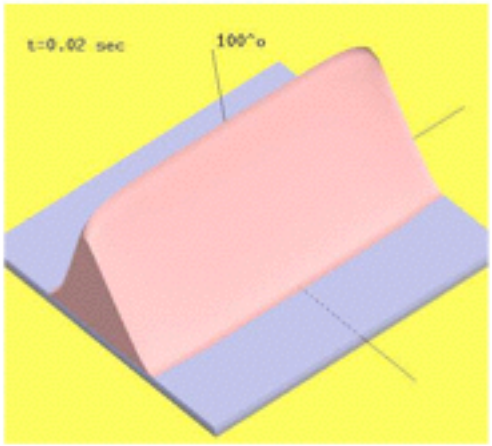
- Lithium expelled when strikepoint was positioned over sample holder

  - UCLA modeling suggests that higher than expected induced currents (300 - 400 A) in sample holder required for *jxB* forces to expel lithium

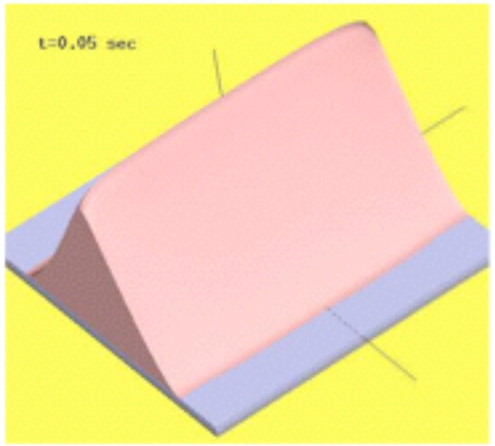
  - Small volume and lithium in foil layers greatly reduced heat dissipation

Recommendation for NSTX

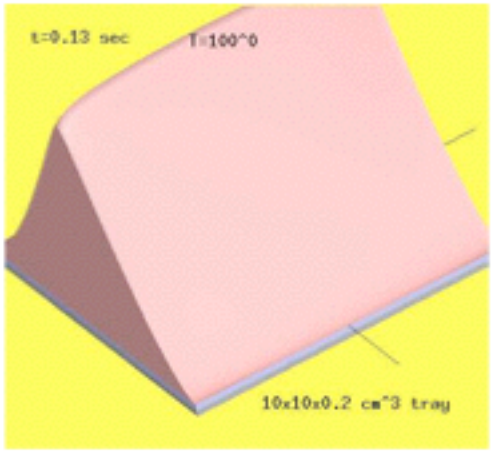
- UCLA modeling should be performed to determine effect of *jxB* forces on liquid lithium in planned divertor target with larger lithium volume



Li 2 mm tray, $t = 0.02$ sec



$t = 0.05$ sec



$\Delta T_s < 30^o, \quad t = 0.13$ sec

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Summary

CDX-U experience to date addresses several key divertor target issues

- Materials, design, and safe handling of lithium
  - Toroidal break an issue for NSTX divertor
- Liquid lithium loaders available

Information from CDX-U experiments before shutdown will be limited

- Vertical field can be ramped to look for suppression of Marangoni flow if maximum achievable value is adequate to produce observable effect

Remaining issues best addressed with NSTX experiments and modeling

- Divertor plasmas not possible with present coil configuration on CDX-U
  - Effect of lithium in divertor from pellet injection observed in NSTX
- UCLA modeling should be performed to determine effect of *jxB* forces on liquid lithium in planned divertor target