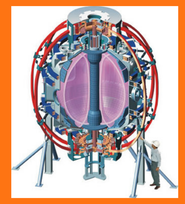
Identification and time evolution of impurities in NSTX plasmas

J. K. Lepson[a], P. Beiersdorfer[a,b], M. Bitter[c], L. Roquemore[c], G. Zimmer[c], S. Gerhardt[c], J. Kallman[c], R. Kaita[c]

[a] Space Sciences Laboratory, University of California, Berkeley CA 94720
[b] Lawrence Livermore National Laboratory, Livermore CA 94550
[c] Princeton Plasma Physics Laboratory, Princeton, NJ 08543

lepson@ssl.berkeley.edu



OVERVIEW

Operation of the NSTX tokamak with lithium-coated plasma facing components has shown many beneficial changes, including MHD quiescence and higher electron temperatures near the edge. Impurity accumulation, however, is of concern, especially during ELM suppression. Spectroscopic diagnostics are important in determining the composition and concentration of plasma impurities, which can vary dramatically between shots and for different run conditions. We present data from the Livermore XEUS and LoWEUS spectrometers which observe the extreme ultraviolet and soft x-ray regions on NSTX. XEUS and LoWEUS are complementary, and have been set up to cover the 10-250 Å range during the most recent run period. Because of their higher spectral resolution than provided by the SPRED spectrometer, the instruments can discern lines from different elements and charge states. We have also implemented time resolved data acquisition, providing the first data on when the particular metal impurities appear in the plasma. The time resolution presented here is 150 ms, but we achieved a resolution of <50 ms at the end of the 2009 run.

We present spectra from NSTX exhibiting a wide range of impurities, including lithium, boron, carbon, oxygen, neon, iron, copper, titanium, and nickel, which serve as reference spectra for tracking the different impurities.

LoWEUS was designed and built at LLNL and is based on the XEUS spectrometer at NSTX, which was used for laboratory astrophysics at the Livermore electron beam ion traps EBIT-II and SuperEBIT before being moved to Princeton. The two instruments are complementary, with XEUS covering the 10-60 Å range and LoWEUS the 60-200 Å range, extendable to 400 Å.

Because the NSTX plasma has an electron density approximately 2 orders of magnitude greater than EBIT plasmas, XEUS and LoWEUS provide an important complement to the EBIT laboratory astrophysics program.

The spectral range covered by XEUS and LoWEUS encompasses a number of emission lines from ions that are diagnostically important for plasma conditions inside NSTX, as well as for laboratory astrophysics. The strong line of hydrogenic lithium at 135 Å is of particular interest for NSTX diagnostics, especially relative to other impurities, notably oxygen and carbon. Emission lines of iron, particularly the Fe L-shell 2->2 transitions in the 10-15 Å and 88-135 Å region and the Fe M-shell 3->3 transitions in the 170-220 Å region, are important density diagnostics for solar and stellar astrophysics. Other important diagnostic lines include the O IV-VI group at 170 210 Å and C III and C IV in the 250 - 400 Å range.

Fig. 1) CCD images from XEUS with a time resolution of ~150 ms and showing evolution of lines of copper, iron, oxygen, nitrogen, carbon, and boron. Shot was 1.3 seconds long, with T_e (max) 0.9 keV and neutral beam injection 4 MW. Frame 6, with maximum emission strength, is shown separately for clarity.

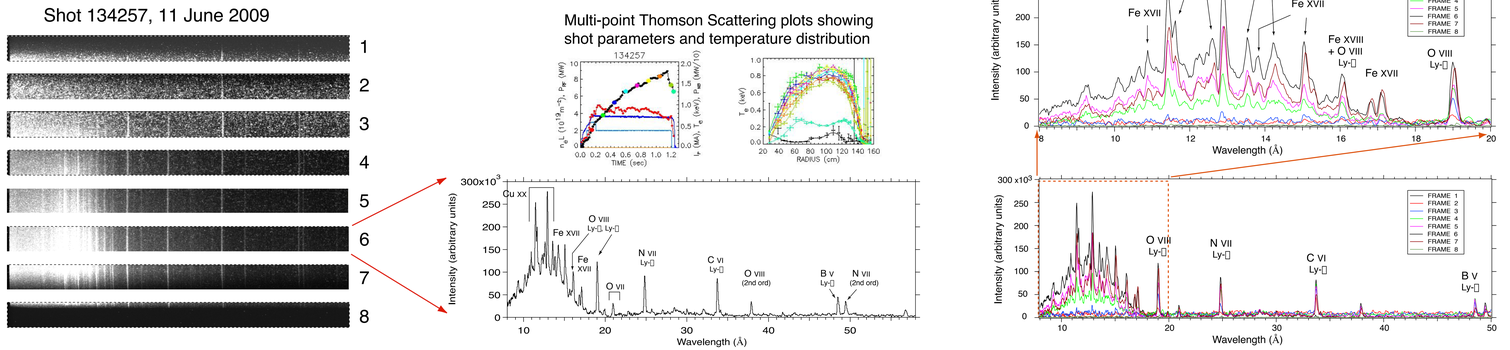


Fig. 2) Two spectra from XEUS taken on 06 July 2009. The top spectrum is a sum of three ohmic shots and is dominated by L-shell iron, while the bottom is an ohmic shot dominated by L-shell copper.

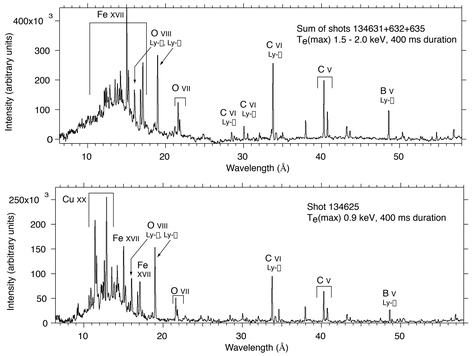
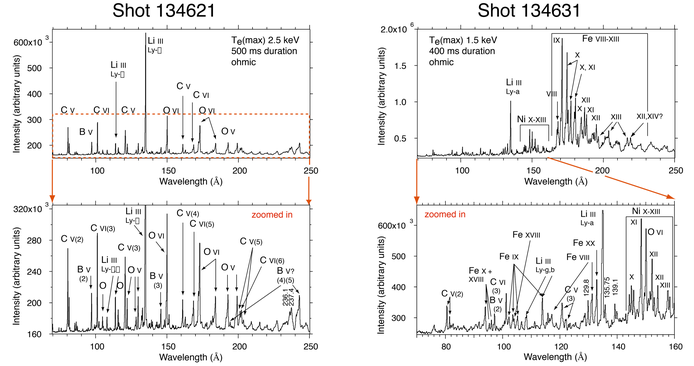


Fig. 3) Two spectra from LoWEUS taken on 06 July 2009, showing impurities in NSTX plasma. Shot 134621 (left) shows the omnipresent lithium, boron, carbon, and oxygen, while shot 134631 (right) is dominated by lines of M-shell nickel and iron.



Spectrometer Specifications:

Variable spacing grating spectrometer
XEUS: mean 2400 lines/mm, 3º blaze angle
LoWEUS: mean 1200 lines/mm, 1.3º blaze angle

LN_2 cooled, 1340 x 1300 pixel CCD chip, ~1 cm^2

Functional range
XEUS: 5 - 120 Å; ~50 Å spread
LoWEUS: 25 - 400 Å; ~150 Å spread

Line width
XEUS: ~0.1 Å FWHM
LoWEUS: ~0.3 Å FWHM

Resolving power
XEUS: ~100 at 10Å to ~500 at 50 Å
LoWEUS: ~200 at 60 Å to ~500 at 150 Å

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