ZAPP z2870-2871-2872-2873-2874 shots summary, October 2015

This was the second Z Astrophysical Plasma Properties (ZAPP) fundamental science shot series of 2015. ZAPP experiments measure fundamental properties of atoms in plasmas to solve the following important astrophysical puzzles:

- Why can't we accurately model the opacity of Fe at the convection zone boundary in the Sun?
- How accurate are the photoionization models used to interpret data from x-ray satellite observations?
- Why doesn't spectral fitting provide the correct properties for White Dwarfs?

These experiments are a multi-institutional collaboration including scientists from SNL, UT-Austin, WVU, LANL, LLNL, and others. Specific onsite participation for these shots included UT student Marc Schaeuble, UT Professor Don Winget, WVU students Ted Lane and Matt Flaugh.

On this shot series we acquired data to advance all the ZAPP science topics by conducting five separate experiments on each Z shot utilizing the z-pinch dynamic hohlraum as a heating and ionizing radiation source.

Machine performance was excellent and reproducible. Each shot timeline was remarkably smooth and efficient even for especially large of experiments and ride-alongs fielded on this specific shot series. We met all major objectives with excellent data collected on all diagnostics with five shots obtained in five days.

This is only possible with the hard-work of the dedicated personnel participating in these experiments, lab 101, Z DAS, Vacuum, LTS, ESS, center section, target fab, shot directors and last but not least the diagnostic fielding group. We are most thankful for their dedication.

A description of the goals and results for each physics topic is given below.

Guillaume Loisel, Jim Bailey and the ZAPP collaboration.

Goals of this October 2015 ZAPP series

We met all primary goals for all experimental topics.

Opacity measurements at solar interior conditions

Goals:

1) Measure the opacity of Fe and Cr LTE samples at the "anchor2" plasma conditions similar to the solar convection/radiation boundary (190eV temperature and $4x10^{22}$ cm^{-3} electron density).

2) Measure the opacity of Fe to increase the existing set of measurements and ensure reproducibility.
3) Measure the opacity of Cr to increase the accuracy of measurements initially started in March 2015. The Mg areal density was increased by about a factor of two to collect additional areal density measurements to better measure the high transmission continuum.
4) Develop an experimental strategy to measure space and time-resolved Mg K-shell absorption in opacity samples.

Goals 1-3 were met.
Goal 4 was partially met, Mg lines are clearly observed but elliptical crystal quality will hamper data analysis.

<u>Radiative properties of photoionized plasmas in astrophysical accretion-powered objects</u>
Goals:
1) Drive photoionized silicon plasma with different areal densities of Silicon in the x-ray drive direction. Silicon targets are twice as thick and twice as thin as in past measurements.
2) Measure self-emission of the different new target types with the two different thicknesses and two different length along the emission sightline (ie 3 and 12mm)
3) Ensure photoionized target conditions are reproducible through absorption spectroscopy (shots z2873 and z2874) for the new target thicknesses.

All goals were met.

<u>White Dwarf Photosphere Experiment (WDPE)</u>
Goals:
1) Use helium gas fill in our ACE gas cell to assess feasibility of measuring line profiles from helium plasma
2) Adjust the experiment configuration to measure hydrogen profiles at higher electron densities

Both goals were met.
The helium shot (z2870) did not produce the absorption lines we were expecting. We did not acquire emission data, because of an experimental problem. Good data aimed at measuring higher density hydrogen line profiles were obtained on shots z2872 and z2873.

<u>Stark broadening benchmark for HED diagnostics</u>
Goal:
1) Evaluate the feasibility of using an additional limiting aperture to control the spectral irradiance incident of x-ray driven samples

This goal was met by using a combination of space-resolved crystal spectrometers and time-resolved x-ray imaging cameras to measure plasma formation around the limiting aperture. The data will be used to assess whether the aperture modifies the x-ray drive experienced by samples in a controlled manner.

<u>Ride-alongs</u>
- Optical-Fiber Feed-GaP (OFFGaP) Experiment. The goal was to assess the feasibility of using a dopant (NaCl) to observe spectral lines from a plasma in the final-feed gap. This goal was met.
Applying dopant to upper-cathode surface apparently had no negative effect to the load-current delivery as determined by comparing final B-Dot pulse shapes with previous shots.
Further processing is needed to determine how well the dopant spectral line was observed if at all.

- Measurements on time-integrated elliptical crystal spectrometers were taken to assess crystal quality and prepare future ride-along measurements.

- Development of the high photon energy DAHX spectrometer was advanced. This ride-along should also help evaluate the amount of >MeV radiation generated by the z-pinch dynamic hohlraum load.

- Development of the high-energy CRITR transmission crystal upgrade CRITR-X. Data was collected with Quartz crystal (101) cut showing W L-lines, the background was effectively reduced by about a factor of 2 compared to the original CRITR design, mainly due to zeroth order light mitigation. This advances our evaluation of the CRITR-X performances.

Machine configuration and performance

Short pulse mode, 85kV charge, 36 modules.
12-post convolute, large diameter steel posts; alcohol wipe cleaning protocol.

	5 shot Average	**z2870**	**z2871**	**z2872**	**z2873**	**z2874**
Max stack current	**27.44 MA ± 0.40%**	27.40 MA	27.59 MA	27.29 MA	27.48 MA	27.44 MA
5 MA time	**2996.98 ± 1.3 ns**	2999.20 ns	2996.80 ns	2995.80 ns	2996.80 ns	2996.3 ns
Peak x-ray time	**3106.8 ± 1.6 ns**	3109.42 ns	3106.78 ns	3106.10 ns	3106.15 ns	3105.36 ns

Load configuration

Nested tungsten, 240/120 wires, 11.36 µm diameter wires, 40/20 mm array diameters, 6mm diameter 12 mm tall 14.5 mg/cc CH_2 foam on axis

Foil on top of dynamic hohlraum, White Dwarf Gas Cell

Diagnostics

Top axial package – two PODD-CCP spectrometers at 9^{o}, two PODD-ECP at 0^{o}
LOS 10 DAHX spectrometer
LOS 50 XRDs , bolometer, PCDs and TEP viewing pinch
LOS 90 SVS1 & SVS2 streaked spectrometers
LOS 130 Two space resolved TIXTLs
LOS 170 MLM imaging of side pinch emission
LOS 210 x-ray power and energy measurements
LOS 250 CRITR-X spectrometer
LOS 300 XRS3 self-emission spectrometer
LOS 308 OFFGap probe SVS3 streaked spectrometer
LOS 330 TREX , crystal performances