Measurements of radiated power and spectroscopic emission during LiTER lithium conditioning experiments in NSTX

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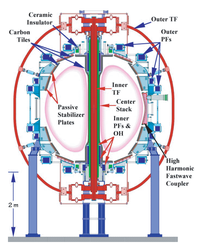
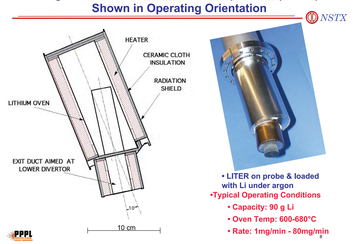
Abstract: TP8.00065 Lithium vapor was injected into the NSTX vacuum vessel by heating lithium in a stainless steel oven that was placed in close proximity to the plasma facing components during the 2007 experimental campaign. Low-Z coating experiments using carbonization, boronzation, an lithium pellets have been used for many years to improve confinement and performance. Time-resolved radiated power profiles of the total plasma radiation in the mid-plane was measured using a 16-channel tangential bolometer. Results showed that confinement was appreciably affected during the runs with lithium deposition. Generally, ELM's were either reduced or eliminated for hundreds of milliseconds, and the density profiles were peaked, rather than flat as in typical H-mode plasmas. The metallic impurity profiles tended to be highly peaked as well, often accompanied by strong impurity accumulation in the center of the plasma. In the more severe cases, the volume-integrated radiated power would exceed 50% of the total input power and the estimated concentration of metals on axis (modeled using iron as the representative impurity) reached 0.2% of the electron density.



Good diagnostic access to NSTX, a spherical tokamak

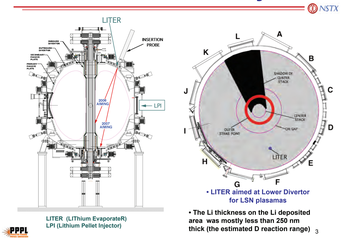
- Open divertor configuration
- Allows viewing from midplane and between plate structures

Diagram and Photo of LIThium EvaporatoR (LITER) Shown in Operating Orientation



- LITER on probe & loaded with Li under argon
- Typical Operating Conditions
  - Capacity: 90 g Li
  - Oven Temp: 600-680°C
  - Rate: 1mg/min - 80mg/min

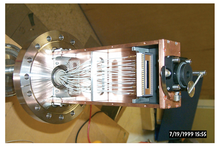
Poloidal and Toroidal Layout



- LITER aimed at Lower Divertor for LSN plasamas
- The Li thickness on the Li deposited area was mostly less than 250 nm thick (the estimated D reaction range)

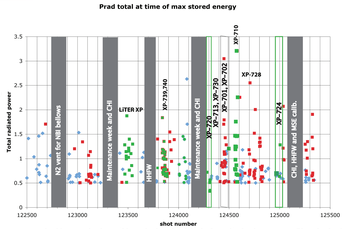
Photograph of Tangential Bolometer

NSTX bolometer is a 16-channel XUV photodiode array



- The bolometers used in NSTX were convenient to implement because 16 detectors are contained in a single array. The pin-hole camera, along with the shutters and shielding is comparatively compact.
- The AXUV sensors that detect soft X-ray emission are very sensitive compared to heat-sensing foil bolometers.
- The disadvantage is that the signal is linearly proportional to incident photon flux only for photon energies above 50 eV, so in NSTX, the bolometer is used to detect radiation from the high temperature core.

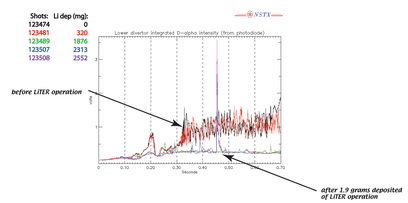
Overview of high emitted radiation shots in the NSTX campaign in 2007



- Plotted here are only those shots with substantial total radiated power. Short shots, fizzles, etc. are omitted. Maintenance weeks, RF operation and CHI operation are blanked out.
- While there are ample shots with impurity accumulation during LITER opeations, there are also a large number of shots that accumulate without LiTER (and prior to LiTER).
- The blue points are those high Prad shots that DID NOT have peaked profiles. The green and red points are high radiation shots that were peaked.

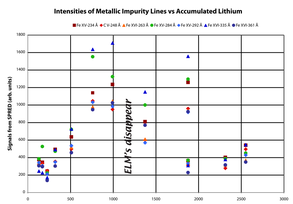
Folliwing the Liter XP, there were as many peaked Prad shots with LiTER as without

After 2 grams of Li deposition, the ELM intensity was greatly reduced



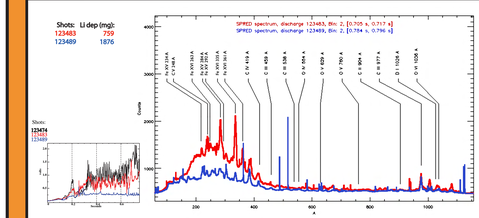
- One very noticable trend is that shortly after several about 2 grams of lithium are deposited, the ELM's disappear.
- At the outset of Li operation, the accumulation and impurity radiation rises significantly, but there are ample exceptions.
- Example of EXCEPTIONS: impurities on shot 123487 (with 1,373 mg accumulated LI) did accumulate, though the ELM intensity was comparable to the previous shot.

Radiated power seen from Soft UV Spectroscopy showed increase INITIALLY



- With initiation of Li deposition the radiated power from the metals rose and peaked when 1 gram was applied.
- But afterwards, the emitted power fell to pre-Li levels, though the ELM's continued to be suppressed.
- The principle metallic lines are iron, with some nickel, and occasionally some copper.

But after 1 gram of Li deposition, emission from metallics (iron) decreases.

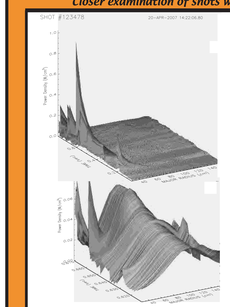


- After 500 mg of lithium deposited, the peak SXUV emission increases by at least a factor of two.
- With 1,000 mg lithium deposited, the ELM's are reduced to very low levels and SPRED shows that the radiation from metals does too.
- The ELM reduction FOLLOWS the decrease in metallics emission.

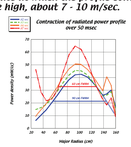
Summary and Conclusions

- While there are ample shots with impurity accumulation during LiTER opeations, there are also a large number of shots that accumulate without LiTER (and prior to LiTER operation).
- At the outset of Li operation, the accumulation and impurity radiation rises significanty,
- With 1,000 mg lithium deposited, the ELM's are reduced to very low levels and the radiation from metals does too.
- Shortly after several about 2 grams of lithium are deposited, the ELM's disappear.
- With more lithium deposited, the inward accumulation occurs at a much slower rate, but it occurs for a long period of time, typically several hundred milliseconds.

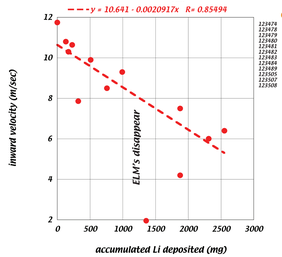
Closer examination of shots where accumulation of impurities are observed



- At first glance, Shot 123478 did not appear to show any evidence of impurity accumulation.
- Expanding the scale from .62 to .67 seconds shows that peaking of the profile does occur, but the peak power density is relatively low (60 mW/cc) and the duration over which the accumulation occurs is brief, about 40 msec.
- The rate at which the profile contracts is quite high, about 7 - 10 m/sec.

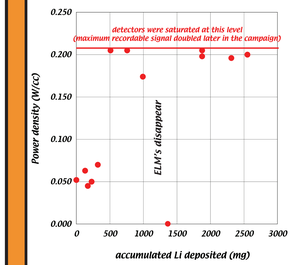


Plot of maximum time rate of change of the width of the P_{rad} profile



- The inward convection of high-Z impurities is very rapid for the reference shots for this series of discharges, but it occurs for a brief period of time about 20-40 msec.
- With more lithium deposited, the nward accumulation occurs at a much slower rate, but it occurs for a long period of time, typically several hundred milliseconds.
- There are EXCEPTIONS: impurities on shot 123487 (with 1,373 mg accumulated LI) did not convect into the center at all. The Prad profile was hollow.

Plot of the peak radiated power density on axis



- After 500 mg of lithium deposited, the peak power density abrupt increases by at least a factor of four.
- With more lithium deposited, the inward accumulation occurs at a much slower rate, but it occurs for a long period of time, typically several hundred milliseconds.
- There are EXCEPTIONS: impurities on shot 123487 (with 1,373 mg accumulated LI) did not convect into the center at all. Prad on axis was 0.

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