National Ignition Facility & Photon Science

NIF and High Energy Density Science

Supporting stockpile stewardship, demonstrating laser fusion ignition, pursuing high energy density science, furthering U.S. competitiveness, and operating as a national user facility.

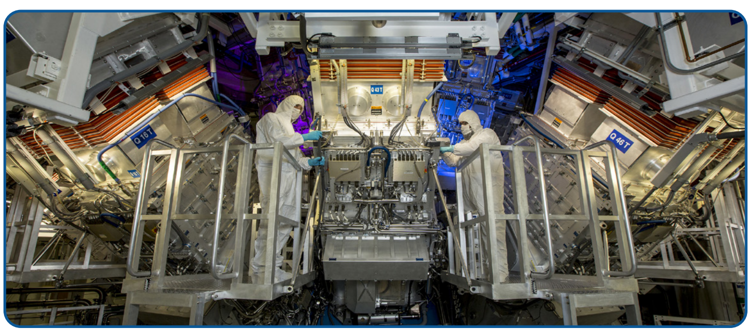
World's Highest-Energy Laser

The National Ignition Facility (NIF), the world's most energetic laser system, creates the extreme temperatures and pressures necessary to advance science-based stockpile stewardship, achieve laser fusion ignition, and deepen our understanding of the universe. Tens of thousands of optics strengthen and guide light from NIF's 192 laser beams into a 10-meter-diameter Target Chamber and onto miniature, highly engineered targets.

As the premier facility creating conditions relevant to understanding the operation of modern nuclear weapons, NIF is a crucial element of stockpile stewardship, producing experimental data that validates 3D weapon simulation codes, improves understanding of important weapon physics, and investigates questions remaining from underground nuclear tests. NIF experiments inform Life Extension Programs (LEPs), the regularly planned nuclear weapons system refurbishments that ensure long-term reliability.

National Ignition Facility

Home of the world's most energetic, reliable, and reproducible laser system.



And inertial confinement fusion (ICF) experiments also aid in investigating questions remaining from underground nuclear testing. These and other experiments study high energy density (HED) science, supporting a range of national security applications and the work of laboratory and university researchers to recreate astrophysical phenomena located light years away.

Accomplishments

Since NIF became operational in March 2009, more than 4,400 shots have been conducted by researchers from national laboratories, the military, federal agencies, academia, and the international scientific community. NIF is a critical element of stockpile stewardship to maintain the effectiveness of America's nuclear weapons. NIF is the only facility capable of achieving fusion ignition and thermonuclear burn, a scientific grand challenge of the stewardship program.

- On Dec. 5, 2022, NIF made scientific history with a shot that achieved fusion ignition in a laboratory for the first time. The shot generated 3.15 MJ of fusion energy from an input of 2.05 MJ of laser energy. Ignition was achieved four more times in 2023. This capability provides new opportunities for stockpile stewardship applications and enhances the prospects for an inertial fusion energy future.
- NIF has safely executed more than 20 plutonium diffraction experiments, returning important scientific data on plutonium's behavior at high pressure.
- NIF experiments have helped stockpile stewards answer questions important to the current Life Extension Program for the Air Force W80-4 warhead.
- LLNL scientists developed an experimental platform at NIF to measure the melting curve of iron to 1,000 GPa. The Discovery Science Program, which provides academic users access to NIF's HED regimes and enhances collaborations between LLNL scientists and academia, made this work possible.
- NIF produced a record 2.15 megajoules (MJ) of UV energy and 438 terawatts of peak power, a 15 percent improvement over NIF's original 1.8 MJ design specification.
- The Advanced Radiographic Capability (ARC), a high-energy, high-intensity laser embedded within NIF, can create more penetrating x rays for new radiography capabilities, revealing phenomena with never-before-seen clarity for classified weapons science experiments.

HIGH ENERGY DENSITY SCIENCE

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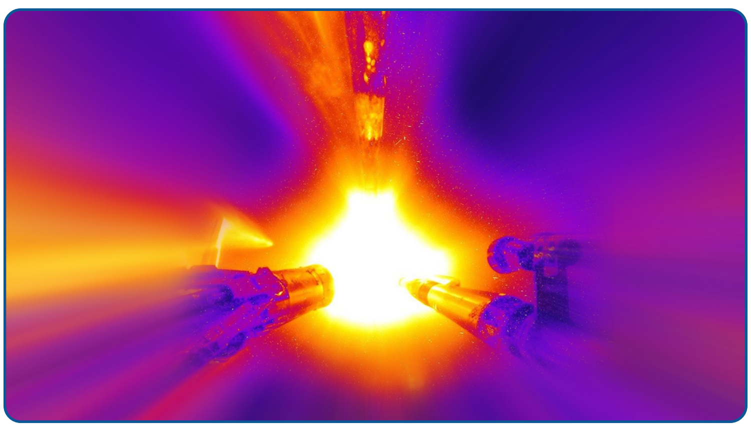
- Use of NIF by the radiation effects community is growing rapidly and NIF is studying how electronics and materials behave when exposed to extreme neutron pulses.

Scientific Underpinning

NIF embodies several LLNL core competencies, including HED science; lasers and optical science; advanced materials and manufacturing; ultrafast detectors and precision diagnostics; and nuclear, chemical, and isotopic science. HED research examines materials under pressures and densities found in stars, the cores of giant planets, and detonating nuclear weapons, helping to advance fields such as astrophysics and materials science. Advanced diagnostic instruments provide unprecedented insights into HED systems. Experimental data inform and validate 3D weapon simulation computer codes. Many NIF shots focus on advancing ICF ignition for the stewardship program. Experiments rely on intricate targets, leveraging LLNL's materials science and advanced manufacturing strengths.



NIF Target Implosion

A NIF target at the moment of implosion. The target positioner is at left and a hardened gated x-ray imaging diagnostic is at right.

- Designing successful experiments in NIF's often unprecedented regimes draws upon LLNL's expertise in many scientific disciplines, including high-pressure materials science and computational, atomic, radiation, nuclear, and plasma physics.
- LLNL scientists have made significant progress in preventing damage to optics in high-intensity laser light. Patented processes make optics' surfaces more resilient by removing impurities and absorbing microfractures; these breakthroughs extend the lifetime of optics and permit increased energy from NIF laser light.
- Experimenters rely on an array of more than 120 nuclear, optical, and x-ray diagnostic instruments — many designed and fabricated at LLNL in collaboration with universities and the other national labs — to record vital data from NIF shots at micrometer-length scales and picosecond (trillionths of a second) timescales. These instruments push the state-of-the-art in measurement capabilities.
- NIF experiments rely on a wide variety of targets that all have intricate assemblies of extremely small parts. Designing, machining, and assembling these parts with micro-manipulators into precisely manufactured targets requires a complex interplay among target designers, physicists, materials scientists, chemists, engineers, and technicians. Continuous improvements in NIF targets is a key to continual progress in increasing ignition energy yields.

The Future

By providing the capabilities to achieve fusion ignition and burn in a laboratory setting, NIF will continue to be a critical experimental facility for stockpile stewardship. As the last underground tests recede into history, NIF experiments will become more critical to stewardship and for paving the way toward an inertial fusion energy future. The high rigor and multidisciplinary nature of NIF experiments also help LLNL attract, retain, and train future stockpile stewards.

NIF scientists and engineers are pushing on all fronts to increase NIF's capabilities to address challenges, including higher energy and power limits, next-generation optics, improved targets with tighter specifications, and enhanced diagnostics.

With NIF having achieved fusion ignition, further improvements will lead to robust and reproducible high-yield implosions, enabling the stewardship program to conduct experiments in new physical regimes.

Continued research, together with sustainment and enhancements of NIF, will lead to better implosions and improved understanding of fusion ignition requirements.

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