Z Fundamental Science Program

Presented by

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Z compresses energy in space and time to generate high energy density (HED) conditions.

Z today couples several MJ out of 22 MJ stored to the load hardware region at the machine center.

Z is an "Engine of Discovery" for stewardship and fundamental HED science.
Z is a Precision tools for high energy density science

Radiation Science

Drive current

Dynamic Material Properties

cathode

anode / flyer

Sample

Uncompressed Stress Wave Front

Inertial Confinement Fusion

Drive current

Radiation Science

Drive current

Dynamic Material Properties

Inertial Confinement Fusion
Pulsed power is exquisitely suited for HED science

• Sandia’s Z machine is ideal for Mbar material experiments
  – Compression of solids and liquids
  – Generate conditions found in the interiors of gas giants and the Earth/super earths, other exoplanets

• The Z machine produces MJ's of x-rays
  – Radiation effects on materials
  – Fundamental properties of matter

• Fundamental plasma physics
  – Spectroscopy and plasma conditions: line broadening and opacity

• Strong integration between experiments, theory, and simulations
  – From quantum mechanics to MHD and beyond

Decades of exciting HED Science research lies ahead
Z Fundamental Science Program is a growing community

**Resources over 10 years**
- 115 dedicated ZFSP shots (8% of all Z shots)
- Ride-along experiments on Z program shots, guns, DICE, and THOR

**Science with far-reaching impact**
- Nature, Nature Geoscience, SCIENCE
- More than 40 total peer reviewed publications and 10 conference proceedings
- 70+ invited presentations

**Popular outreach**
- National Public Radio, “All things considered”, 2014
- Discover Magazine
  - Reportage 9/16/2012
  - Iron rain #62 in top 100 Science stories in 2015
- Albuquerque Journal Front Page 9/2017
- Twice local TV coverage on planetary science

**Earth and super earths**
Properties of minerals and metals

**Jovian Planets**
Water and hydrogen

**Stellar physics**
Fe opacity and H spectra

**Photo-ionized plasmas**
Range of ionization param. ξ

**12+ students are currently involved**
Z uses 26 MA of current to create > 1 MJ of x-rays

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<thead>
<tr>
<th></th>
<th>ZR &gt; 2011</th>
<th>Z &lt; 2007</th>
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<tbody>
<tr>
<td>Marx Energy</td>
<td>20.3 MJ</td>
<td>11.4 MJ</td>
</tr>
<tr>
<td>$I_{\text{peak}}$</td>
<td>25.8 MA</td>
<td>21.7 MA*</td>
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<tr>
<td>Peak Power</td>
<td>220 TW</td>
<td>120 TW</td>
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<tr>
<td>Radiated Energy</td>
<td>1.6 MJ</td>
<td>0.82 MJ</td>
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* Wagoner et al., PRSTAB 11 (2008)

Several institutions perform multiple radiation-driven science experiments on a single Z shot

**Fe foil** (Stellar opacity)

**Si foil** (Accretion disk)

**Stellar opacity**

**Question:** Why can’t we predict the location of the convection zone boundary in the Sun?

**Achieved Conditions:**

$T_e \sim 200 \text{ eV}, n_e \sim 10^{23} \text{ cm}^{-3}$

**Question:** How does ionization and line formation occur in accreting objects?

**Achieved Conditions:**

$T_e \sim 20 \text{ eV}, n_e \sim 10^{18} \text{ cm}^{-3}$

**Question:** Why doesn’t spectral fitting provide the correct properties for White Dwarfs?

**Achieved Conditions:**

$T_e \sim 1 \text{ eV}, n_e \sim 10^{17} \text{ cm}^{-3}$

**Partners:** LLNL, LANL, University of Texas, Ohio State, West Virginia U., U. Nevada-Reno, CEA

Is opacity-model uncertainty responsible for disagreements between interior structure models and helioseismology data?

**Convection-Zone (CZ) Boundary**
Models are off by 10-30 σ

Models depend on:
- Composition (revised in 2005*)
- EOS as a function of radius
- The solar matter opacity
- Nuclear cross sections

**Question:** Is opacity uncertainty the cause of the disagreement?

**Objective:** Measure Fe opacity at CZ base conditions.

The measured iron opacity accounts for roughly half the change needed to resolve the solar discrepancy

We need to understand what’s causing the iron model-data discrepancy
• Is the experiment flawed?
• Do opacity models miss important physics?

J.E. Bailey et al., A higher-than-predicted measurement of iron opacity at solar interior temperatures, Nature (2015)
First systematic opacity study at stellar interior conditions reinforced confidence and suggest opacity refinements.

Experiments with multiple elements help test hypotheses for:
- Experiment flaws
- Model refinements

Stellar models using opacity models closer to the Z data are in closer agreement with helioseismology results.

J.E. Bailey et al., A higher-than-predicted measurement of iron opacity at solar interior temperatures, Nature (2015)
ZFS Program has transitioned to a yearly Call for Proposals

ZFSP is a core part of our research strategy

- 115 dedicated shots since the start in 2010
- Goal of 10% of the shots on Z, ~14 per year
- 4-7 independent projects

Proposal format

- 12 page research narrative
- Shot plan, target and diagnostics needs, etc.
- PI CV/resume

Review

- Facility review for safety and readiness (target, diagnostics)
- Review of scientific relevance and impact by an independent review panel

ZFSP 2020 workshop TBD, Albuquerque

- Sunday evening – Wednesday afternoon
- Typically been held at Hotel Andaluz, downtown ABQ
ZFSP call for proposals timeline:

- **June 15:** call for proposals open
  - Award period: April 1, 2021 through March 31, 2023

- **August 2-5:** ZFS Workshop
  - Tentatively at the Hotel Andaluz, Downtown Albuquerque

- **September 18:** call closes

- **October/November:** evaluation and selection
  - Facility review: experimental feasibility, safety, and diagnostics
  - Scientific review of international panel mid-November
  - Mid-December, distribution of shots

- **Notification of Awards on December 14, 2020**

Two-year award period