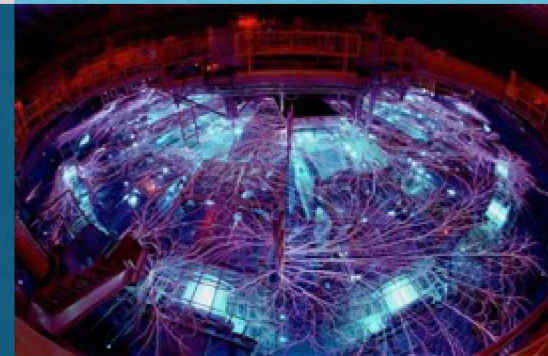


A Sample of Lasers and Optics at Sandia National Laboratories



PRESENTED BY

Patrick Rambo

Meeting of the Albuquerque Chapter of the Optical Society of America
April 17, 2019



Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. SAND2019-1355 PE.



Sandia National Laboratories

- Brief overview



Broader Legacy in Lasers and Optics

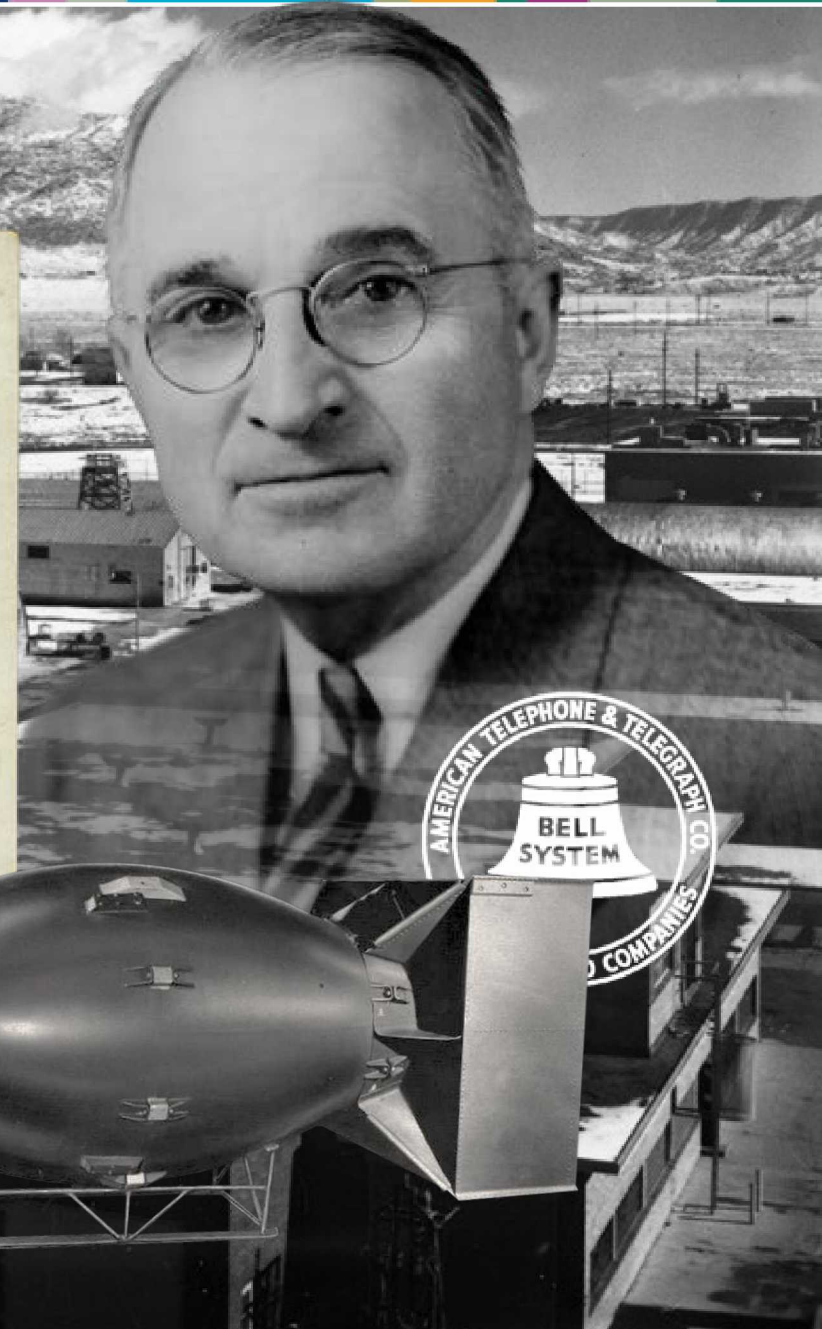
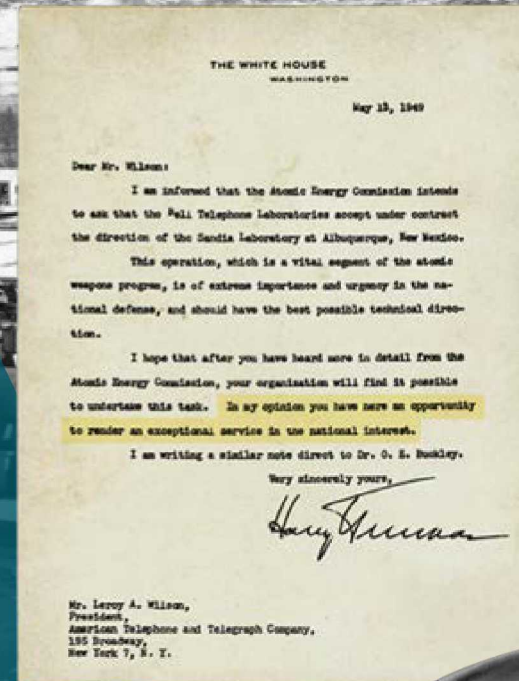
- Highlights



Applications in High-Energy Density Science

- VISAR
- Laser-Triggered Switching
- Z-Backlighter Laser Overview

- July 1945: Los Alamos creates Z Division
- November 1, 1949: Sandia Laboratory established. Government owned, contractor operated:
 - AT&T: 1949–1993
 - Martin Marietta: 1993–1995
 - Lockheed Martin: 1995–2017
 - Honeywell: 2017–present
- Sandia is presently the largest of the 17 U.S. Department of Energy National Laboratories
- Regular employees: 12,769
- Budget (FY18): \$3.64B



SANDIA HAS FACILITIES ACROSS THE NATION.



Main sites

- Albuquerque, New Mexico: 11,341 staff
- Livermore, California: 1,428 staff



Activity locations

- Kauai, Hawaii
- Waste Isolation Pilot Plant, Carlsbad, New Mexico
- Pantex Plant, Amarillo, Texas
- Tonopah, Nevada





Sandia develops
advanced technologies
to ensure global peace.

ADVANCED SCIENCE & TECHNOLOGY



- Sandia has 5 major program portfolios: AS&T, Nuclear Deterrence, Global Security, National Security Programs, and Energy & Homeland Security
- AS&T integrates multidisciplinary efforts to advance the science of the possible for Sandia's missions.

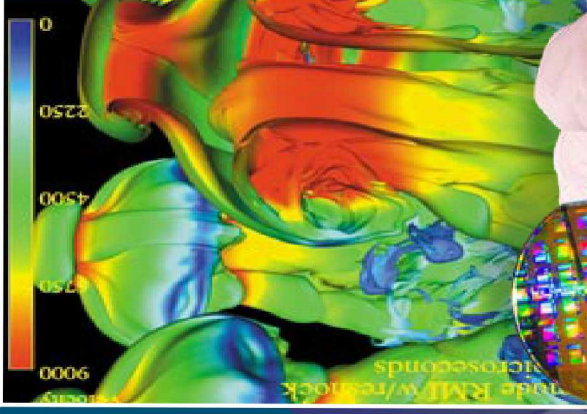
Nanodevices & Microsystems



Computing & Information Science



Engineering Science

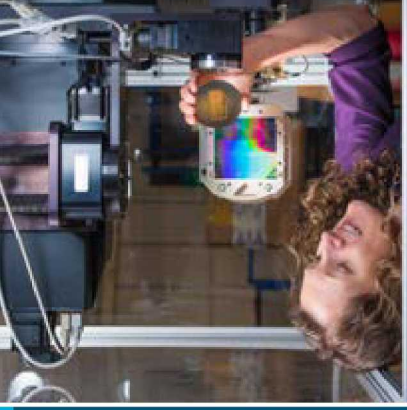


Geoscience

Radiation Effects & High Energy Density Science



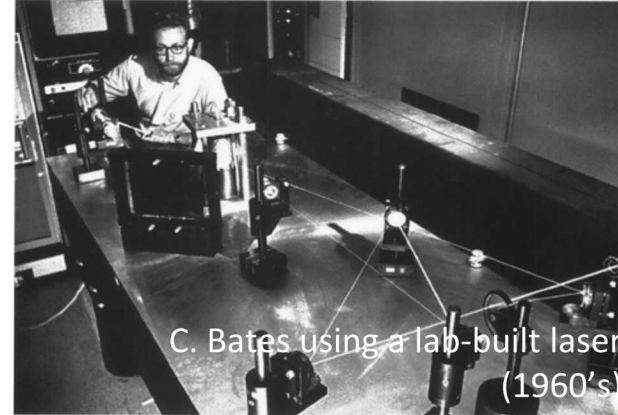
Materials Science



Bioscience



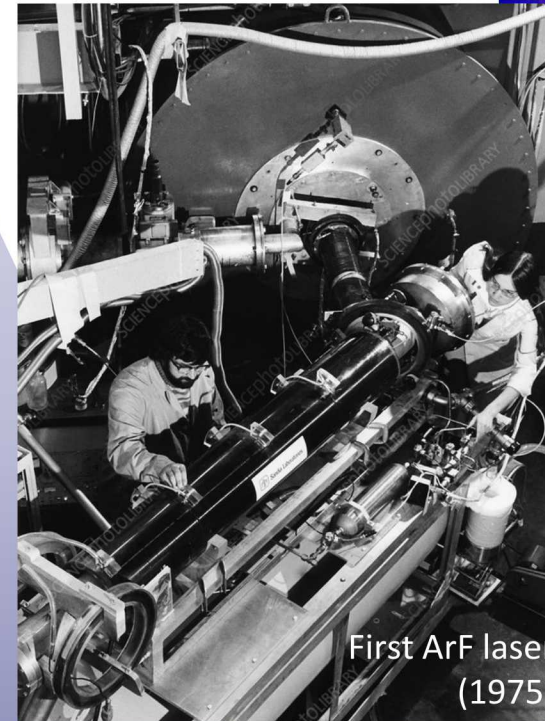
- 1960: The laminar clean room is developed at SNL.¹
- 1962: Ruby lasers are used to detonate HE.¹
- 1962: FO probes are used for NDE of weapons.¹
- 1969: Sandia laser programs demonstrate the 1st laser-produced neutrons in the U.S.²
- Early 1970's: Lasers are initially used for combustion research.¹
 - CRF at SNL-CA is still a key research area.
- 1972: Velocity interferometer system for any reflector (VISAR) is developed at SNL.³
- 1974: Sandia develops 1st nuclear fission pumped laser.¹
- 1975: HF laser work demonstrates most energetic pulse at that time.¹
- 1975: Sandia demonstrates the first ArF laser.⁴
- Mid-1970's: LAZAP facility established.⁵
- 1983: SDI work begins.¹
- 1985: Osbourn develops strained super lattice theory at Sandia.¹
- 1985: Rimfire laser-triggered switches demonstrate 6MV switching.²
- 1998-2001: Z-Backlighter Laser Facility begins.²



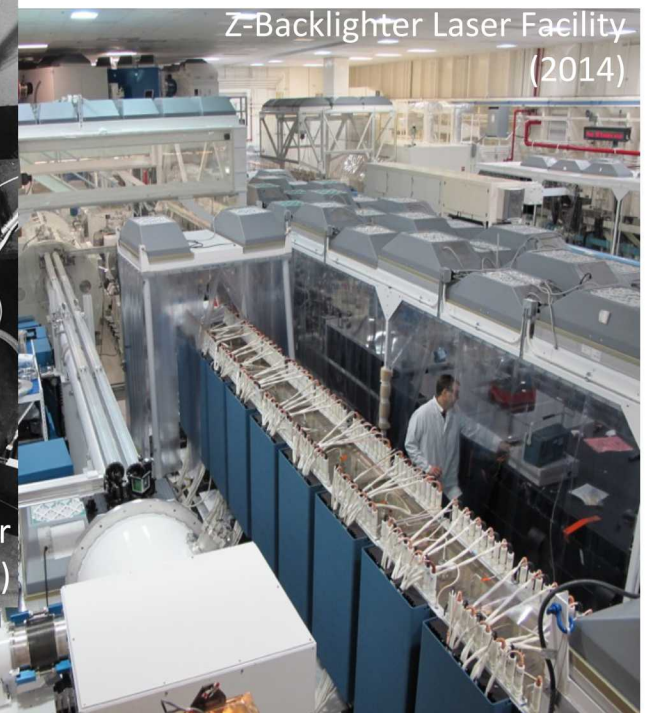
C. Bates using a lab-built laser
(1960's)



LAZAP Facility at work (2009)



First ArF laser
(1975)



Z-Backlighter Laser Facility
(2014)

1. Leland Johnson, "A History of Exceptional Service in the National Interest" (SAND97-1029)
2. Anne Van Arsdall, "Pulsed Power at Sandia National Laboratories: The First Forty Years" (SAND2007-2984P)
3. L.M. Barker and R.E. Hollenbach. Journal of Applied Physics **43**, 4669 (1972)
4. <https://www.sciencephoto.com/media/147162/view/first-argon-fluoride-pumped-laser-1975>
5. <https://www.sandia.gov/LabNews/091009.html>

- 2001: “Sandia's Z-Beamlet laser confirms even pellet compression”¹
- 2002: “Sandia Launches Solid-state Lighting Website”²
- 2003: “Sandia UV LEDs emit record power”³
- 2006: “Polymer mirrors ready for space test”⁴
- 2007: “LASER OPTICS: Deformable thermal-lens-correcting mirror has single actuator”⁵
- 2011: “Sandia National Labs completes final laser dynamic range imager scan of space shuttle program”⁶
- 2012: “Sandia's laser-guided bullet prototype can hit small targets a mile away”⁷
- 2014: “Sandia's adaptive zoom riflescope offers push-button magnification”⁸
- 2018: “Sandia light mixer generates 11 colors simultaneously”⁹
- 2019: “Sandia metamaterial design software now available to license for free”¹⁰
- 2019: “New device in Z machine measures power for nuclear fusion”¹¹



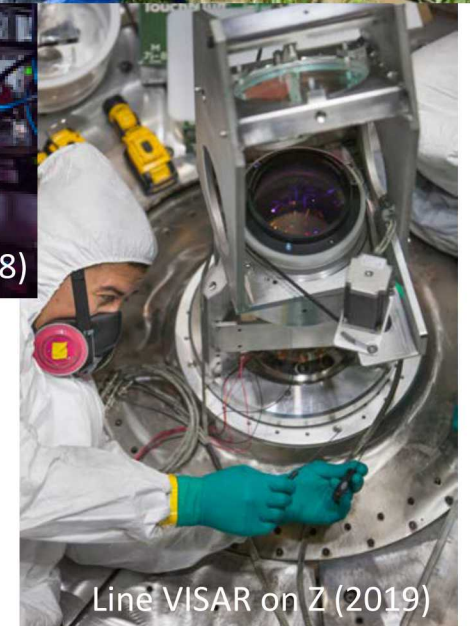
LED on guided bullet at night
(2012)



RAZAR riflescope
(2014)



Metamaterial Work (2018)



Line VISAR on Z (2019)

1. <https://www.laserfocusworld.com/articles/2001/09/sandia39s-z-beamlet-laser-confirms-even-pellet-compression.html>

2. <https://www.laserfocusworld.com/articles/2002/04/sandia-launches-solid-state-lighting-website.html>

3. <http://optics.org/article/18634>

4. <http://optics.org/article/25614>

5. <https://www.laserfocusworld.com/articles/print/volume-43/issue-2/world-news/laser-optics-deformable-thermal-lens-correcting-mirror-has-single-actuator.html>

6. <https://www.laserfocusworld.com/articles/2011/07/sandia-national-labs.html>

7. <https://www.laserfocusworld.com/articles/2012/02/sandia-laser-guided-bullet-prototype-can-hit-small-targets-a-mile-away.html>

8. <https://www.laserfocusworld.com/articles/2014/10/sandia-s-adaptive-zoom-riflescope-offers-push-button-magnification.html>

9. https://share-ng.sandia.gov/news/resources/news_releases/optical_mixer/

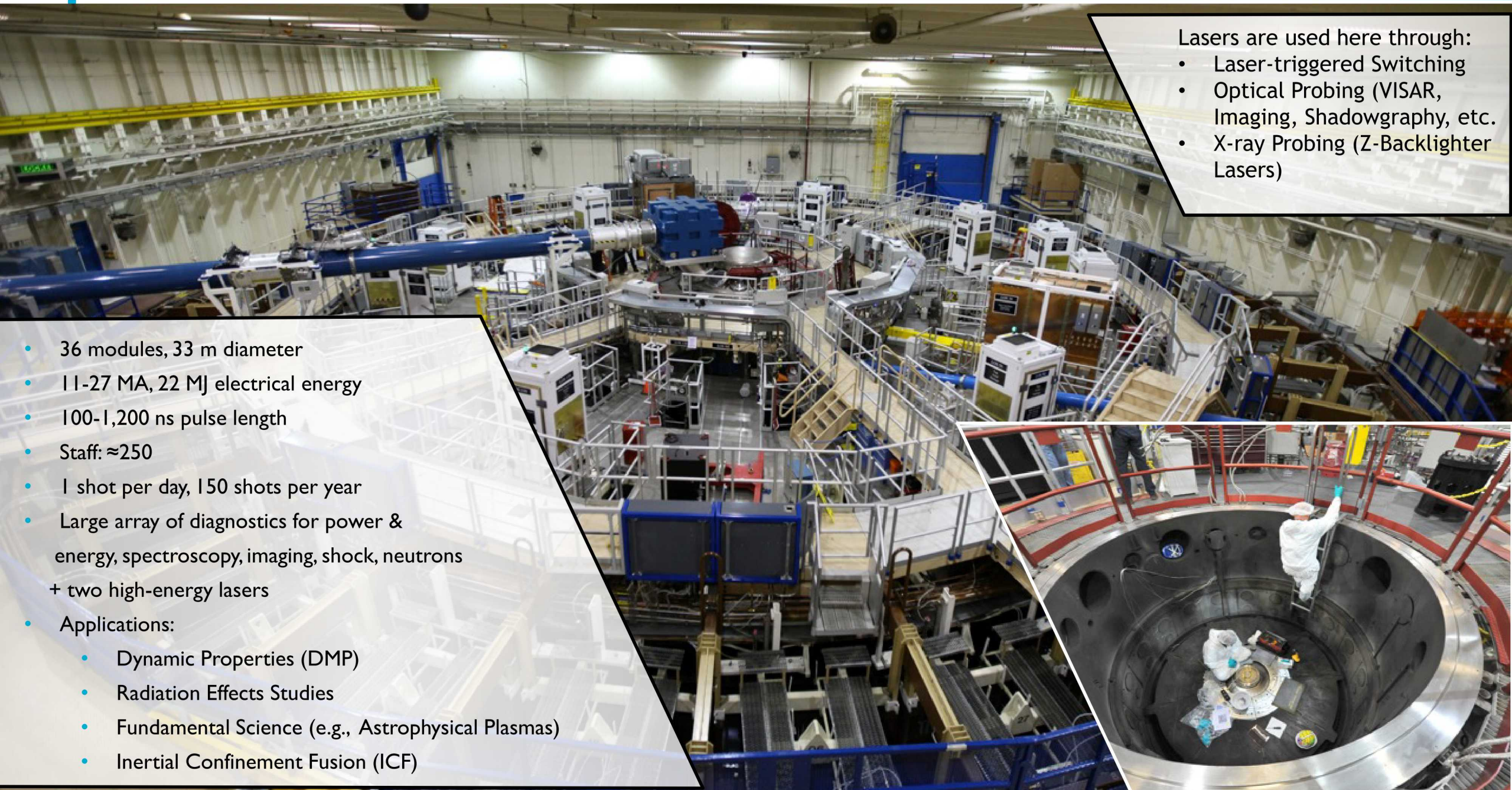
10. <https://www.laserfocusworld.com/articles/2019/03/sandia-metamaterial-design-software-now-available-to-license-for-free-see-video.html>

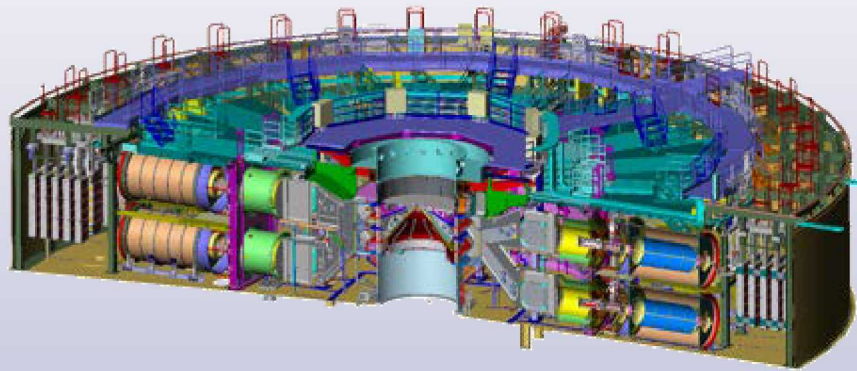
11. https://share-ng.sandia.gov/news/resources/news_releases/line_visar/

Lasers are used here through:

- Laser-triggered Switching
- Optical Probing (VISAR, Imaging, Shadowgraphy, etc.)
- X-ray Probing (Z-Backlighter Lasers)

- 36 modules, 33 m diameter
- 11-27 MA, 22 MJ electrical energy
- 100-1,200 ns pulse length
- Staff: ≈ 250
- 1 shot per day, 150 shots per year
- Large array of diagnostics for power & energy, spectroscopy, imaging, shock, neutrons + two high-energy lasers
- Applications:
 - Dynamic Properties (DMP)
 - Radiation Effects Studies
 - Fundamental Science (e.g., Astrophysical Plasmas)
 - Inertial Confinement Fusion (ICF)

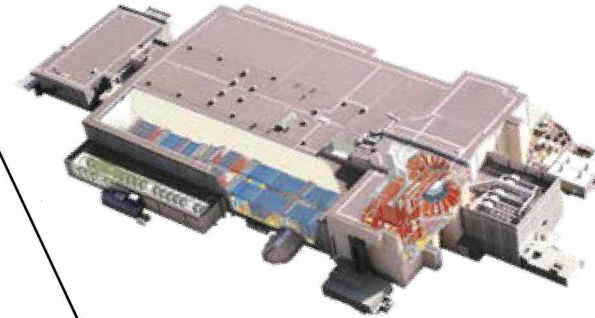




Z FACILITY

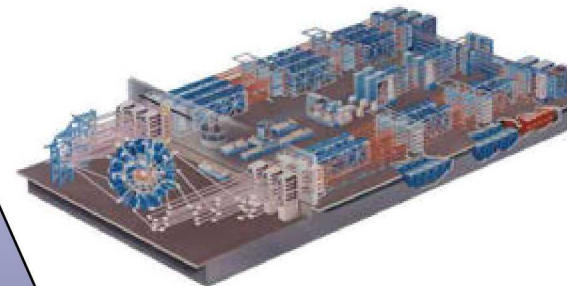
- Larger samples & time scales than NIF
- Largest pulsed power facility on Earth
- 80 TW / 3 MJ (Max Power & Energy)

NATIONAL IGNITION FACILITY

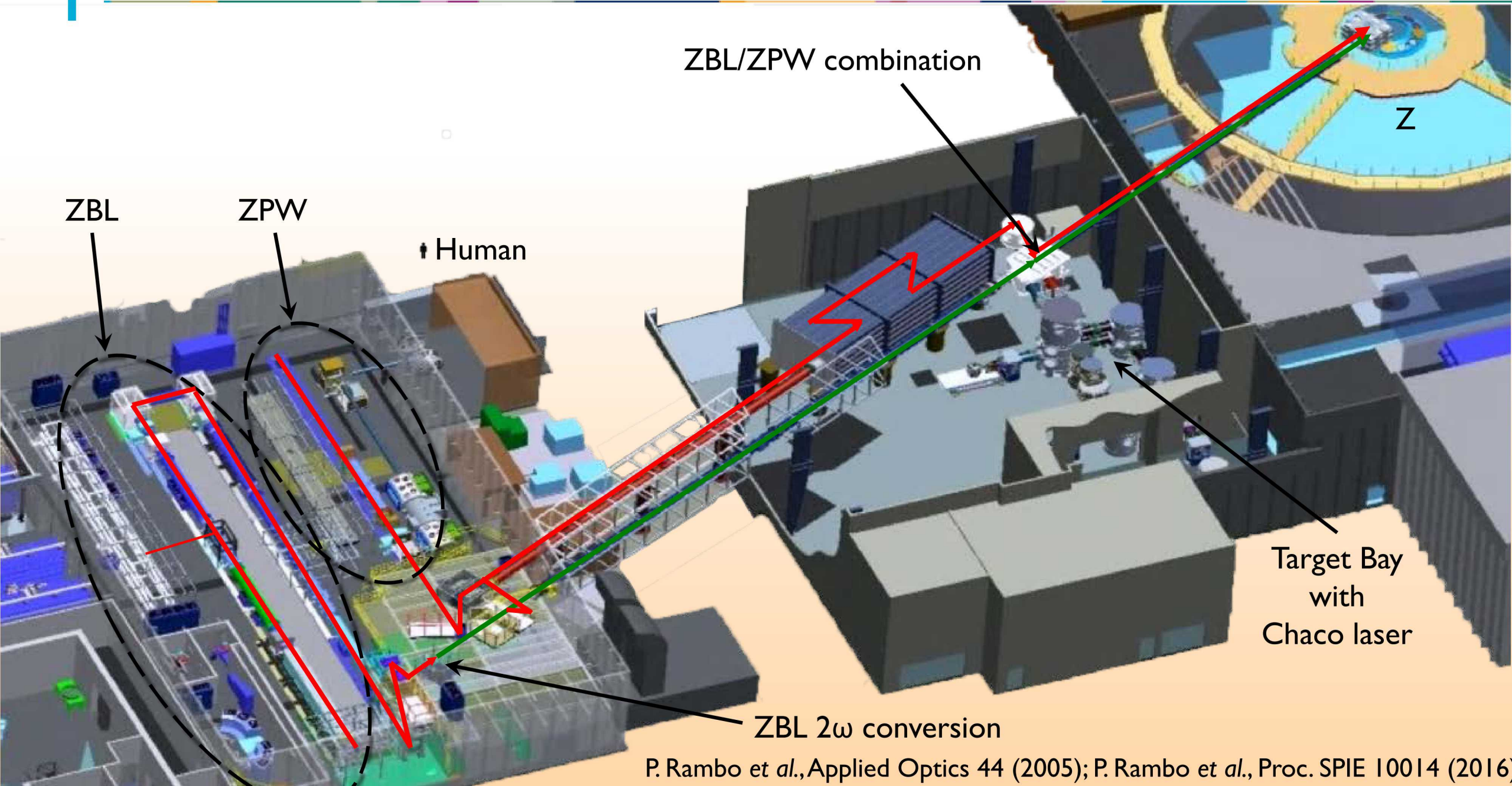


- Hottest temperatures and highest pressures on Earth
- Largest laser on Earth
- 400 TW / 1.8 MJ (Max Power & Energy)

OMEGA FACILITY



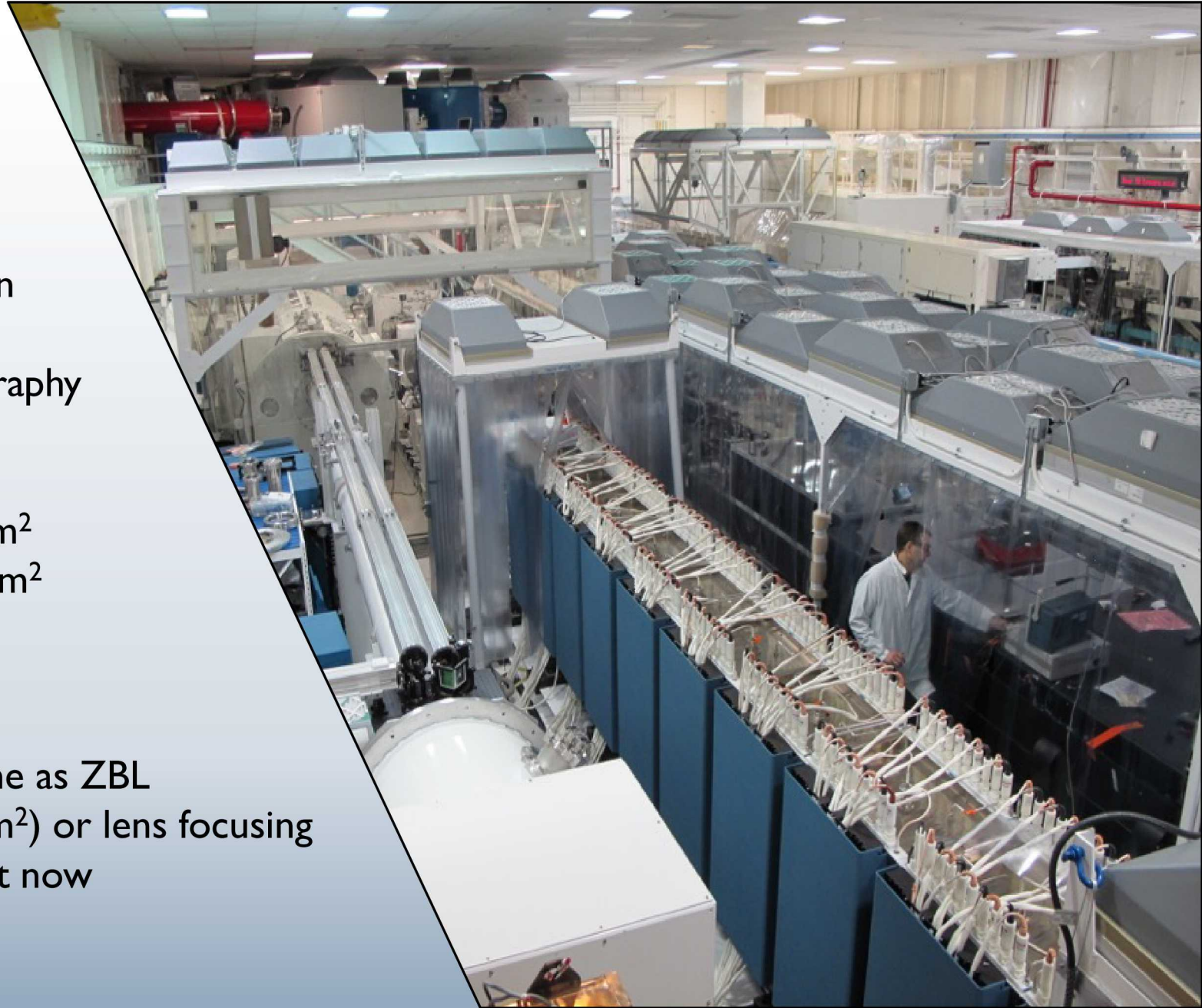
- High shot-rate academic laser facility
- Platform and diagnostic development
- 20 TW / .03 MJ (Max Power & Energy)

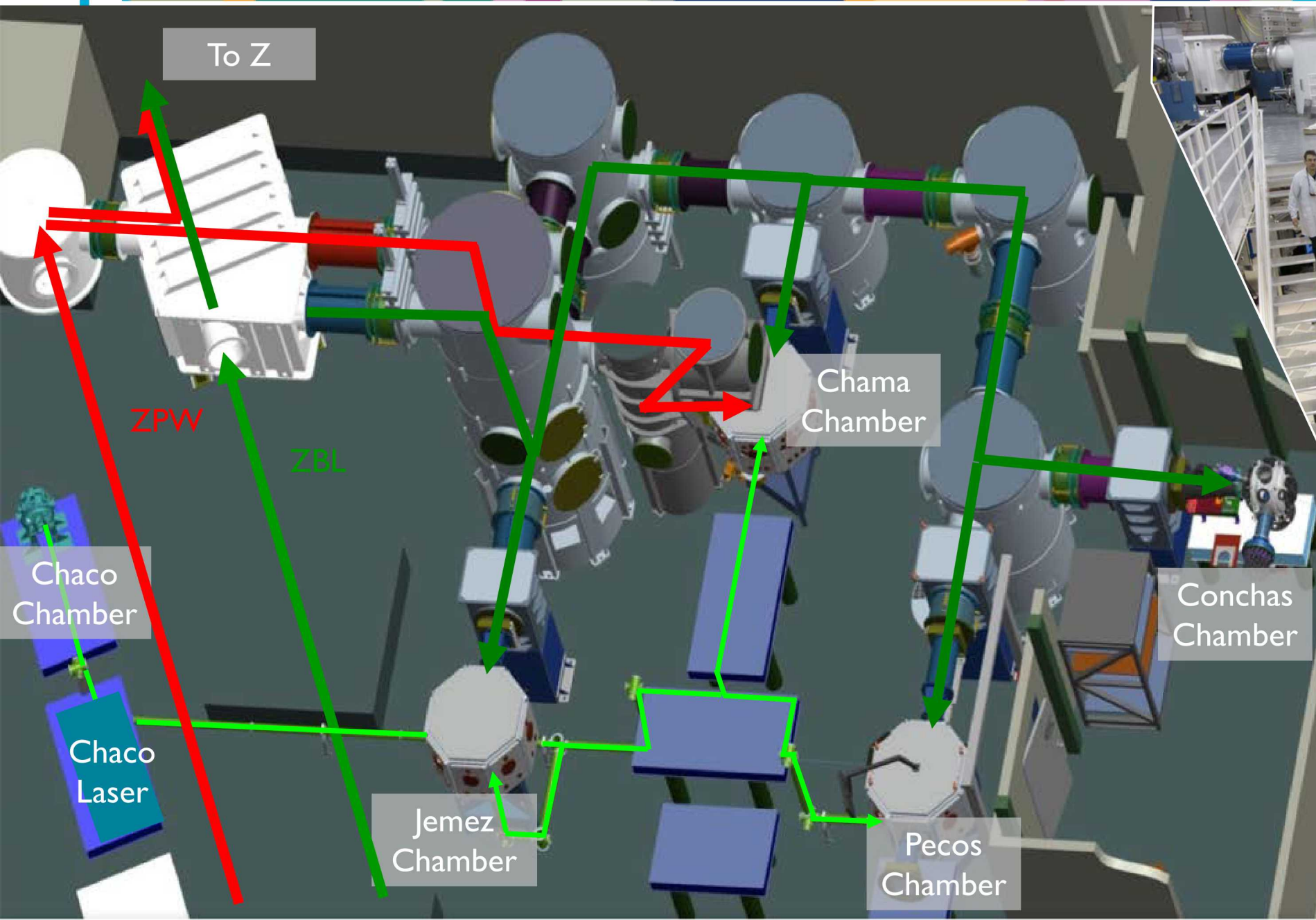


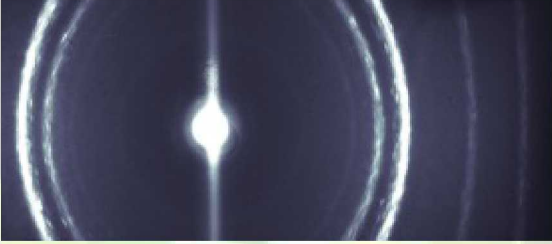
- 1992 – 1998: NIF prototype (Beamlet)
- Since 2001: Z-Beamlet at Sandia
- Main uses:
 - Preheat MagLIF fuel
 - X-ray source for backlighting/diffraction
- Parameters:
 - 6 kJ @ 1053 nm, , 30 x 30 cm² beam
 - 4.5 kJ @ 527 nm, 30 x 30 cm² beam
 - 3 shots per day
 - 4 target chambers + Z
 - Phase modulation system
 - Lens & phase plates for focusing ($I_{\max} \approx 10^{17}$ W/cm²)
 - Arbitrary temporal shape, typ. 0.5 ns pre-pulse+1-4 ns main



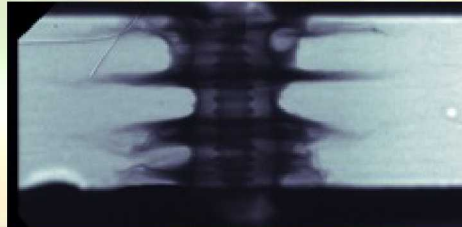
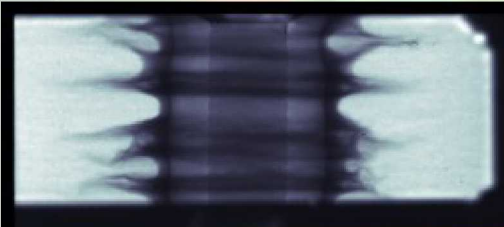
- Shortpulse, 1ω operation
 - Particle acceleration/ γ -rays
 - Above-10 keV x-ray generation
- Co-injection into ZBL and 2ω operation
 - Additional energy for ZBL pulse
 - Flexible prepulse for MagLIF/radiography
- Parameters:
 - 500 J @ 1053 nm, 500 fs, $27 \times 31 \text{ cm}^2$
 - 1000 J @ 1053 nm, 10 ps, $27 \times 31 \text{ cm}^2$
 - 1000 J @ 527nm, 2 ns, $27 \times 31 \text{ cm}^2$
- 3 shots per day
- 1ω : 2 target chambers + Z, 2ω : same as ZBL
- Off-axis parabola ($I = 2 \times 10^{20} \text{ W/cm}^2$) or lens focusing
- Full-aperture upgrade on-going right now



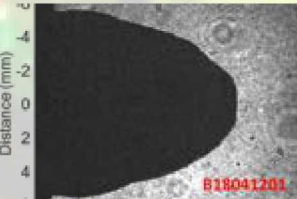
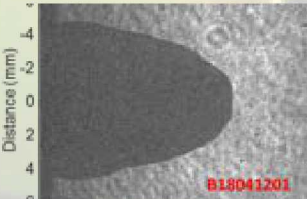
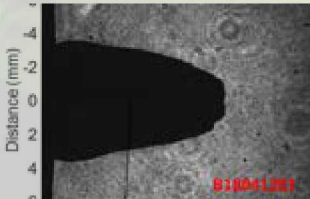




Dynamic x-ray diffraction



Time-gated x-ray
crystal backlighting

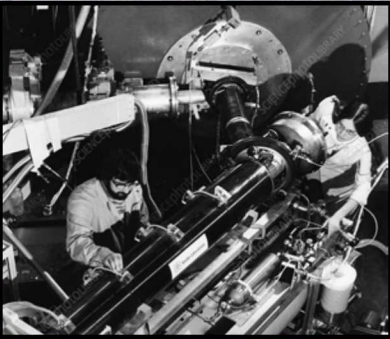


Laser-heating
of MagLIF fuel



Sandia National Laboratories:

- Largest one of the 17 National Labs
- 12,700 employees, \$3.64B budget



Optics and Laser History:

- Numerous contributions since the early 1960's



Z Backlighter Facility:

- Home of the Z-Beamlet, Z-Petawatt, and Chaco lasers
- Missions: MagLIF preheat, x-ray backlighting, x-ray diffraction on Z