June 21, 2010

Science Life at Sandia National Laboratories' Z Pulsed Power Facility

Mike Lopez
Manager, Z Pulsed Power Facility Operations
Sandia National Laboratories

Questions to the crowd

- How many of you consider yourselves scientists?
- How many of you consider yourselves engineers?
- How many of you consider yourselves to be business people?
- What do you plan to do after graduation?

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A little bit about me

- Family man – Married with three kids
- I like to listen to books and trying to learn guitar
- PhD, Nuclear Engineering, University of Michigan (2003)
- Certified Lean Six Sigma Black Belt (Lockheed Martin Corporation)
- Associate Vice President of the Society of MAES

Summer 2003: Me and my baby girl in Ann Arbor, MI

- Graduate of the CCUI Advanced Corporate Coaching Program (175 hours of coach training). Over 200 hours of professional career and corporate coaching experience (professional credential pending)
- Also a corporate recruiter for SNL and Lockheed Martin

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This talk is for you
What do you want to know?

A. A story about hunting for, choosing, and starting a new job and my one piece of advice.

B. What we do at Z.

Choose your own adventure . . .

Where should I start?

What do you want to know?

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Questions that came from the DOE/NNSA SSGF conference audience:

1. How did I find my position?
2. What factors went into deciding where to go?
3. What factors went into deciding what to do?
4. When did I start looking for a job?
5. How do you get time on Z?
6. What kept me from going to academia?

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Pointers on job hunting

- Basic: Use your advisor, get business cards, and go to technical conferences.
- Be bold
  - Invite yourself to places you want to see and then go see them.
  - Celebrate your successes
- Cultivate relationships
  - People like people who like their work
  - Sandia courted me for years before the job offer

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Why I chose to work at Sandia National Labs

- Albuquerque is a decent place to live
  - Affordable
  - Very sunny – more heat than cold
- The work sounded good
- Unbelievably great people interviewed me and they conveyed the following message
  - You will be challenged
  - You will have fun
  - You will be highly valued

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Being challenged, feeling valued, and having fun

- Expect to be stretched.
  - December 2003 – The honeymoon and learning the ropes
  - Spring 2004 – The LANL Collaboration
  - Spring 2006 – Z Load Hardware Project & Target Fabrication
  - Fall 2009 – Manager of Z Pulsed Power Facility Operations

Sandia is excellent at developing people by having them work on a series of projects of increasing complexity and difficulty.

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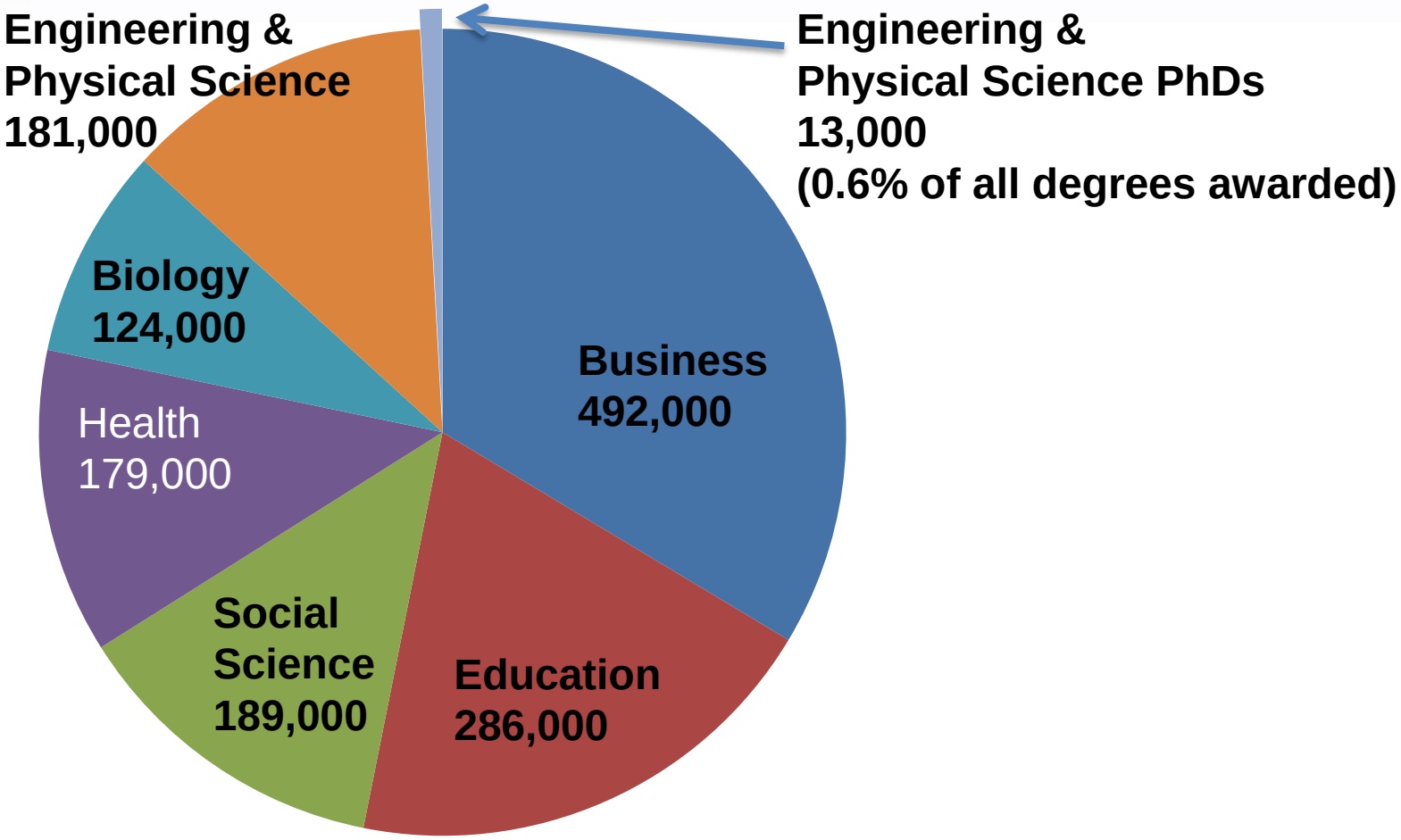
All of that leads to my one piece of advice



We live in a diverse nation where scientists are the minority

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My one piece of advice

- Cultivate a love for the eclectic

eclec·tic

1. selecting what appears to be best in various doctrines, methods, or styles.
2. composed of elements drawn from various sources; also : heterogeneous

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Try these doctrines, methods, and styles

- Finance & Economics
  - Money moves in mysterious ways
  - Warren Buffett, Wall Street Journal, federal funding process
- Psychology
  - Social interaction dominates life
  - Learn the science behind driving change
- Sales & Marketing
  - You have ideas. You want them to be supported.
  - There is little difference between your ideas and iPods

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Innovation is more than just invention . . .

If you . . .

make your idea accessible,
make your idea real,
make your idea something that can be felt . . .

someone will buy it.

Learn to sell and people will buy your good idea.

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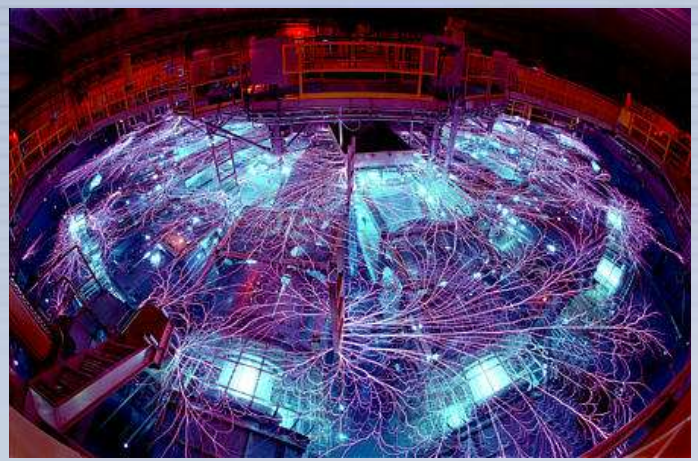
Science at Sandia National Laboratories' Z Pulsed Power Facility



2010 DOE NNSA SSGF Annual Conference

Washington, DC, June 21, 2010

Mike Lopez

Sandia National Laboratories

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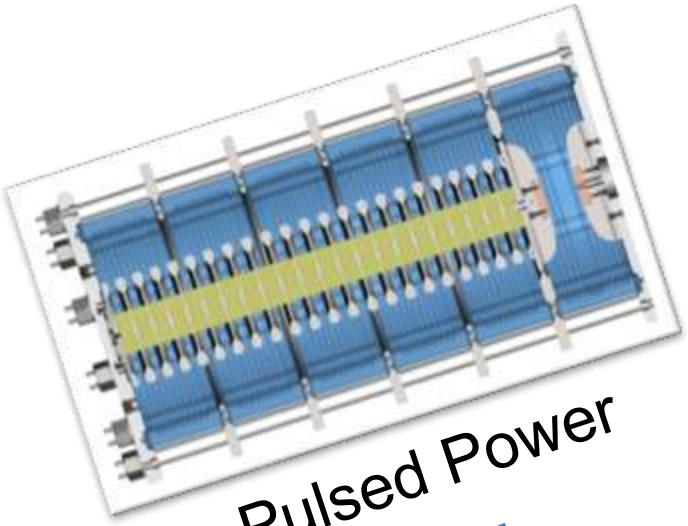
Many people contributed to this talk

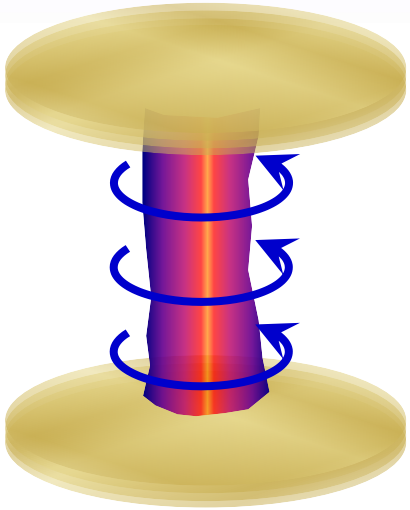
Thanks to:

D. Ampleford, B. Atherton, J. Bailey, G. Bennett, G. Cooper, C. Coverdale, M. Cuneo, M. Desjarlais, A. Edens, M. Geissel, D. Hanson, D. Headley, M. Herrmann, C. Jennings, B. Jones, M. Jones, M. Knudson, K. LeChien, R. Leeper, G. Leifeste, R. Lemke, F. Long, M. Lopez, K. Matzen, T. Mehlhorn, R. McBride, R. McKee, A. McPherson, T. Nash, K. Peterson, J. Porter, P. Rambo, G. Rochau, G. Robertson, D. Rovang, C. Ruiz, D. Sandoval, M. Savage, J. Schwarz, A. Sefkow, D. Sinars, S. Slutz, I. Smith, K. Struve, W. Stygar, R. Thomas, P. VanDevender, R. Vesey, E. Waisman, and the Z and Z-Beamlet operations teams

Three major research thrusts



Pulsed Power



Applications
(HED Science)

Lasers

Z Backlighter

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The Z Pulsed Power Facility is located at Sandia National Laboratories in Albuquerque, NM

Z Website: http://z.sandia.gov

BBC Horizon TV show:
Can we make a star on earth?
http://bit.ly/11iRBZ

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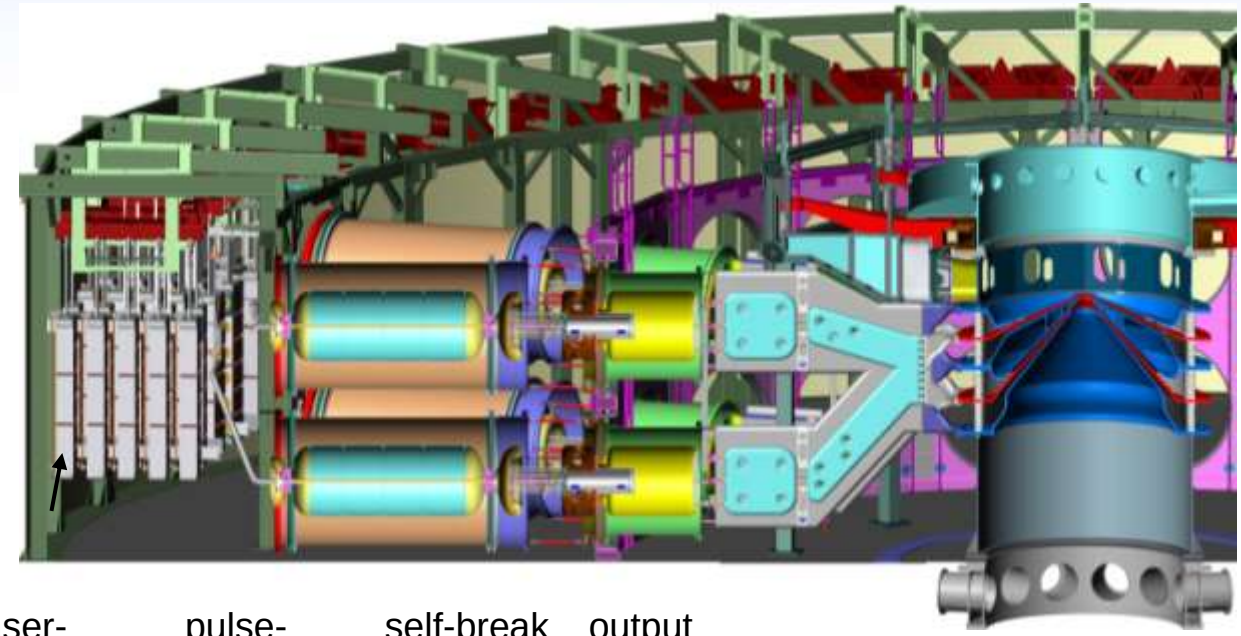
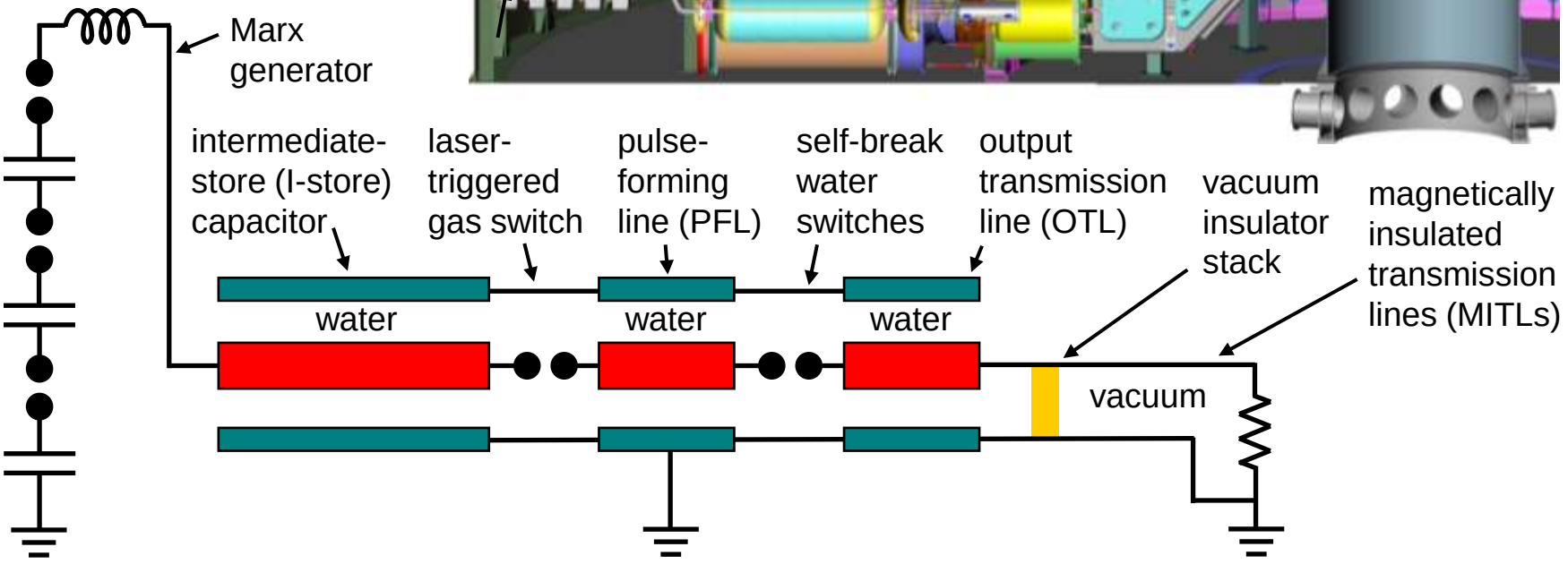
Each Z-accelerator module performs several stages of electrical-pulse compression

Marx voltage	stored energy
80 kV	19 MJ
85 kV	21 MJ
90 kV	23 MJ

The Marx generator is charged in 100 s, and discharged in 1 μs.



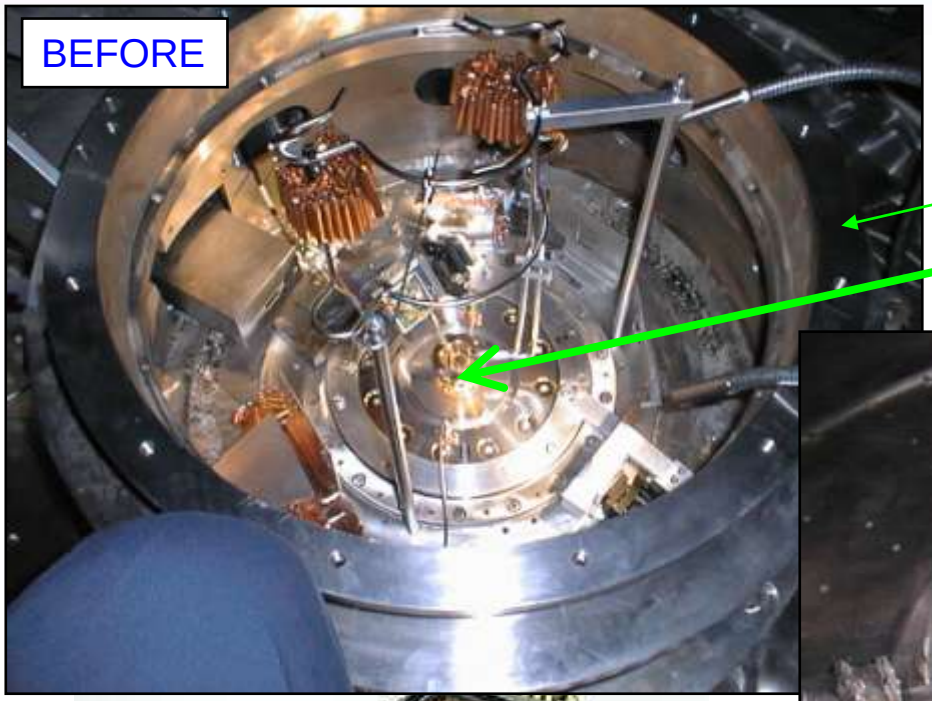


The I-store capacitor is charged in 1 μs, and discharged in 200 ns.

The PFL is charged in 200 ns, and discharged in 100 ns.

The pulse is delivered to a physics package, which is the load of the accelerator circuit.

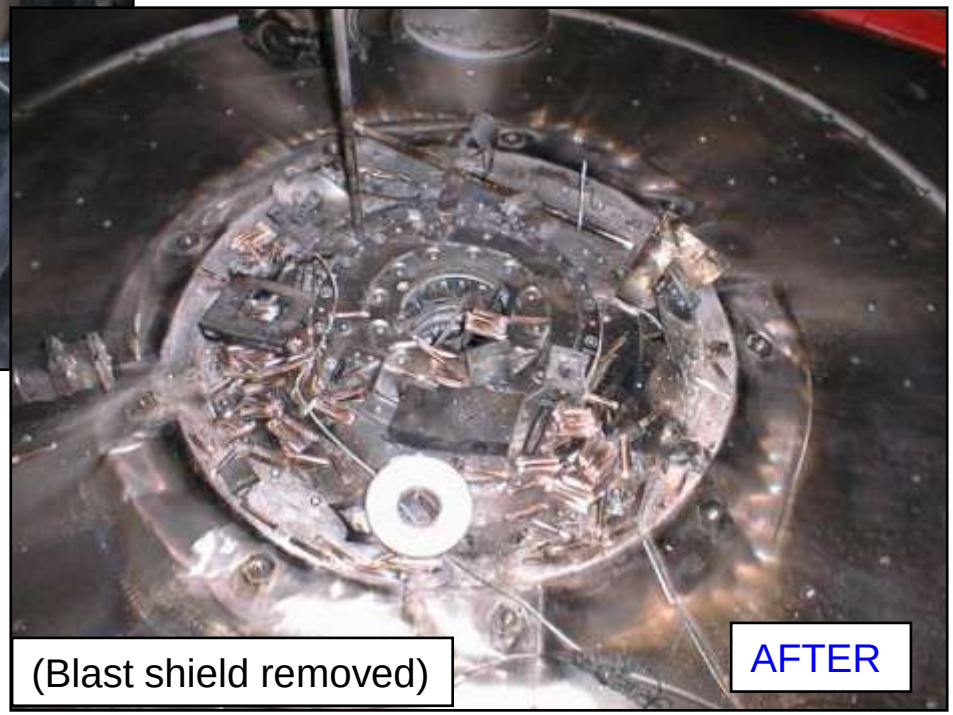
The enormous magnetic and radiation pressures destroy the load hardware on each shot



Equivalent to 2 lbs high explosive released in a few ns in <1 cc volume!

Blast shield

Wire array



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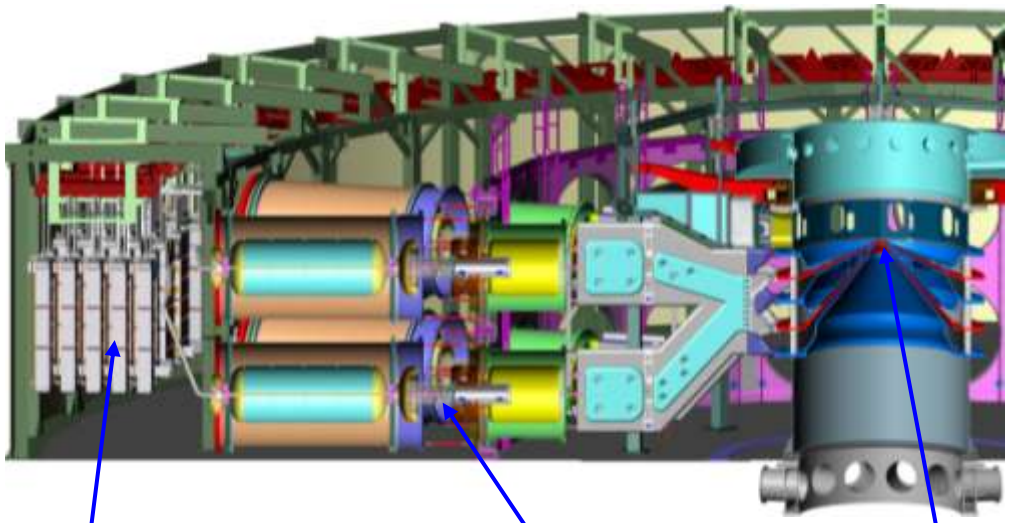
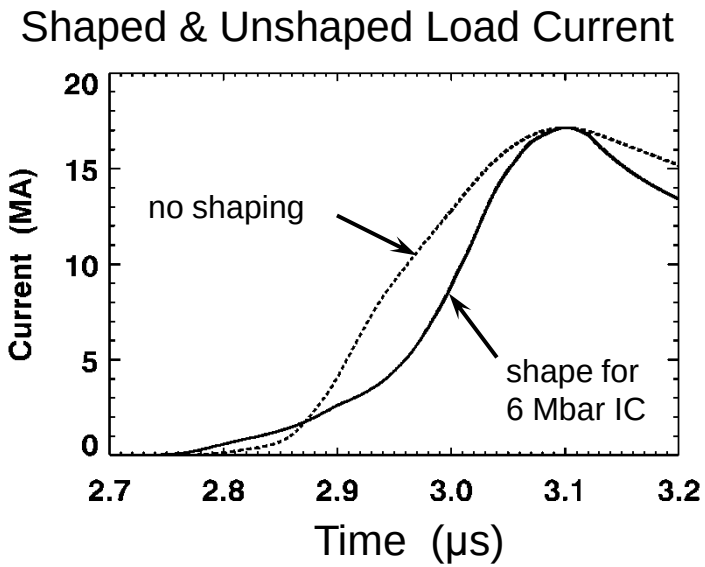
Z was designed to enable precise control of the current rise time for dynamic materials experiments



Marx generator

laser-triggered gas switch

Flyer / ICE load



Timing of 18 pairs of independently laser triggered switches determined by detailed circuit model of Z in BERTHA with 2D MHD results.

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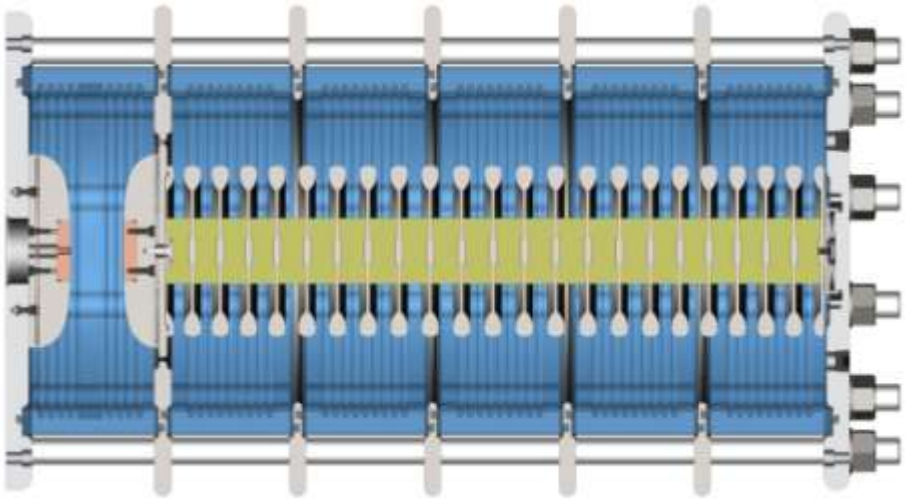
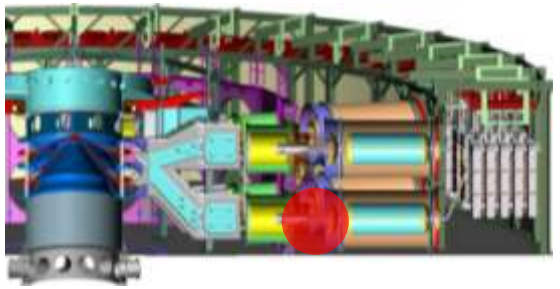
Keith LeChien and his team received a 2010 Defense Programs Award for Excellence (DPAE) for dramatically improving the performance and reliability of the gas switch

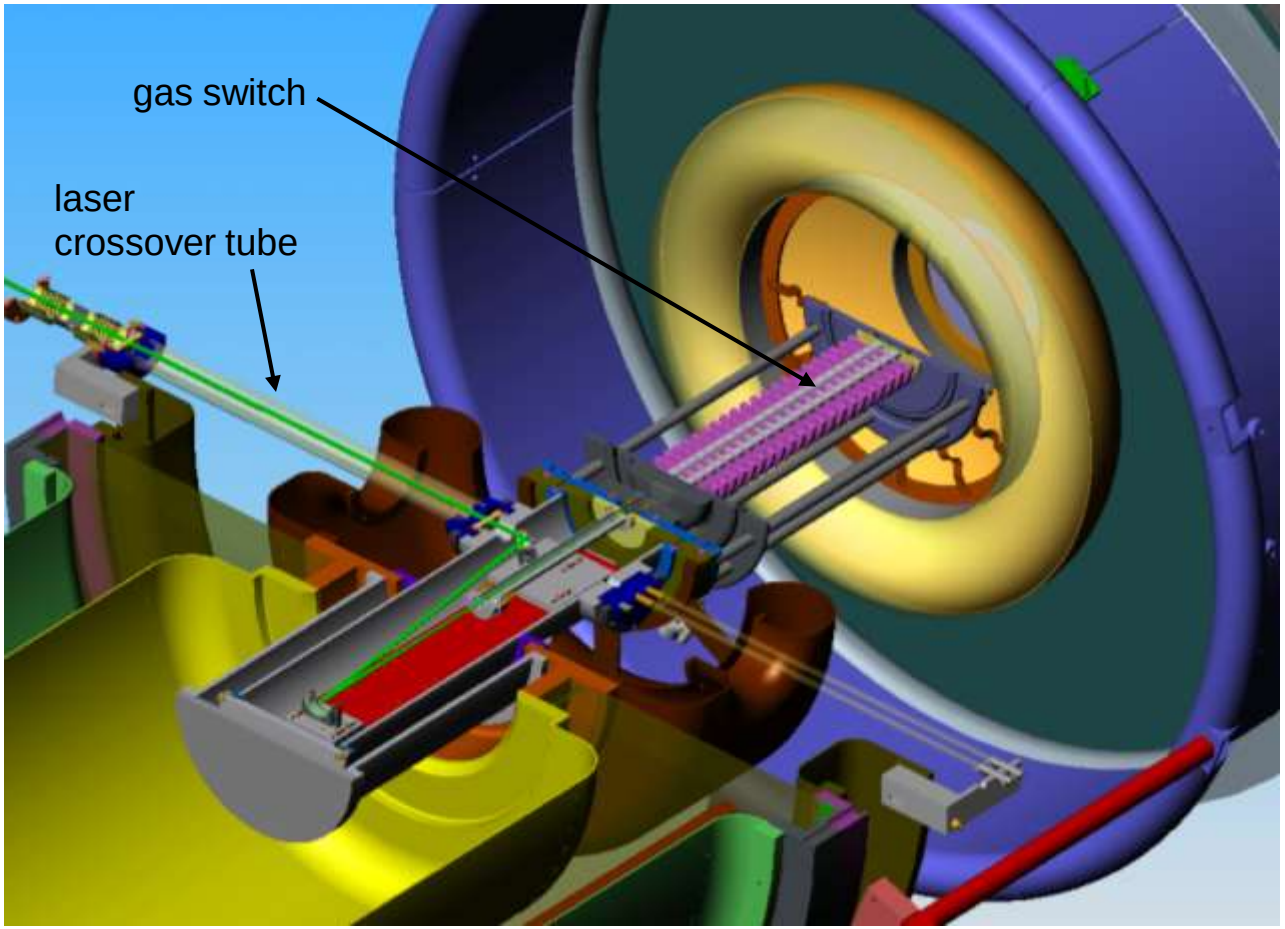
performance parameter	new Z gas switch
prefire rate	0.1%
jitter	5 ns
flashover rate	0.1%
replacement interval	100 shots

- Previously, several switches routinely failed each shot.
- We completed the upgrade to the new switch on 28 June 2009.
- We have recently demonstrated 49 consecutive Z shots (i.e., 1764 switch shots) without a single switch failure.



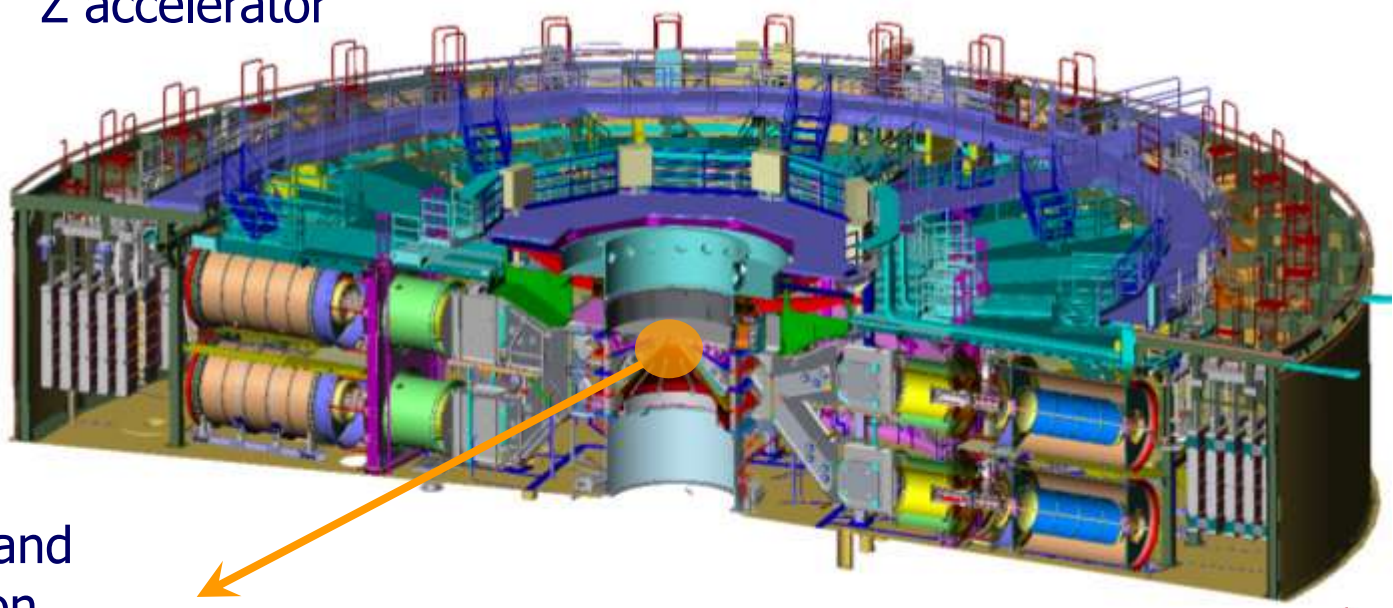
Pulsed power is high tech



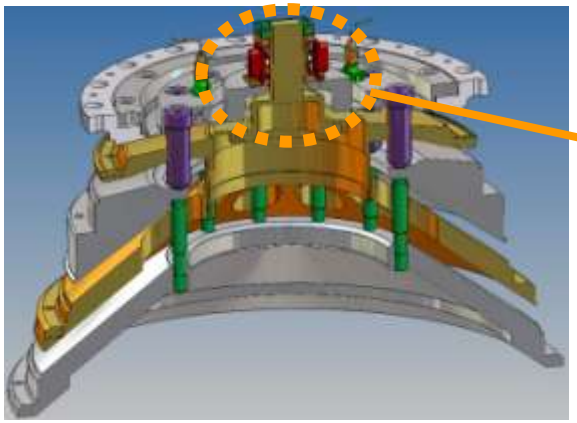


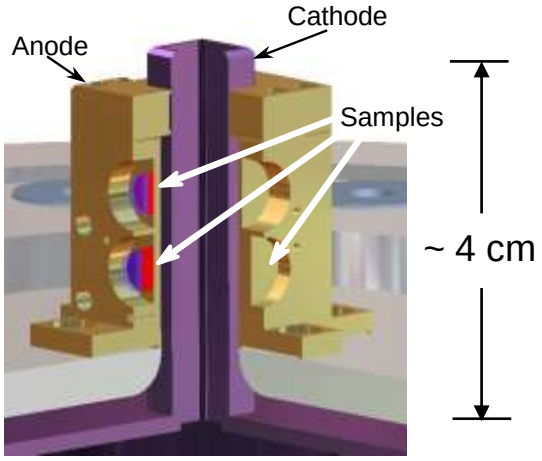
High Energy Density Physics experiments are mounted at the center of the Z accelerator

Z accelerator

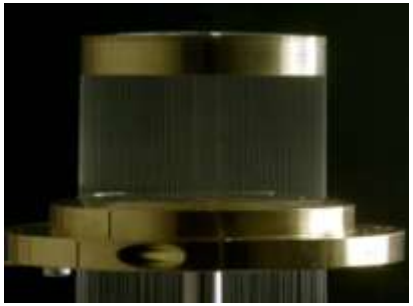


Convolute and load region





Material property experiment



Wire array experiment

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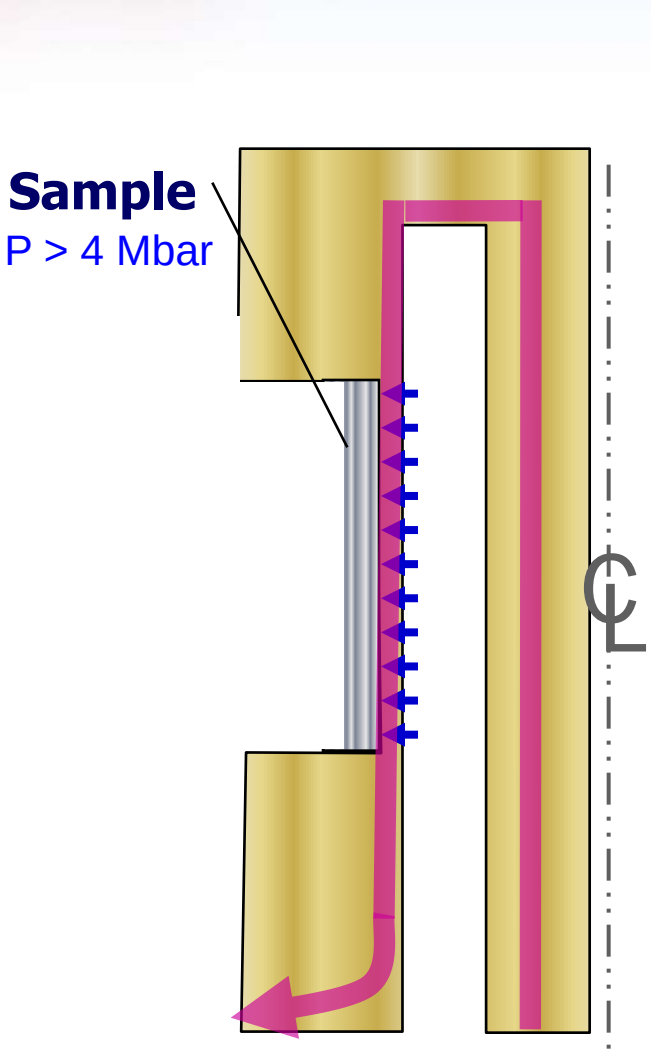
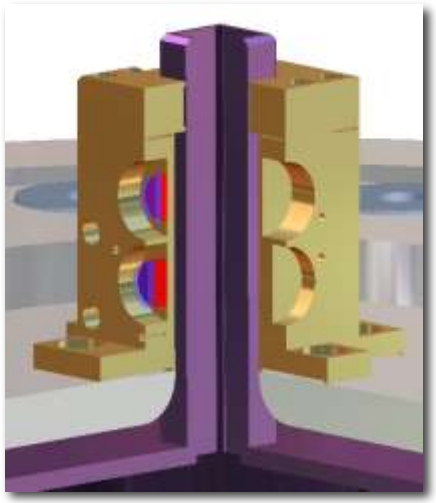
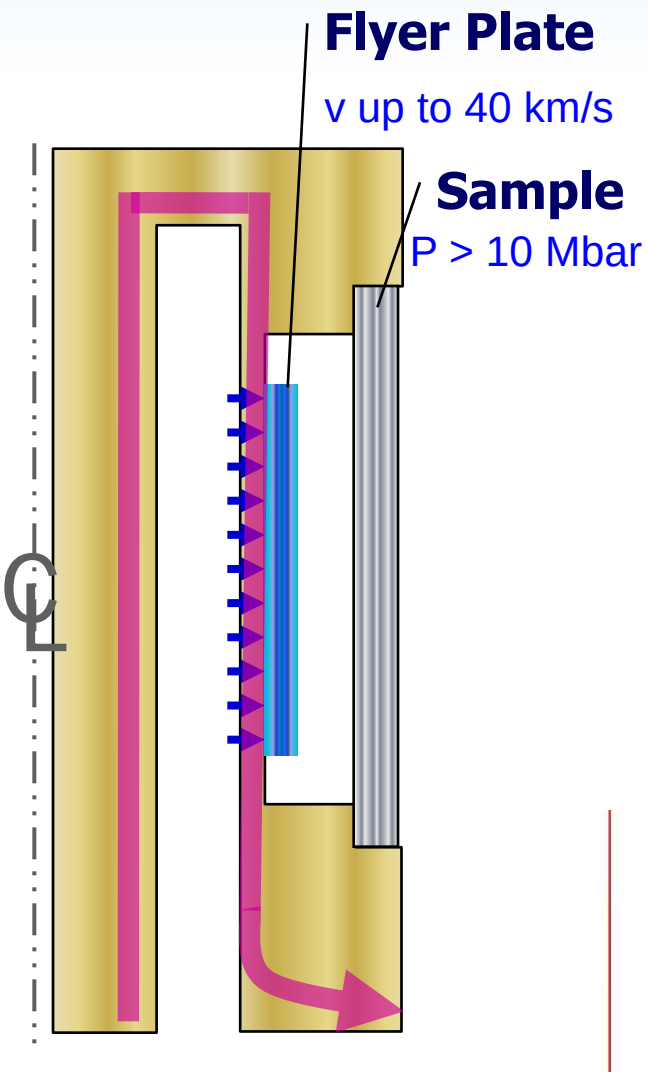
Isentropic compression and shock wave experiments are both possible on Z







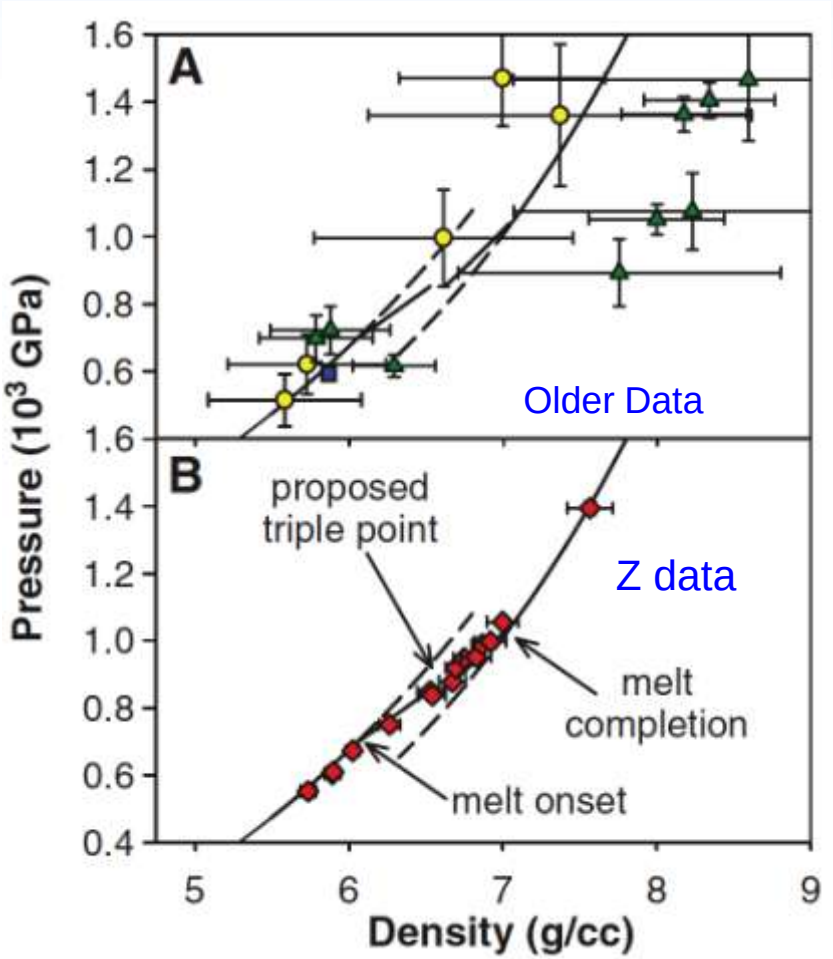
Isentropic Compression Experiments:
gradual pressure rise in sample

Shock Hugoniot Experiments:
shock wave in sample on impact

Experiments on Z have determined the shock melting of diamond with unprecedented accuracy

At what shock pressure does diamond melt?

Accuracy of shock impact experiments on Z allowed for quantitative comparison with Quantum Molecular Dynamics (QMD) predictions



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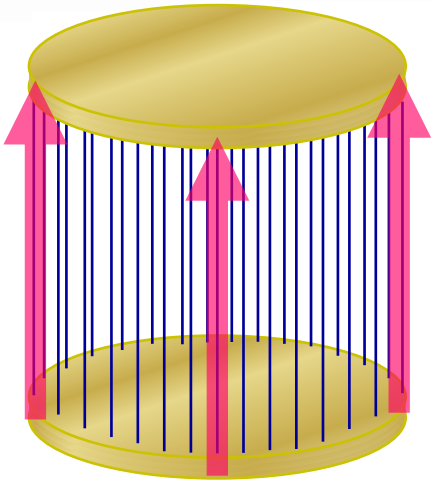
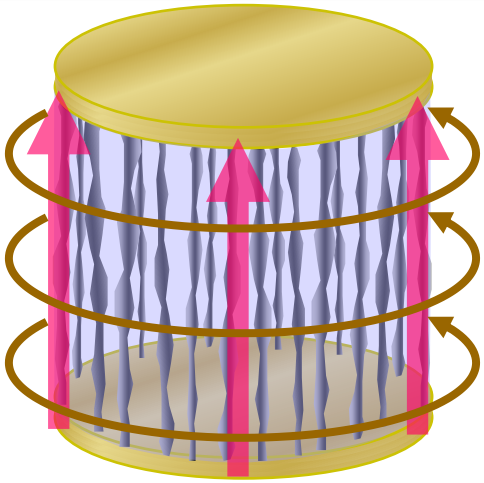
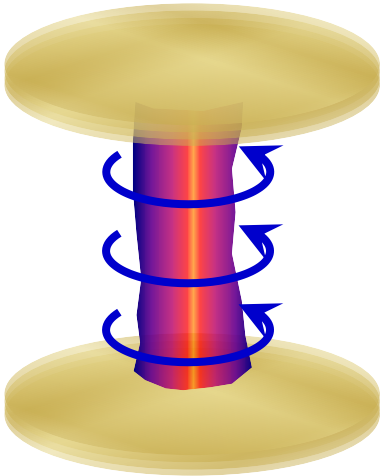
Magnetically-driven z-pinch implosions efficiently convert electrical energy into radiation



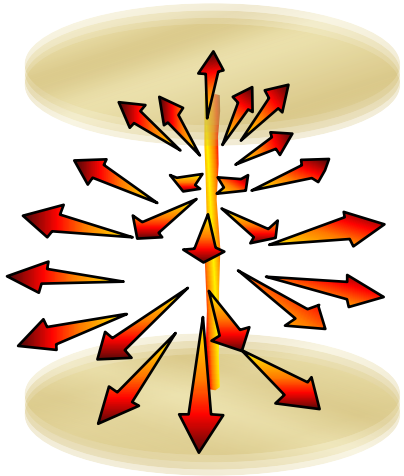
Initiation



Ablation



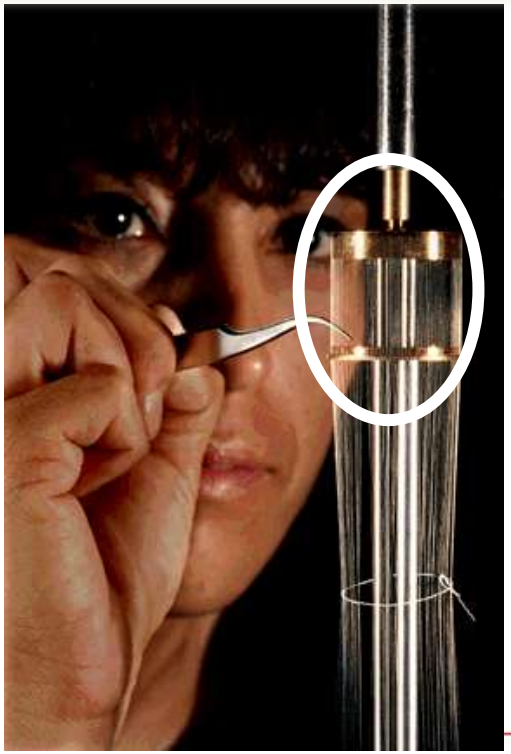
Implosion



Stagnation

On Z:

- Energy: x-ray
  ≈10% of stored electrical
- Power: x-ray
  ≈3 times electrical



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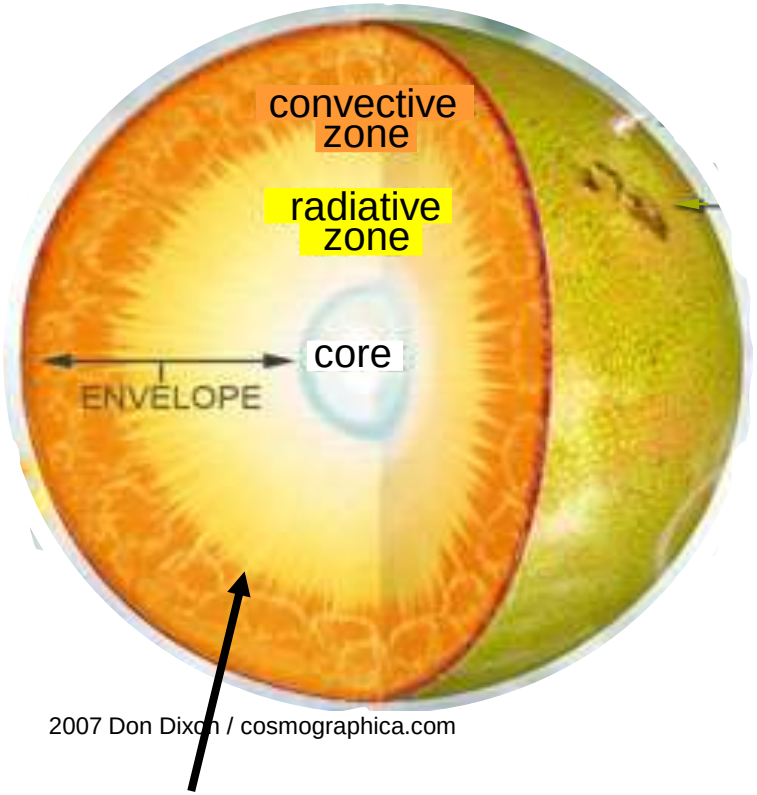
Z experiments test opacity models that are crucial for stellar interior physics



2007 Don Dixon / cosmographica.com

Predictions of solar structure do not agree with observations

Solar structure depends on opacities that have never been measured

Challenge: create and diagnose stellar interior conditions on earth

High T enables first studies of transitions important in stellar interiors

Solar convective zone boundary

T_e = 193 eV, $n_e = 1 \times 10^{23}$ cm^{-3}

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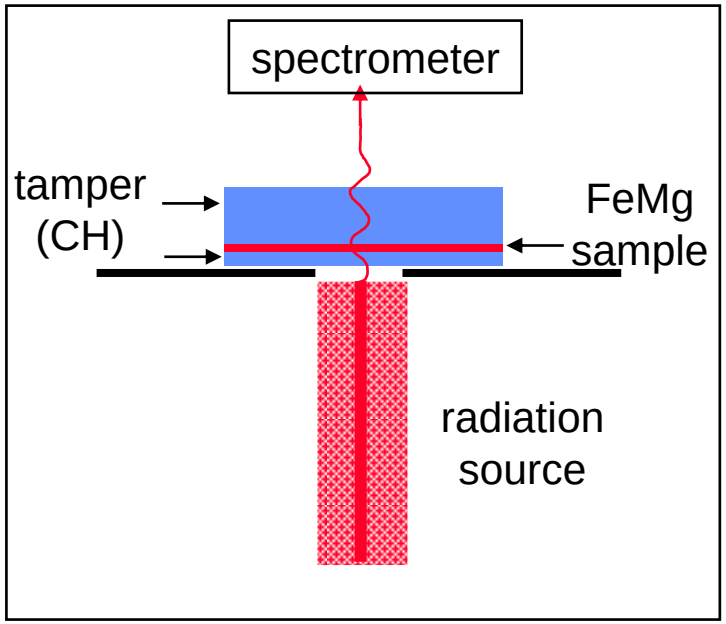
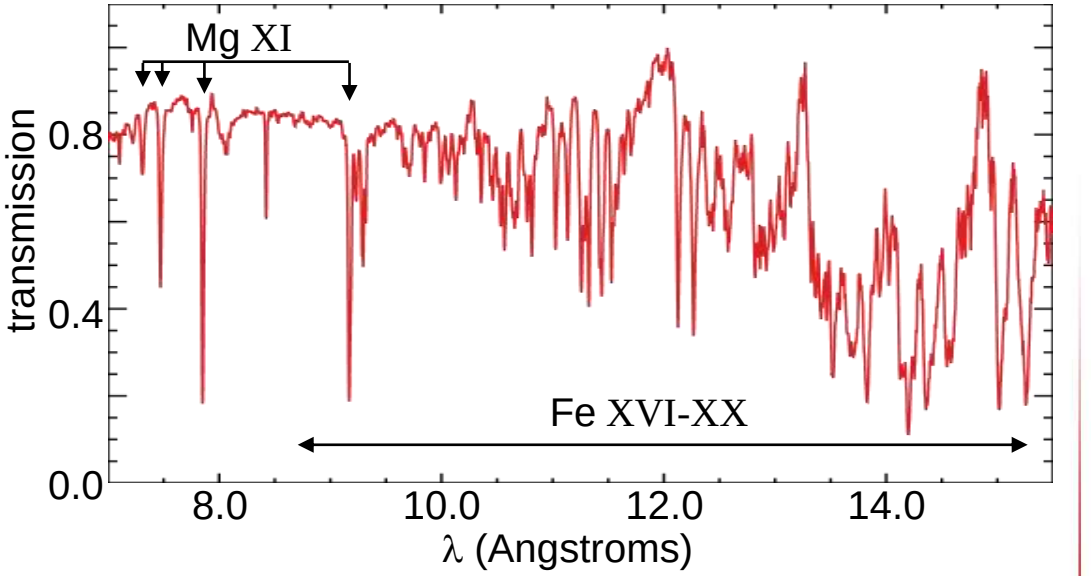
Opacity measurements on the upgraded Z are now very close to replicating solar interior conditions



Fe + Mg transmission

Mg is the “thermometer”, Fe is the test element



Experiments on upgraded Z are much closer to Fe conditions in the Sun

~20% increase in T_e to ~190 eV

~300% increase in n_e to ~2 x 10^{22} cm^{-3}

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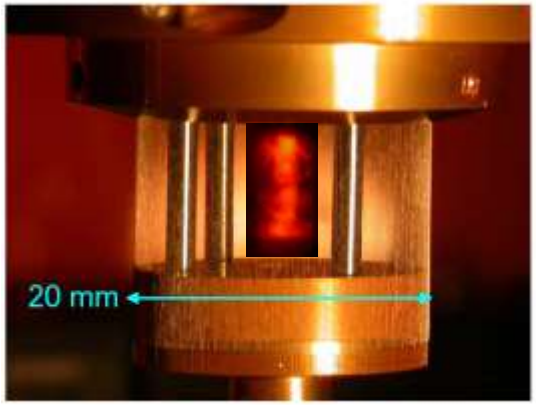
How can we use this efficient x-ray source to do ICF?

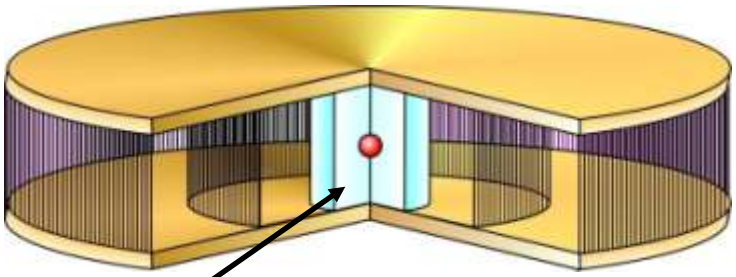


Where do we put the capsule?

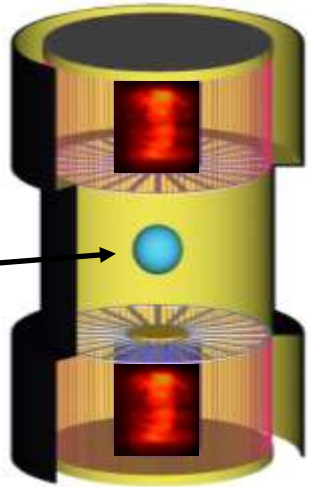
We want high intensity (high Tr) for high ablation pressure
-> let the capsule see the pinch

We need high uniformity (~1%) in x-rays the capsule sees for symmetry
-> hide the capsule from the pinch

Dynamic Hohlraum



Double-Ended Hohlraum



This approach is the most conservative

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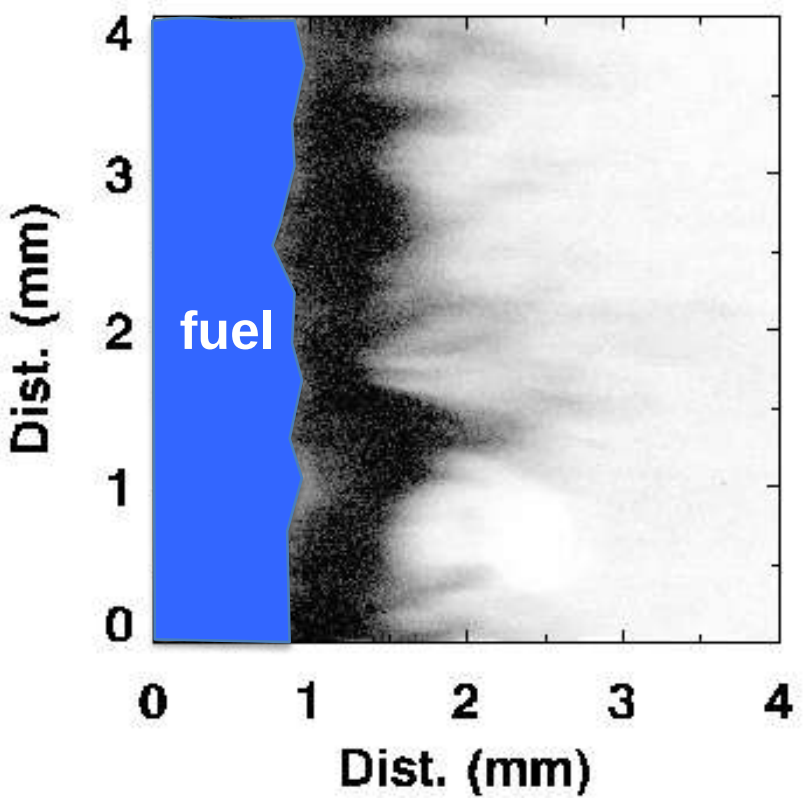
Direct magnetic compression of fuel could increase coupling efficiency by 20X!



Use stabilized cylindrical implosion to compress fuel

CR ~ 10:1

Magnetic pressure at I=16 MA and r=1.5 mm

P ~ 18 Mbar

Ultimate convergence ratio of this pinch ~20:1 giving

P ~ 160 Mbars

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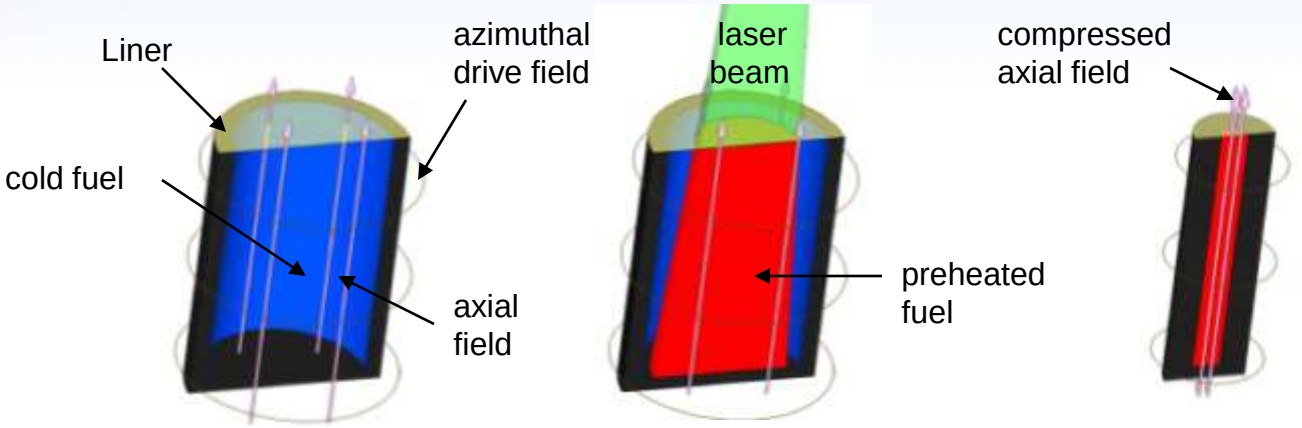
Fuel magnetization and preheat provide beneficial effects for liner driven ICF



A magnetic field inhibits thermal conduction and enhances alpha particle deposition within the fuel

Preheating the fuel reduces the compression needed to obtain ignition temperature

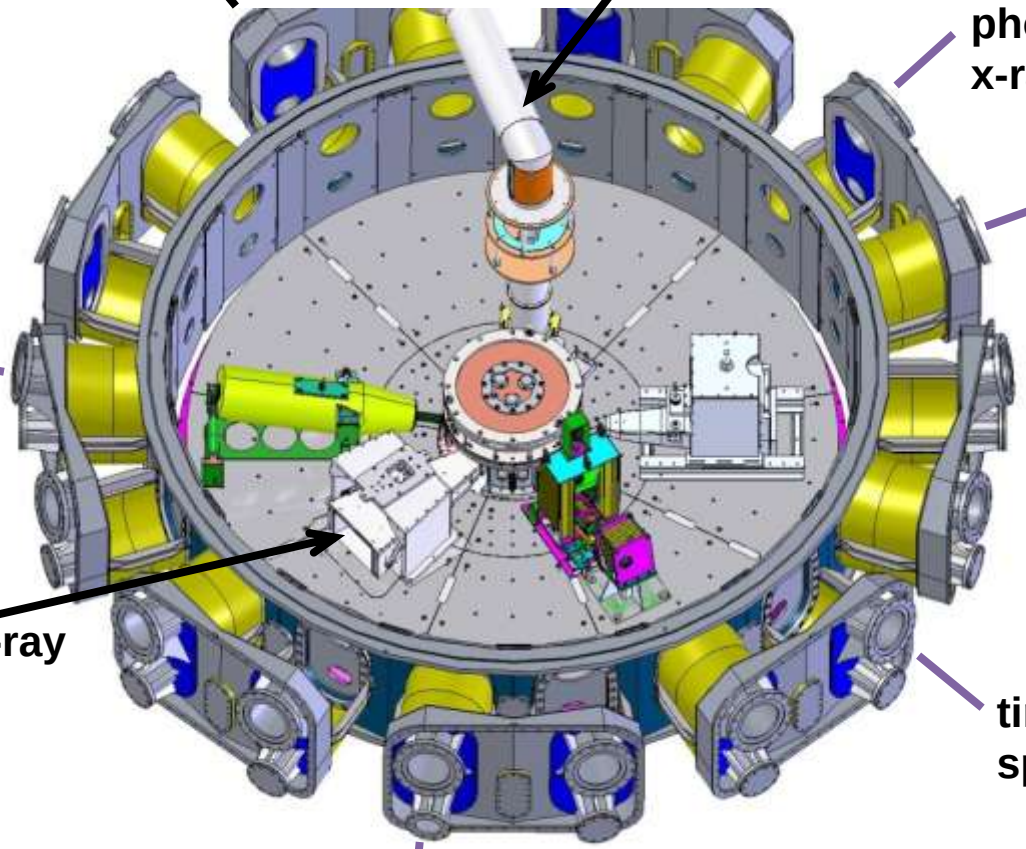
…calculations indicate this could be done by the Z Beamlet laser

Simulations indicate significant yields on ZR with modest convergence ratios and implosion velocities

The Magneto-Rayleigh-Taylor instability will be a key issue for this concept

S. Slutz, M. Herrmann

There are many diagnostics and experimental systems available for each shot



cryogenic target system

time-resolving x-ray spectrometer

bolometers, x-ray diodes, photoconducting detectors, x-ray power (TEP)

VISAR fiber feedthrough

neutron time-of-flight spectrometer

in-chamber x-ray spectrometer

time-integrating x-ray spectrometer

bolometers, x-ray diodes, photoconducting detectors

time-resolving x-ray pinhole camera

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The Z facility has an extensive suite of x-ray diagnostics

X-ray Power and Energy

Filtered X-ray Diodes (XRDs)……. < 4 keV Power
Photo-Conducting Diamonds (PCDs)…….. > 1 keV Power
Silicon Diodes (TEP)……. Broad-band Power
Bolometers……..... Broad-band Energy

X-ray Spectroscopy

Elliptically Curved Crystals……0.7-10 keV Time-gated
Convex Curved Crystals…….. 0.7-10 keV Time-integrated
Spherically Curved Crystals…… 0.7-10 keV Time-integrated
Transmission Crystals……> 10 keV Time-integrated

X-ray Imaging

Filtered Pinhole Cameras……..> 0.7 keV Time-gated
Multi-layer Mirror Pinhole Cameras……0.277±0.003 keV Time-gated

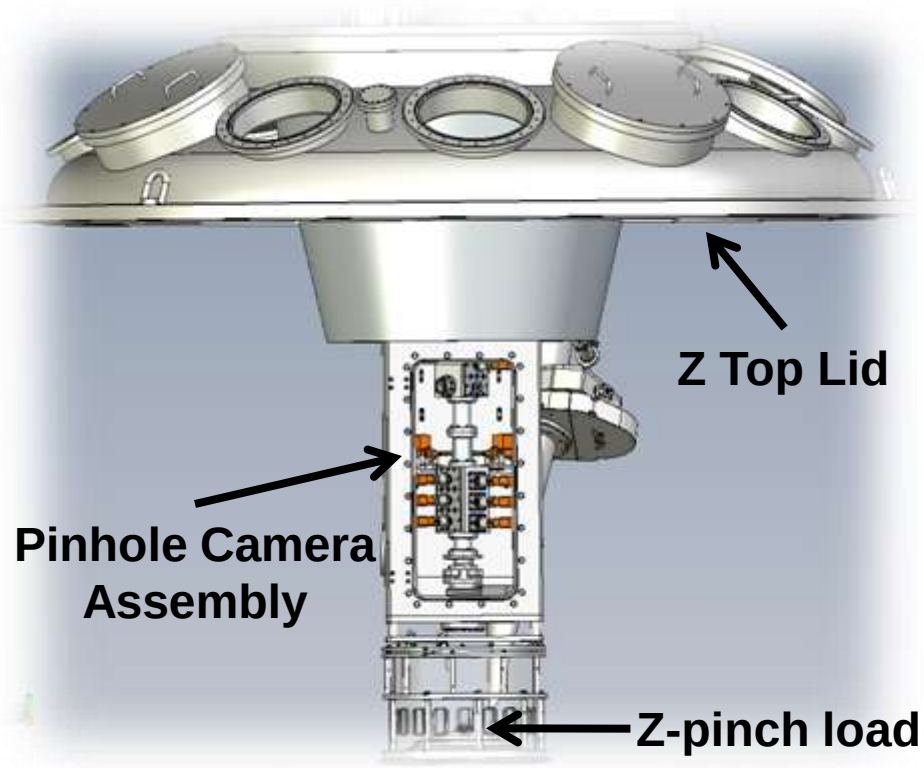
X-ray Backlighting

Point-projection……two-frame @ ~1kJ ea.
1 or 2-color Monochromatic Imaging.....two-frame @ ~1kJ ea.

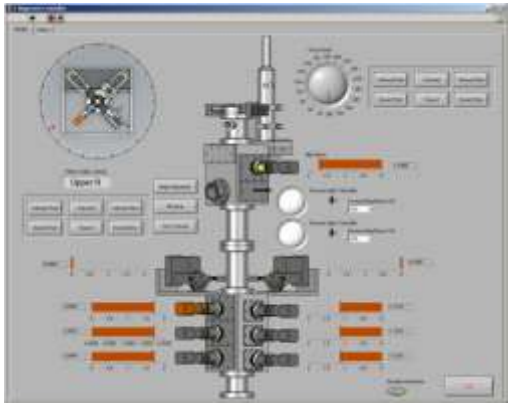
Sandia National Laboratories

A new gated pinhole camera provides x-ray imaging at 10 times greater sensitivity

GRAPHIC
Gated Re-entrant Axial PinHole Imaging Camera



LabView Based Remote Diagnostic Control System



- **Magnification: 1**
- **Spatial Resolution: ≥ 50 μm**
- **Time Resolution: ≥100 ps**
- **Time Frames: 8**

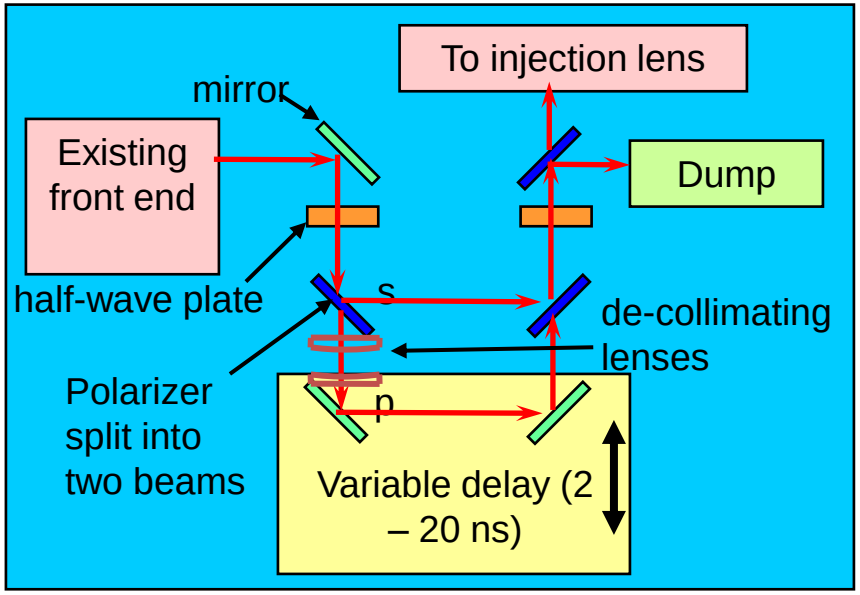
This technology enables imaging on the time-scales required for accurate diagnosis of inertial fusion plasmas

Sandia National Laboratories

Z-Beamlet now enables 2 x-ray backlighting images to be acquired on a single Z shot

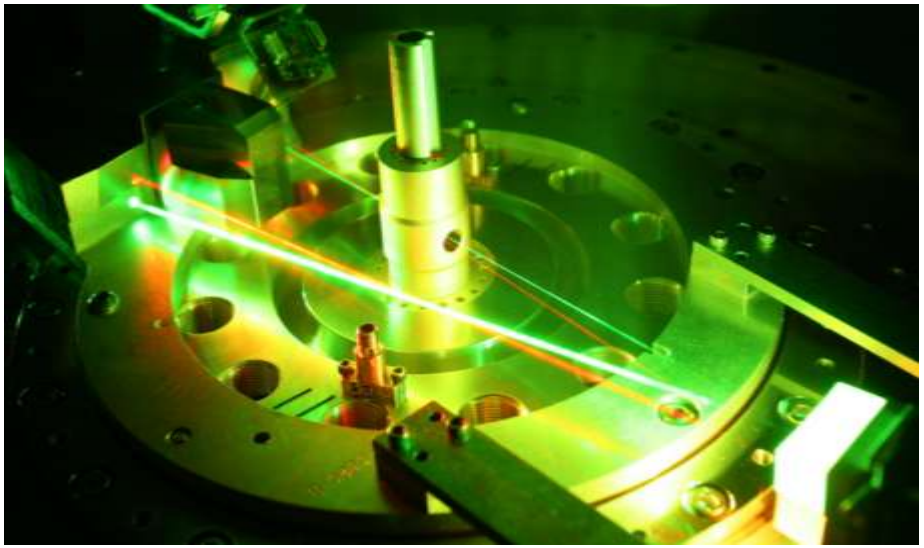
Modifications of Z-Beamlet laser

- The output from the front end is split into two beams.
- A 2-20 nsec time delay introduced between the 2 beams.
- The beams are injected into the main cavity amplifiers with a 1.3 mrad angular separation.



Modifications of backlighter detector

- The 2 beams are focused onto foil targets and are imaged by 2 spherically bent crystals at 1.865 keV or 6.151 keV onto 2 image plate detectors.



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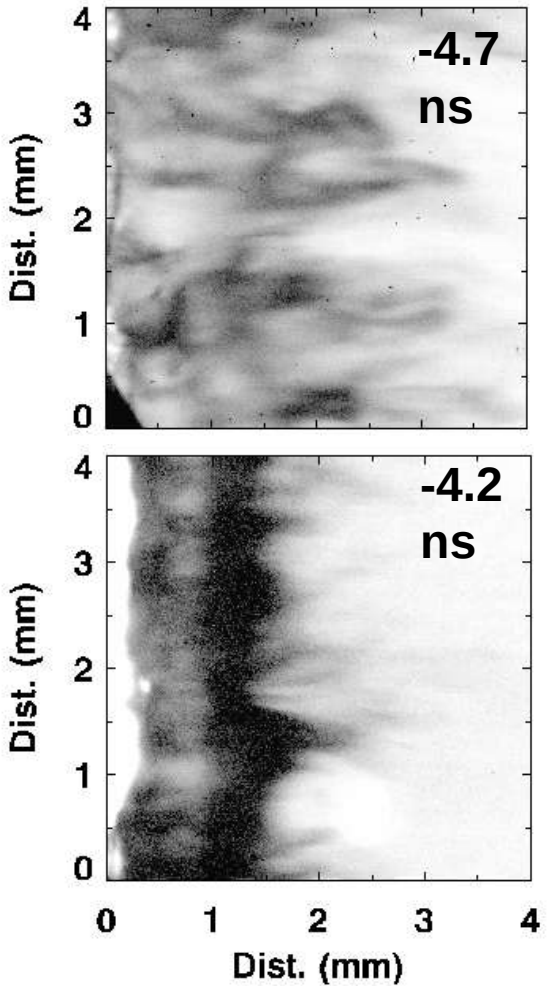
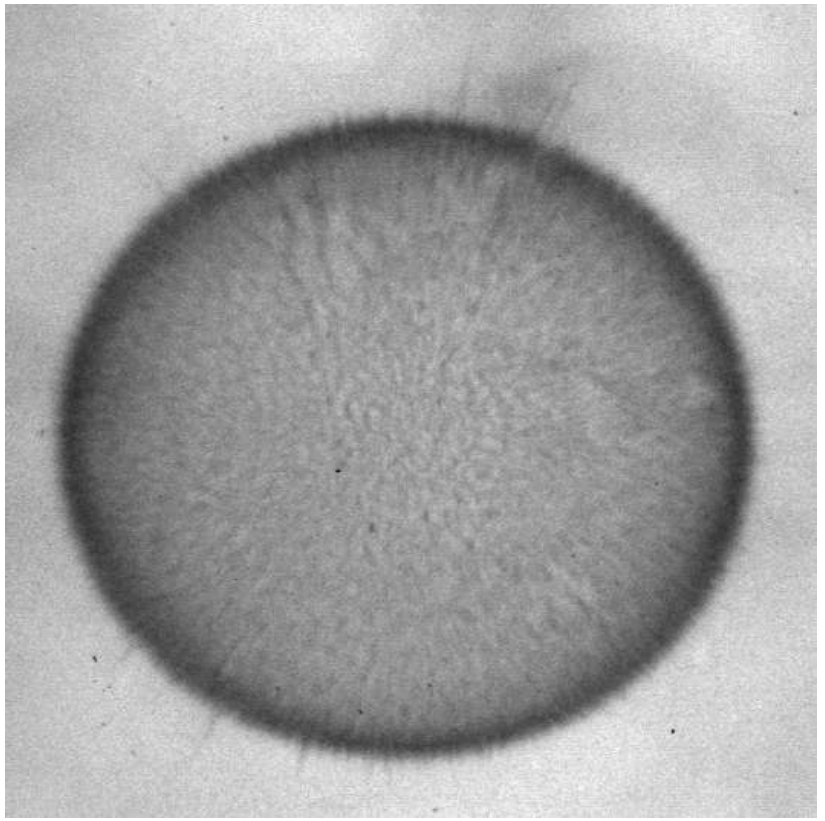
Two-frame, high resolution x-ray backlighting is an important diagnostic now in routine use on Z

Z-pinch implosion



6.151 keV x-ray radiograph of imploding capsule (C_r = 1.7)



Backlighter developed by: D. B. Sinars, G. R. Bennett

Experiments by Cuneo et al

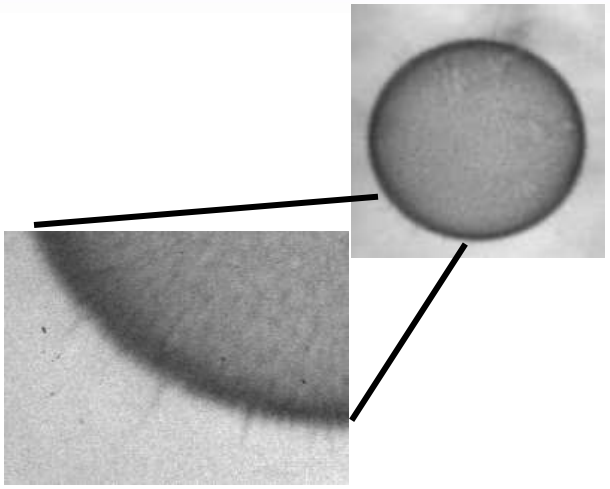
Sandia National Laboratories

The Z-Beamlet and Z-Petawatt laser backlighters are a powerful new capability for Z experiments

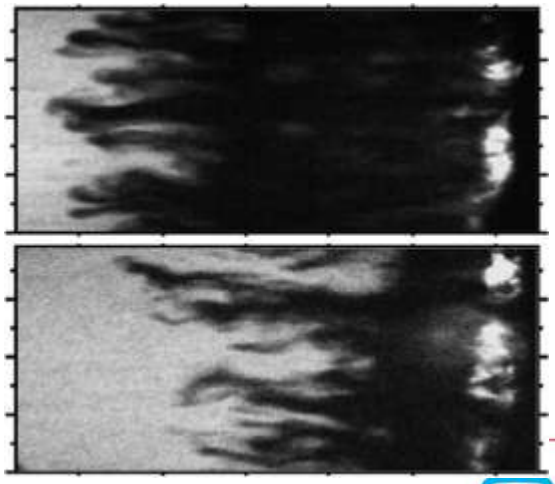
Z facility

Z-Beamlet and Z-Petawatt lasers

imploding capsule



imploding z-pinch



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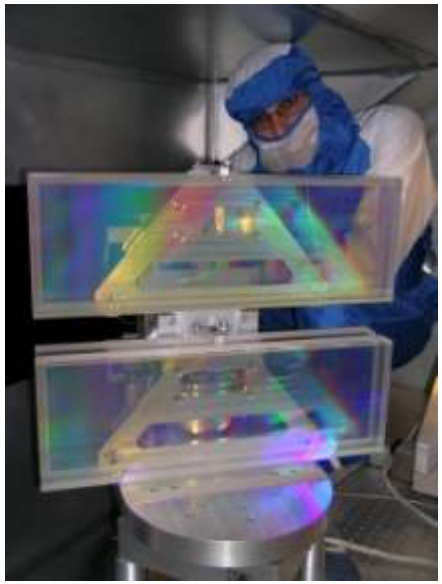
The Z-Backlighter Facility is a research treasure of its own

Z-Beamlet

- λ = 527 nm
- τ = 0.3 - 8 nsec
- $\phi \geq 75$ μm spot size
- E ≤ 1.5 kJ (5 kJ planned)
- I ≤ 10^{17} W/cm^2
- 3 hr/shot

Z-Petawatt



- λ = 1054 nm
- τ = 0.5 - 15 psec
- $\phi \geq 30$ μm spot size
- E ≤ 300 J (2kJ planned)
- I ≤ 5 x 10^{19} W/cm^2
- 3 hr/shot

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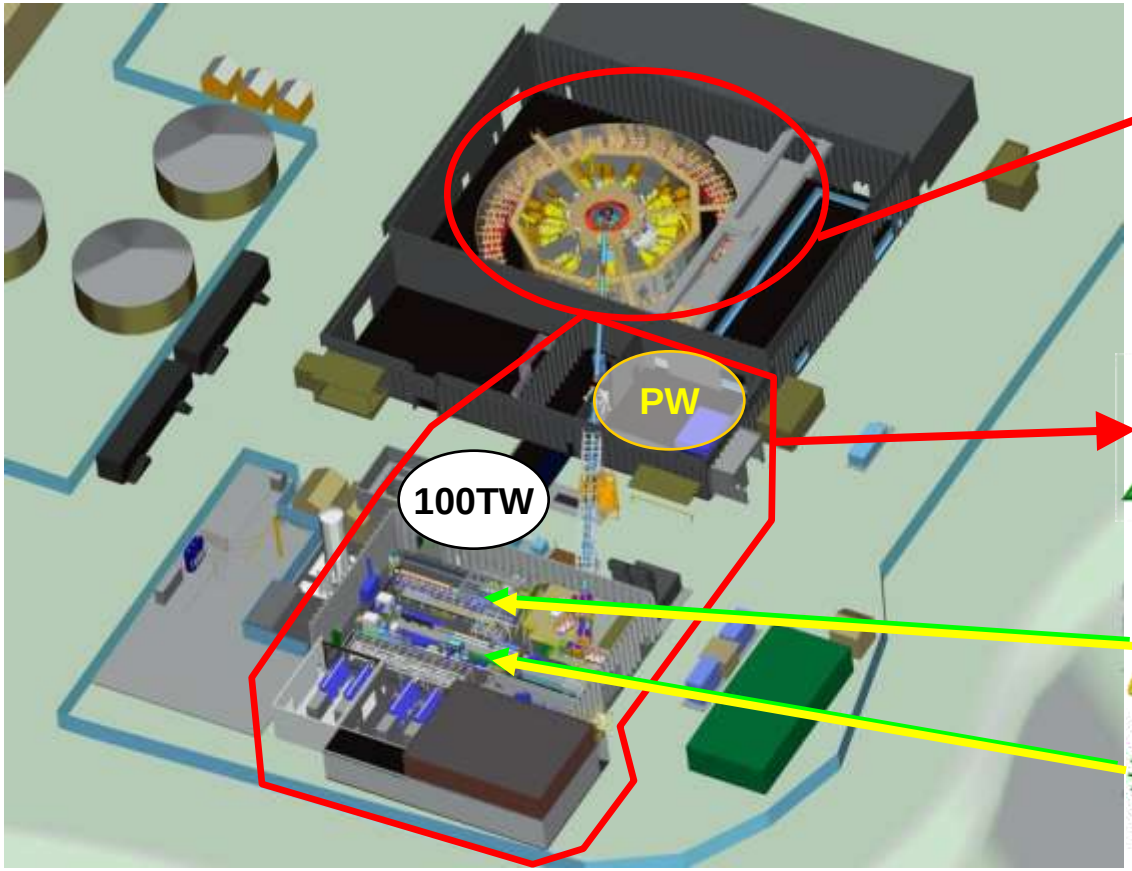
Z Facility Overview



Z

Z Backlighter

Z Petawatt

Z Beamlet

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