Dependence of impurity accumulation on Ip and the outer gap in the presence of lithium deposition in NSTX

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Abstract

Lithium coatings have been routinely applied by evaporation onto the carbon surfaces of the lower divertor and other plasma-facing components in NSTX. Shortly after commencing evaporation, a reduction in the frequency of ELMs was observed, eventually completely suppressing them for periods up to about 1s as deposition continued. Co-incident with ELM suppression, the effective ion charge increased as a result of a buildup in carbon, though lithium itself remained at a low level in the core. Radiated power steadily increased as medium-Z metallic impurities, notably iron, accumulated in the core of the plasma. This phenomenon might occur in these NBI-heated, deuterium H-mode plasma because the lithium coating modifies the recycling of hydrogenic species, affecting the plasma's edge. Another possibility includes the role of sputtering from metal surfaces by fast ions introduced by NBI heating as a result of the changes in the plasma edge and scrape-off layer. This has been investigated by changing the amount of fast beam ion loss by varying the plasma current, neutral beam tangency radius and the gaps between the plasma boundary and surrounding components. Results from bolometry and XUV spectroscopy show that at the plasma current much more strongly affects accumulation of metals compared to the gap between the plasma and the outer limiter.

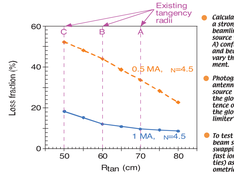
Overview of experiment

- Operations in the presence of lithium, deposited on plasma facing components, have resulting in many shots exhibiting strong impurity accumulation. (see S.F. Paul, C.H. Skinner, J.A. Robinson, R. LeBlanc, H.W. Kugel, J. Nuc. Mat., vol. 390-391, pp. 211-215).
- This experiment is designed to investigate the dependence of impurity generation on a number of operational parameters.
- One hypothesis is that impurity accumulation may be observed only with lithium because the reduction in the neutral gas blanket that normally surrounds the plasma.
- One scan is performed at high plasma current, designed to minimize the loss of fast ions by keeping the width of banana orbits of trapped fast-ions small. Particles orbits close to the magnetic axis (where the banana width is largest according the formula):

$$\delta_{Ban} = \frac{mv}{qB_\theta} \propto I_p^{-1/2}$$

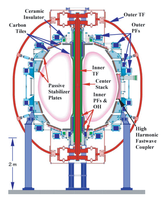
have the largest banana widths. A large outer gap keeps the magnetic axis farther from the plasma facing components. The expectation is that accumulation of metallic impurities will decrease when the outer gap is increased

Background and Justification



Beam ion loss rate model shows strong dependence on I_p and R_{tan} of beamline

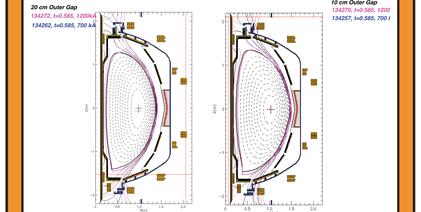
- Calculation of the beam ion loss rate shows a strong dependence on Ip and Etan of the beamline, with particles from the beam source with largest tangency radius (source A) confined best. Both the plasma current and beam geometry are the tools used to vary the lost fast ion flux in this experiment.
- Photographs taken previously of the NSTX RF antenna limiter during NBI with source C (the source with the largest tangency radius) show the glowing edge of the limiter. The persistence of the light after the shot indicates that the glowing is from IR emission from the limiter's being heated to high temperatures.
- To test the effects of beam geometry, only two beam sources are used, thus allowing the swapping of sources so that the differences in fast ion losses (and fast-ion induced impurities) associated with the difference beam geometries can be isolated.



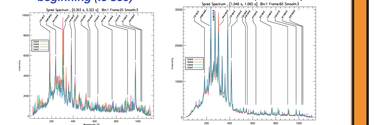
Good diagnostic access to NSTX, a spherical tokamak

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

Shapes used in this XP showing differences in outer gap and plasma current

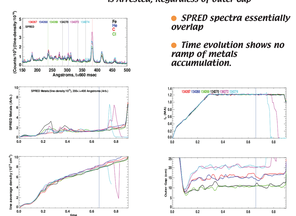


Early injection of NBI (during current ramp up) showed no difference at any time.



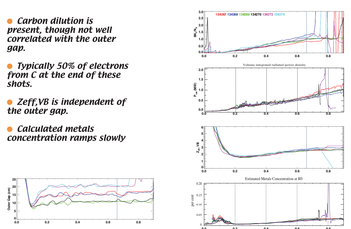
- Both at the beginning of the discharge .3 seconds through the end (1.05 sec) the SPRED spectra virtually overlay
- Very little effect was seen when beam timing was varied

At IP=1,200 kA, BT=0.5 Tesla, SPRED Shows that Accumulation of Metals is Arrested, Regardless of Outer Gap



- SPRED spectra essentially overlap
- Time evolution shows no ramp of metals accumulation.

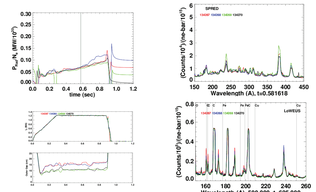
At IP=1,200 kA Prad and Carbon Dilution is independent of outer gap



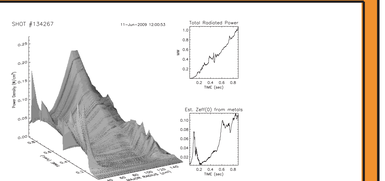
- Carbon dilution is present, though not well correlated with the outer gap.
- Typically 50% of electrons from C at the end of these shots.
- Zeff,VB is independent of the outer gap.
- Calculated metals concentration ramps slowly

At 1,200kA, the observed metal lines are small and independent of the outer gap

As measured by the LoWEUS X-ray spectrometer (150 to 300 Å)

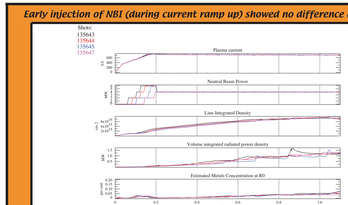


Radiated Power Profiles less peaked at high Ip



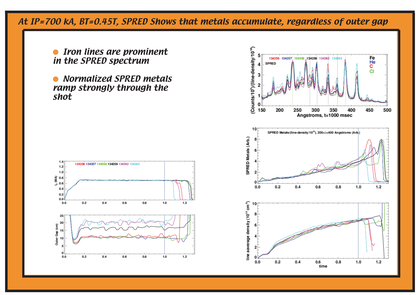
- Slightly less peaked Prad profile at 1,200 kA is indicative of less intense metallic accumulation in the core
- Prad reaches 1.0 MW and the metals Zeff is 0.1 at .9 sec.

Early injection of NBI (during current ramp up) showed no difference at any time.



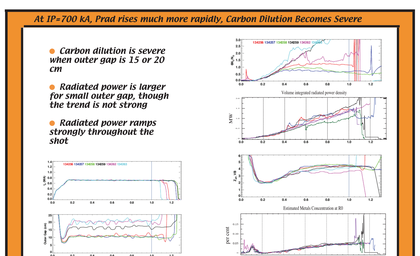
- The total radiataed power and the estimated metals concentration are virtually identical.
- Very little effect was seen when beam timing was varied

At IP=700 kA, BT=0.45T, SPRED Shows that metals accumulate, regardless of outer gap



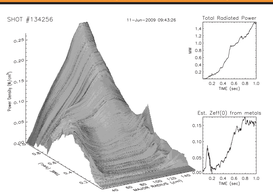
- Iron lines are prominent in the SPRED spectrum
- Normalized SPRED metals ramp strongly through the shot

At IP=700 kA, Prad rises much more rapidly, Carbon Dilution Becomes Severe



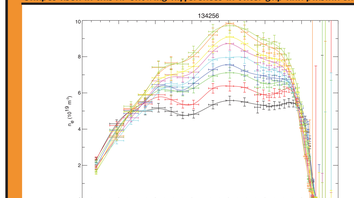
- Carbon dilution is severe when outer gap is 15 or 20 cm
- Radiated power is larger for small outer gap, though the trend is not strong
- Radiated power ramps strongly throughout the shot

Radiated Power Profiles More Peaked at low Ip



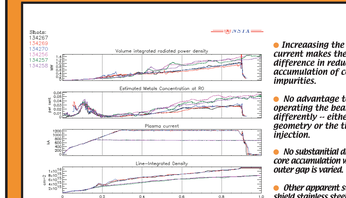
- Peaked Prad profile is indicative of metallic accumulation in the core
- Strong carbon accumulation when the gap is 15 or 20 cm
- Prad reaches 1.2 MW and the metals Zeff is 0.16 at .9 sec.

Shapes used in this XP showing differences in outer gap and plasma current



- Zeff due to metals is responsible for the rising central peak in electron density between R = 0.8 and 1.2 meters
- Metals contribute about 3% of the electrons

Conclusions from experiment



- Increasing the plasma current makes the largest difference in reducing the accumulation of core impurities.
- No advantage to operating the beams differently -- either the geometry or the time of injection.
- No substantial difference in core accumulation when the outer gap is varied.
- Other apparent strategy is to shield stainless steel components at the mid-plane with either refractory metal or graphite.

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