Photons & Fusion Newsletter

NIF Project Completion Campaigns Off to a Fast Start

NIF control room operators monitor the results of a laser shot.

The National Ignition Facility (NIF) continued to close in on its scheduled completion by the end of March 2009 as a series of laser shot campaigns to demonstrate project completion criteria began in December. Project completion campaigns include firing 96 of NIF's 192 laser beams to target chamber center (TCC) with an energy of 500 kilojoules.

Early on the morning of Dec. 15, the first shot of the 96-beam campaign was accomplished: about 40 kilojoules (kJ) of 3ω (ultraviolet) laser energy was fired into the NIF target chamber. All four 48-beam clusters were operated simultaneously.

> ***"This is an incredible success for the entire NIF team"***
>
> ***—Bruno Van Wonterghem***

On Dec. 16 NIF conducted two more shots on the way to project completion. These shots fired 3ω energies of 273 and 325 kJ to the target chamber, exceeding existing laser systems by nearly an order of magnitude in energy. Peak power was 65 terawatts (TW) in a five-nanosecond (ns) pulse, with excellent balance. The time between these shots was five hours and 40 minutes, meeting NIF's eight-hour completion criterion.

On Dec. 19 the NIF team delivered 1.005 megajoules (MJ) of 1ω (infrared) and 626 kJ of 3ω energy to the target chamber. 540 kJ of 3ω energy was produced in 96 beams –

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exceeding the project completion energy criterion developed 12 years ago. And on Dec. 23, the team completed the final two shots of the first phase of the 96-beam operational qualification campaign, four days ahead of the original schedule. The shots produced 207 TW to TCC in a 2-ns pulse in 96 beams, meeting the 200-TW peak power PC requirement. The second shot, fired within five hours, demonstrated a 21-ns pulse on 96 beamlines.

"These shots are an amazing achievement and a huge step towards completing the NIF Project and moving into the Ignition Campaign," said NIF Commissioning Manager Bruno Van Wonterghem. "This is an incredible success for the entire NIF team."

National Ignition Campaign External Review

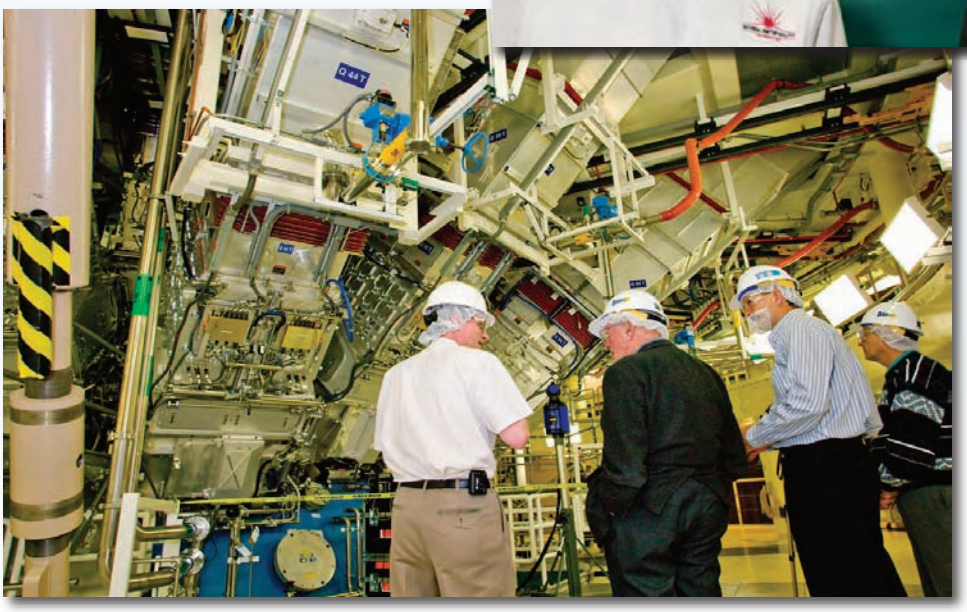
An external review of the National Ignition Campaign (NIC) was conducted at Lawrence Livermore National Laboratory on December 8–10. The review committee was chaired by Dr. John Poate of the Colorado School of Mines and was composed of reviewers from academia, the national laboratories, the U.K.'s Atomic Weapons Establishment (AWE) and France's Commissariat à l'Énergie Atomic (CEA). The committee heard presentations on a wide variety of topics related to the design, preparation and execution of the ignition campaigns. During their out-briefing to the NIC team, committee members remarked that they were very impressed with the progress the team has made.

Laser Pioneer Charles Townes Visits NIF

Nobel laureate Charles H. Townes paid his first visit to the National Ignition Facility on Dec. 19. Dr. Townes, 93, won the 1964 Nobel Prize in physics for developing the laser and maser. Along with Arthur Schawlow, Dr. Townes published a key paper on the theory of the laser in *Physical Review* in 1958 (Phys. Rev. 112, 1940 - 1949 (1958)), which led to the first patent for a laser awarded in March 1960 and the first demonstration of a working laser two months later by Theodore Maiman at Hughes Research Lab. Asked his impression of NIF, Dr. Townes said, "Well, I'm amazed...fantastic. When I was inventing the laser and hoping to build the first one, I was hoping to get...milliwatts of power with a small laboratory device. I just never imagined anything like this coming out of it."

NIF Commissioning Manager Bruno Van Wonterghem said Dr. Townes "was extremely impressed with the scale of the laser and the results we have demonstrated so far. We are proud to have him here while we conduct the demonstration campaigns."

NIF Commissioning Manager Bruno Van Wonterghem (left) with Charles H. Townes, inventor of the maser and co-holder of the first patent on the laser.

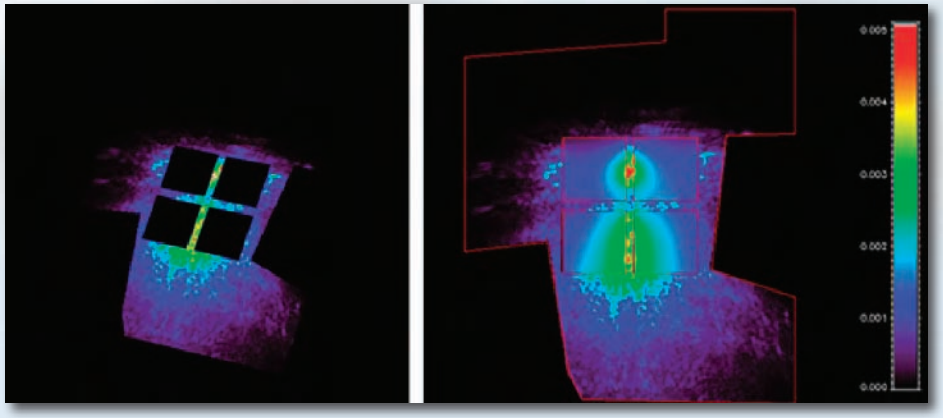


Bruno Van Wonterghem (left) shows Charles Townes (center) the NIF Target Chamber.

Near-Backscatter Imaging Analysis

In an ideal world, all of the laser energy incident on the NIF fusion target would remain in the target. Laser-plasma instabilities, however, cause some of the laser energy to be backscattered, resulting in a reduction of energy available for achieving ignition.

In a presentation during the November Center for Advanced Signal and Image Sciences (CASIS) Workshop at Lawrence Livermore National Laboratory (LLNL), NIF researchers Essex Bond, Pierre Michel, Paul Neumayer and John Moody described NIF's near-backscatter imaging (NBI) system, one of two diagnostic tools used to assess the coupling efficiency of the NIF 3ω (351-nm) laser energy to an ignition target.



Simulated example of time-integrated stimulated Raman backscatter imaging for a NIF quad of four beamlitnes: a calibration sensitivity map is multiplied and summed to obtain total energy (left); the input CCD image is transformed to world view (an undistorted view in front of the plate) (right); and the scattered energy is then interpolated throughout the four beamlines.

The backscattered energy is expected in two primary spectral bands. Stimulated Brillouin scattering is observed in the 350- to 353-nm range, and stimulated Raman scattering is observed in the 450- to 750-nm range. It is important to ensure that the total backscattered energy remains below required levels (~10% of the total incident energy). Using simulated data, the researchers described how the NBI diagnostic uses a gated intensified charge-coupled device (ICCD) camera to quantitatively measure the energy backscattered outside the focusing cone angle of the incident laser beam. The ICCD provides 2-mm resolution over a 2-m field of view at the NIF target chamber wall.

In addition to describing the NBI imaging system and the algorithms used to determine backscattered energy from acquired images, the presentation also discussed the challenges with NBI analysis, including transforming the perspective of an image and interpolating the distribution of backscatter over each laser port entrance.

Laser Scientists Moses, Correll Named AAAS Fellows

Ed Moses

Ed Moses, NIF & Photon Science Principal Associate Director, and Don Correll, Director of LLNL's Institute for Laser Science Applications, have been named fellows of the American Association for the Advancement of Science (AAAS).

Selection as a fellow is an honor bestowed upon AAAS members by their peers. This year, 486 members were recognized by AAAS because of their scientifically or socially distinguished effort to advance science or its applications.

Moses was cited for "distinguished scientific and engineering contributions leading to development and construction of the world's largest and most energetic laser system, the National Ignition Facility."

Don Correll

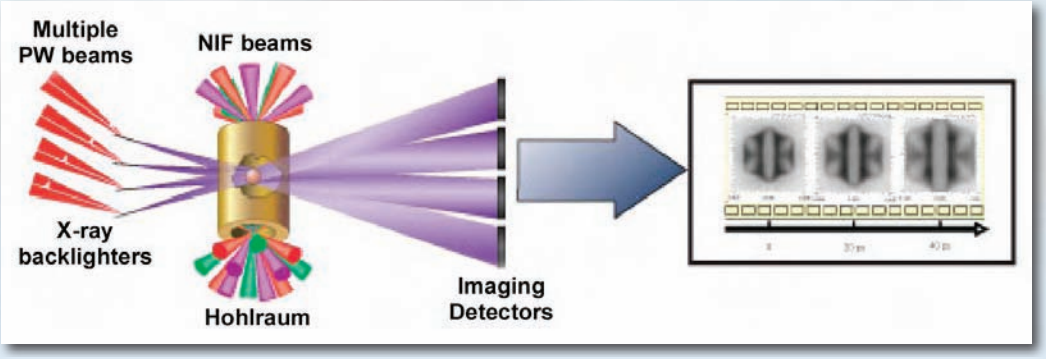
Correll was honored for his "long-standing recognition and distinguished contributions to science education, including communications and materials targeted toward students, teachers and the general public."

Moses was also recently honored by Fusion Power Associates, which selected him for a Leadership Award in recognition of his "more than 20 years of leadership in the development of laser technologies at LLNL and his current leadership of the construction of the National Ignition Facility."

New AAAS fellows will be presented with an official certificate and a gold or blue (representing science and engineering, respectively) rosette pin on Saturday, Feb. 14, at the AAAS Fellows Forum during the 2009 AAAS Annual Meeting in Chicago.

Improved Diagnostics for the NIF Petawatt Capability

Two papers describing progress in developing the Advanced Radiographic Capability (ARC) for the National Ignition Facility were presented at the International Conference on Ultra-high Intensity Lasers held in Shanghai-Tongli, China, from October 27 to 31.



The ARC quad of beamlines can provide up to eight backlighters for ignition evaluation.

For the ARC project, NIF researchers are converting four of the NIF laser system's 192 long-pulse beamlines (one quad) to eight petawatt-class, high-intensity beams. Each of these eight beams can be independently timed, pointed and focused onto high-Z X-ray backlighters in the vicinity of the cryogenic ignition target, producing a multi-frame, short-pulse X-ray movie of the cryogenic fusion target during the compression and ignition phases. The system will also play a critical role in prospective studies of fast-ignition physics on NIF and high energy density science.

ARC is designed to deliver kilojoule pulses from 0.75 picoseconds (ps) to 50 ps with peak focused intensity above 10^{19} watts per square centimeter (W/cm^2) using chirped-pulse amplification. One beamline of ARC incorporates two split beams with different timing and pulse durations. ARC provides high flexibility with respect to inter- and intra-beam timing and allows setting energy and pulse-durations individually per split beam.

Due to NIF's complexity, converting a quad of beamlines to dual use (short- and long-pulse capability) requires novel approaches to design, construction, alignment, controls, dispersion balance and commissioning that are not typically found on petawatt laser systems.

In a paper titled, "Integrating Four Petawatt Beamlines into the National Ignition Facility (NIF)," researchers from the Photon Science & Applications (PS&A) Program and colleagues from the Physics Department at the University of California, Davis, discussed the use of Compton radiography for diagnosing compression symmetry in imploding laser fusion targets for the National Ignition Campaign.

In the second paper, "Precision Diagnostics for the Advanced Radiographic Capability on the National Ignition Facility," PS&A's Constantin Haefner and colleagues described a diagnostics package for obtaining reliable and precise single-shot characterization of the ARC high-energy petawatt laser pulse in the temporal, spatial and spectral domain. The large architecture of NIF, the precise timing requirements, and the high intensities impose challenges to measure the intensity on target.

The precision diagnostic package comprises near- and far-field cameras for alignment; a high-resolution, 16-bit far-field camera for focal spot characterization; frequency resolved optical gating for pulse-duration measurement; a high-resolution spectrometer for spatial chirp and bandwidth analysis; and a lateral shearing interferometry for wavefront and adaptive optics control. For measuring pulse duration and intra-beam delay after compression, the team has developed an ultra-sensitive SHG-scanning cross correlator which is capable of measuring the pulse duration of either split beam or intra-beam timing at energy levels less than 70 picojoules.

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