

National Ignition Facility & Photon Science

The National Ignition Facility: Bringing Star Power to Earth

The National Ignition Facility (NIF), a project of the U.S. Department of Energy's National Nuclear Security Administration, is the world's largest laser and highest energy laser system.

Construction began in 1997, and NIF became operational in March 2009. During experiments, NIF's 192 intense laser beams focus more than one million joules of ultraviolet laser energy in billionth-of-a-second pulses to a BB-size target. NIF is the world's preeminent facility for conducting inertial confinement fusion and laser fusion energy research and for studying matter at extreme densities and temperatures.

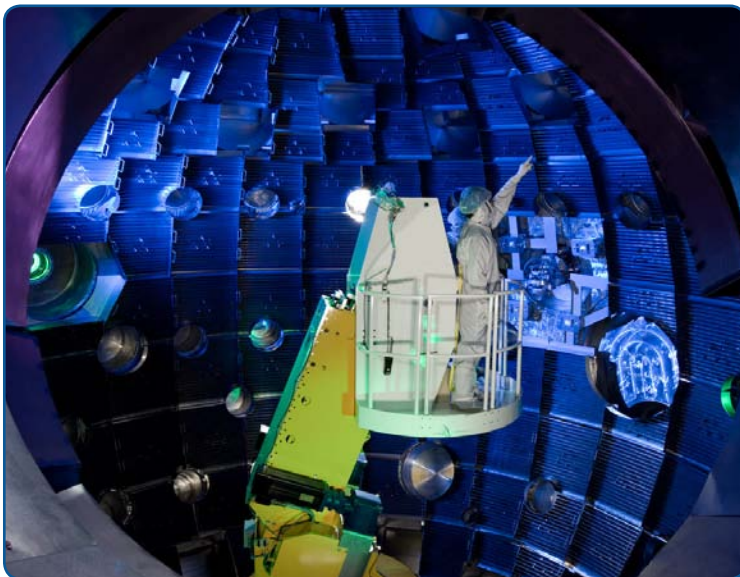
By creating, in essence, a miniature star on Earth, NIF will enable Lawrence Livermore National Laboratory's NIF & Photon Science Directorate to accomplish its three missions: to enable a better understanding of the complex physics of nuclear weapons without underground testing; to provide scientists with the physics understanding necessary to create fusion ignition and energy gain for future energy production; and—as a national user facility—to enable academic collaborators to explore new frontiers in astrophysics, materials science, nuclear science, and many other scientific disciplines.

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



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 millimeter-sized targets, unprecedented temperatures and pressures are generated in the target materials—temperatures of more than 100 million degrees and pressures more than 100 billion times Earth's atmospheric pressure. These conditions are similar to those inside stars, the cores of giant planets, and nuclear weapons.

WHAT IS NIF?

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In March 2009, NIF fired all 192 beams into the center of the target chamber, delivering 1.1 million joules of ultraviolet energy in a pulse that matched the shape necessary for achieving ignition. Since that time, National Ignition Campaign (NIC) experiments have begun. NIC includes all of the experiments, hardware, and infrastructure needed to execute the initial integrated experiments leading to ignition by the end of 2012 and to continue research on ignition in the following years.

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

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 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 AT&T 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 beam-path component enclosures (generally for mirrors and lenses), many weighing tens of tons, were located to a precision of 100 microns using a rigorous engineering process for design validation and as-installed verification. ■



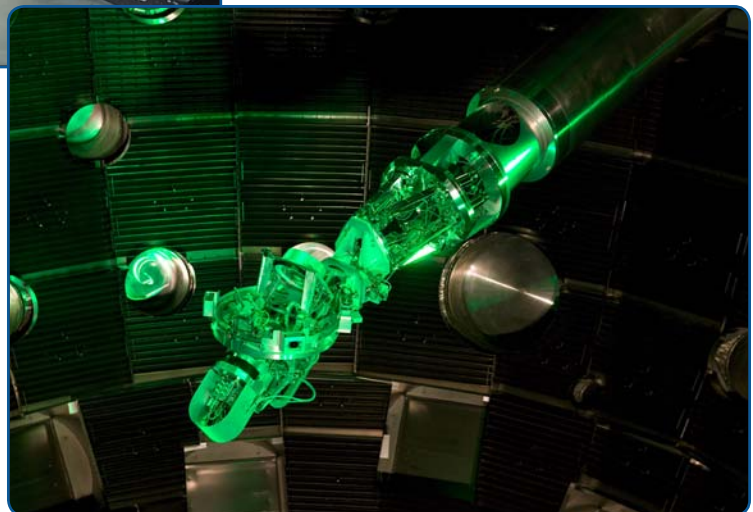
Deformable Mirrors

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

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.

Extraordinary Precision

Every NIF experimental shot requires the coordination of up to 60,000 control points for electronic, high-voltage, optical, and



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.