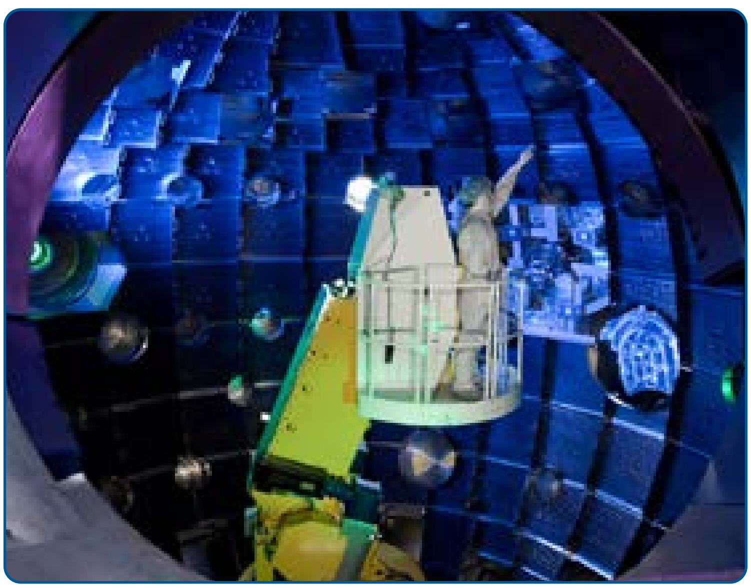
National Ignition Facility & Photon Science

The National Ignition Facility: Science & Technology on a Mission

The National Ignition Facility (NIF) is the world's largest and highest-energy laser system. NIF is an essential experimental tool supporting the Stockpile Stewardship program of the U.S. Department of Energy's National Nuclear Security Administration.

Construction began in 1997, and NIF became operational in March 2009. During experiments, NIF's 192 intense laser beams are capable of focusing more than 1.8 million joules of ultraviolet laser energy and 500 trillion watts of power in billionth-of-a-second pulses on a millimeter-sized target. NIF is the world's preeminent facility for conducting inertial confinement fusion and high energy density science research and for studying matter at extreme densities, pressures, and temperatures.



NIF Target Chamber
Technicians perform scheduled inspection and maintenance inside the NIF Target Chamber using a specially built lift inserted through the bottom of the chamber.

When all of NIF's energy slams into its tiny targets, unprecedented conditions are generated in the target materials—temperatures of more than 100 million degrees Celsius (180 million degrees Fahrenheit), densities many times the density of lead, and pressures more than 350 billion times Earth's atmospheric pressure. These conditions are similar to those inside stars, the cores of giant planets, and nuclear weapons—allowing NIF to create, in essence, a miniature star on Earth. As a premier national user facility, NIF enables Lawrence Livermore National Laboratory's NIF & Photon Science Directorate to accomplish its core missions:

- Support the U.S. National Nuclear Security Administration's Stockpile Stewardship Program, which ensures a safe, secure, and reliable nuclear stockpile, by conducting experiments to enhance understanding of the physics of nuclear weapons;
- Empower academic collaborators to explore new Discovery Science frontiers in astrophysics, materials science, nuclear science, and many other scientific disciplines;
- Further U.S. scientific and economic competitiveness by transferring new technology to the private sector and training future generations of scientists; and
- Provide the scientific basis for a revolution in energy production; inertial fusion energy offers the potential for virtually unlimited safe and sustainable clean energy by harnessing the power of the sun and stars.

The NIF Complex

NIF encompasses three interconnected buildings: the Optics Assembly Building, the Laser and Target Area Building, and the Operations Support Building. Inside the Optics Assembly Building, large precision-engineered laser components are assembled under stringent cleanroom conditions into special modules called line replaceable units for installation into the laser system.

The Laser and Target Area Building houses the 192 laser beams in two identical bays. Large mirrors, specially coated for the laser wavelength and mounted on highly stable 10-story-tall structures, direct the laser beams through the "switchyards" and into the Target Bay. The mirrors are focused to the exact center of the 10-meter-diameter, concrete-shielded, 130-ton Target Chamber.

Construction of all the buildings and supporting utilities was completed in 2001. All 192 enclosures for laser beams were completed in

WHAT IS NIF?

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2003, and the second of NIF's two laser bays was commissioned in 2008, demonstrating a total maximum infrared energy of 4.22 megajoules.

In July 2012, NIF fired all 192 beams into the center of the Target Chamber, delivering 1.8 megajoules of ultraviolet energy and more than 500 terawatts of peak power. The beam-to-beam uniformity was better than 1 percent, making NIF not only the highest energy laser of its kind but also the most precise and reproducible. In May 2018 the NIF lasers set a new energy record, firing 2.15 megajoules of energy into the Target Chamber.

Why Are There 192 Beams?

Imagine trying to squash a water balloon with two hands. No matter how hard you try to spread your fingers evenly over the surface of the balloon, it will still squirt out between your fingers. Many more fingers would be needed to compress the balloon symmetrically. Earlier high-energy lasers were used to study the conditions required to compress tiny spherical capsules to fractions of their initial diameter while still maintaining the capsule's symmetry—a crucial requirement if NIF is to achieve fusion ignition. NIF's designers arrived at 192 focused spots as the optimal number to achieve the conditions that will ignite a target's hydrogen fuel and start fusion burn.

Deformable Mirrors
These adjustable mirrors are used to correct for aberrations that accumulate in the laser beam because of minute distortions in the optics.

Extraordinary Precision

Every NIF experimental shot requires 13.5 to 14 million lines of constantly evolving computer code and coordination of up to 66,000 control points for electronic, high-voltage, optical, and mechanical devices—motorized mirrors and lenses, energy and power sensors, video cameras, laser amplifiers, and diagnostic instruments. Achieving this level of precision requires a large-scale computer control system as sophisticated as any in government service or private industry.

The meticulous orchestration of these pieces results in the propagation of 192 separate nanosecond (billionth of a second)-long bursts of light. The 192 separate beams must have optical path lengths equal to within 9 millimeters so that the pulses can arrive within 30 picoseconds (trillionths of a second) of each other at the center of the Target Chamber. There they must strike within 50 micrometers of their assigned spot on a target the size of a pencil eraser. NIF's pointing accuracy can be compared to standing on the pitcher's mound at Oracle Park in San Francisco and throwing a strike at Dodger Stadium in Los Angeles, some 350 miles away.

Because the precise alignment of NIF's laser beams is extremely important for successful operation, the requirements for vibrational, thermal, and seismic stability are unusually demanding. Critical beampath component enclosures (generally for mirrors and lenses), many weighing tens of tons, were located to a precision of 100 micrometers using a rigorous engineering process for design validation and as-installed verification.

Optics Inspection System
NIF's Final Optics Damage Inspection system, when extended into the Target Chamber from a diagnostic instrument manipulator, can produce images of all 192 beamline final optics assemblies in just a few minutes.

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