A WALK THROUGH THE NATIONAL IGNITION FACILITY

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The National Ignition Facility (NIF) will house the world's most powerful laser system. Figure 1 shows the laser and target area building, as they appear in the Title I Design (see p. vi). The overall floor plan is U-shaped, with laser bays forming the legs of the U, and switchyards and the target area forming the connection. The NIF will contain 192 independent laser beams or "beamlets" that are 40 × 40 cm each. Beamlets are grouped into 2 × 2 "quads," which are stacked two high in 4 × 2 "bundles" (thus eight beamlets per bundle). These bundles are grouped six each into four large "clusters," two in each laser bay, for a total of 192 beamlets (8 beamlets per bundle × 6 bundles per array × 4 clusters. The 192 laser beamlines will require more than 7000 discrete, large optical components (larger than 40 × 40 cm) and several thousand smaller optics. Beams from the laser will strike a series of mirrors, which will redirect them to the large target chamber shown on the right side of Figure 1. The building for the NIF will be about 100 m wide (122 m including the capacitor bays), and about 170 m long.

In the following tour, we track the path of a laser pulse from its beginnings in the master oscillator room (MOR) to the target chamber through the principal laser components.

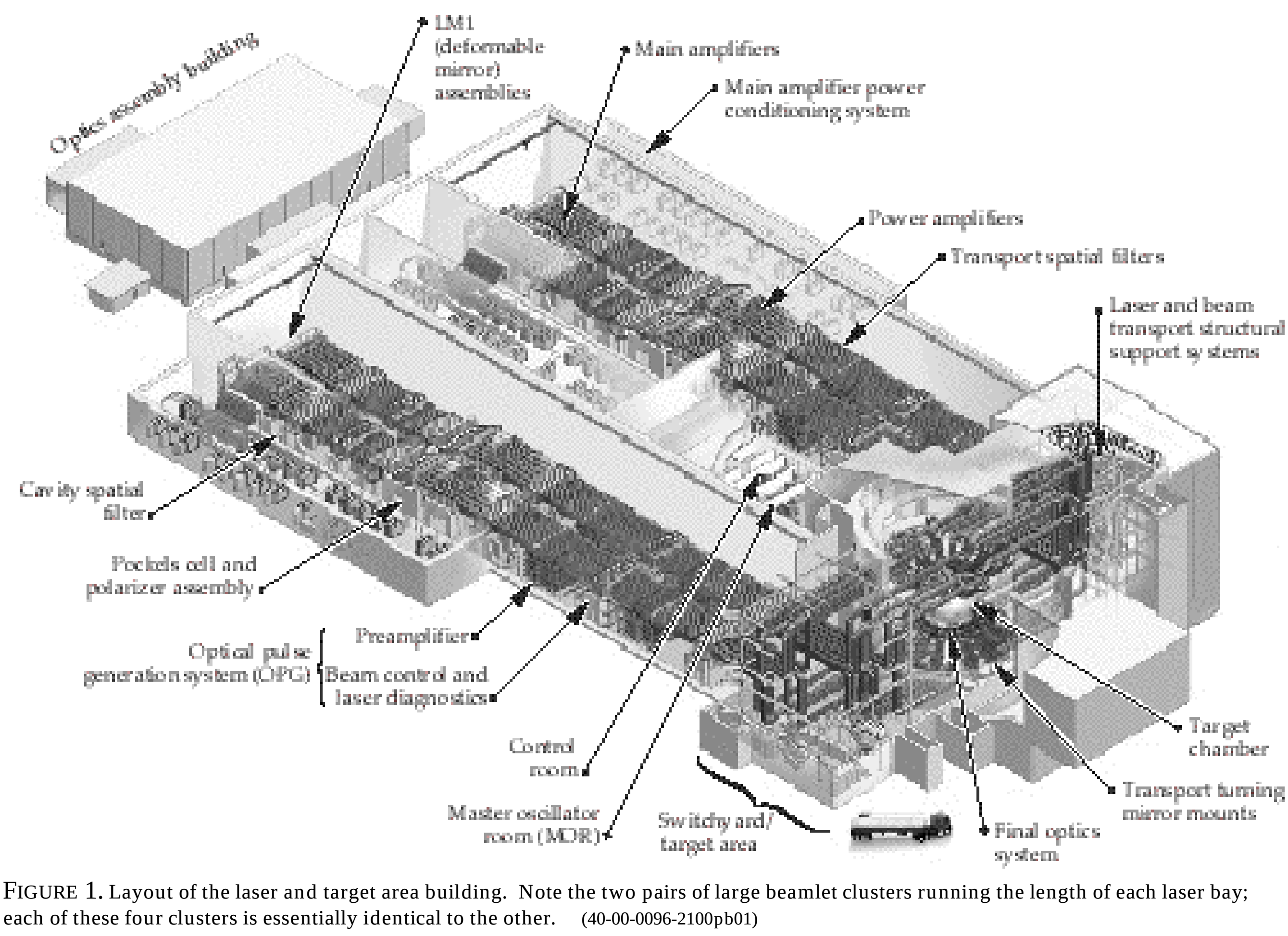

FIGURE 1. Layout of the laser and target area building. Note the two pairs of large beamlet clusters running the length of each laser bay; each of these four clusters is essentially identical to the other. (40-00-0096-2100pb01)

WHY 192 BEAMS?

In deciding how many beams for the NIF, there were two conditions we had to meet. First, there had to be enough beam area facing the target to deliver the required energy. The maximum safe 3ω fluence for an ignition target pulse is about 9 J/cm^2. The maximum practical single beam area is about 1300 cm^2, which would deliver about 11 kJ/beam on the target. At 11 kJ per beam, we need at least 164 beams to put 1.8 MJ on target. Second, we had to consider the conditions required by indirect- (x-ray-) drive targets. These targets (cylindrically symmetric hohlraums) require twice as many beams in the outer cone as in the inner cone, illumination from two directions, and eight or more beam spots per cone. When we multiply these factors together, we find that the beam count must be divisible by 48. The smallest system that satisfies these two conditions is 4 × 48 = 192 beams.

It turns out that it is also very convenient to transport these beams in 48 (2 × 2) clusters, and that this configuration is also compatible with direct-drive uniformity requirements. Finally, 192 beams at 9 J/cm^2 provides 2.2 MJ, a full 20% margin for baseline operation of 1.8 MJ.

Master Oscillator System

The laser pulse is produced in the master oscillator room, where a fiber ring oscillator generates a weak, single-frequency laser pulse. A phase modulator puts on bandwidth for smoothing by spectral dispersion (SSD) and suppressing stimulated Brillouin scattering. Each pulse is then launched into an optical fiber system that amplifies and splits the pulse into 48 separate fibers. The optical fibers carry the pulses to 48 low-voltage optical modulators very similar to those used in high-bandwidth fiber communication systems. These modulators allow us to temporally and spectrally shape each pulse by computer control. An optical fiber then carries each nanojoule, 1-µm pulse to a preamplifier module (PAM).

Preamplifier Module

Optical fibers carrying the pulses from the master oscillator room spread out to 48 preamplifier modules, located on a space frame beneath the transport spatial filters. Each preamplifier has a regenerative amplifier followed by a flashlamp-pumped four-pass rod amplifier. The preamplifier is a two-stage system, designed as a self-contained assembly, that can be pulled out and replaced as needed. The preamplifier brings the pulse to about 10 J, with the spatial intensity profile needed for injection into the main laser cavity. Before entering the main cavity, the output from the preamplifier is split four ways. These four pulses are injected into the four beams that form each of the 48-beam “quad” arrays.

Main Laser System

Figure 2 shows the layout of the main laser components of a NIF beamlet. These components take a laser pulse from the preamplifier to the final optics assembly. A laser pulse from the preamplifier enters the main laser cavity when it reflects from a small mirror labeled LM0 in Figure 2. This mirror is located near the focal plane of the transport spatial filter. The 40-cm-diam pulse exits the transport spatial filter, traveling to the left, and passes through the power amplifier, containing five amplifier slabs.

The beam then enters the periscope assembly, which contains two mirrors (LM2 and LM3) and a switch (a Pockels cell and a polarizer). The pulse reflects off LM3 and the polarizer before passing through the Pockels cell. It goes through the cavity spatial filter and the 11-slab main amplifier, and then reflects from a deformable mirror with 39 actuators. After once again passing through the main amplifier, the beam comes back through the cavity spatial filter to the periscope assembly. Meanwhile, the Pockels cell has been fired to rotate the polarization, so the beam passes through the polarizer and strikes mirror LM2, which redirects it back through the cavity spatial filter for another double pass through the main amplifier. The beam returns to the periscope assembly, passes through the de-energized Pockels cell, reflects off the polarizer and LM3, and is further amplified by the power amplifier. Now the pulse passes through the transport spatial filter on a path slightly displaced from the input path. The output pulse just misses the injection mirror LM0 and enters the switchyard and beam transport area.

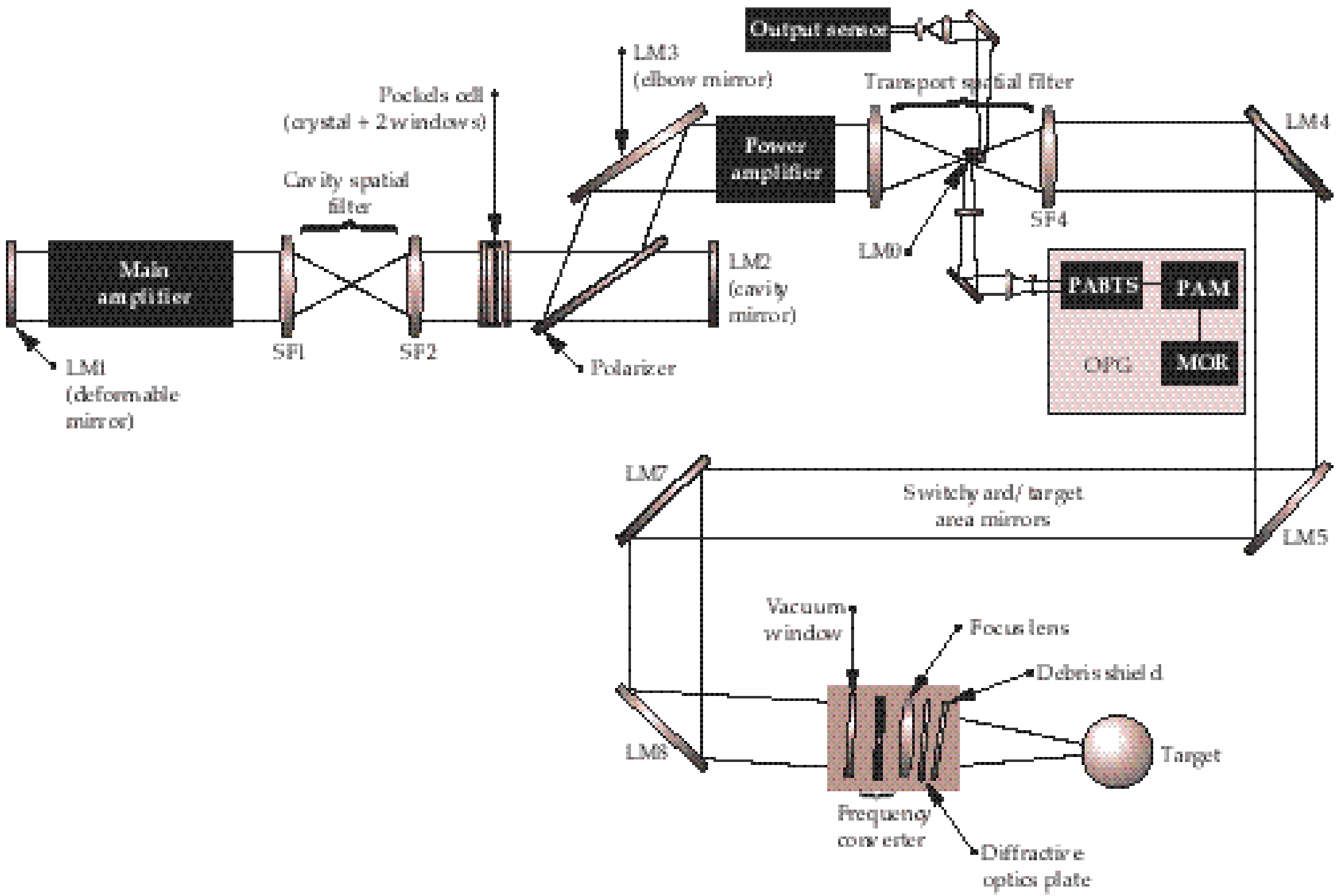

FIGURE 2. Schematic diagram of the NIF laser system. (40-00-0997-1759pb01)

Switchyard and Beam Transport

Between the switchyards and the target chamber room, the beams are in two 2 × 2 arrays: The 4 × 2 bundles are split into 2 × 2 quads, moving up or down to one of the eight levels of the switchyard (see p. 154). Each pulse now travels through a long beam path, reflecting off of several transport mirrors before reaching the target chamber. The transport mirrors can be moved to create the beam configuration needed for direct- or indirect-drive experiments. For indirect drive, mirrors send the beams straight up or straight down to make the cones coming into the top and the bottom of the target chamber cylinder (Figure 3). For direct drive, we can direct 24 beams to circumferential positions around the target chamber by moving two mirrors in each of these beamlines (Figure 4). Once the beams reach the target chamber, they enter the final optics assembly.

Final Optics Assembly

The final optics assemblies are mounted on the target chamber. Each assembly includes a vacuum window at 1ω, a cell that includes a frequency converter (two plates of potassium dihydrogen phosphate crystal) to convert the pulse to 3ω, and the final focusing lens. The cell tips and tilts to tune the frequency converter, and translates along the beam direction to focus the beam on the target. A debris-shield cassette includes the capability of diffractive optics for spot shaping. Once a pulse travels through this assembly, it proceeds to the target in the target chamber.

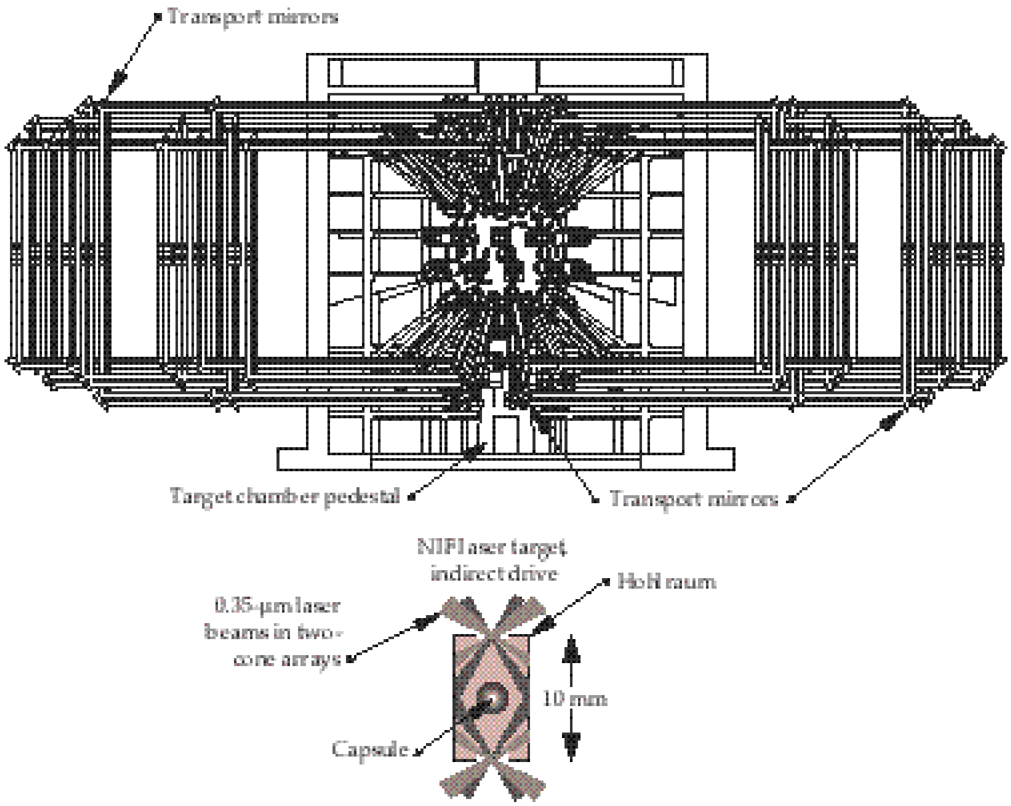

FIGURE 3. Beam transport layout for indirect-drive experiments (end view).
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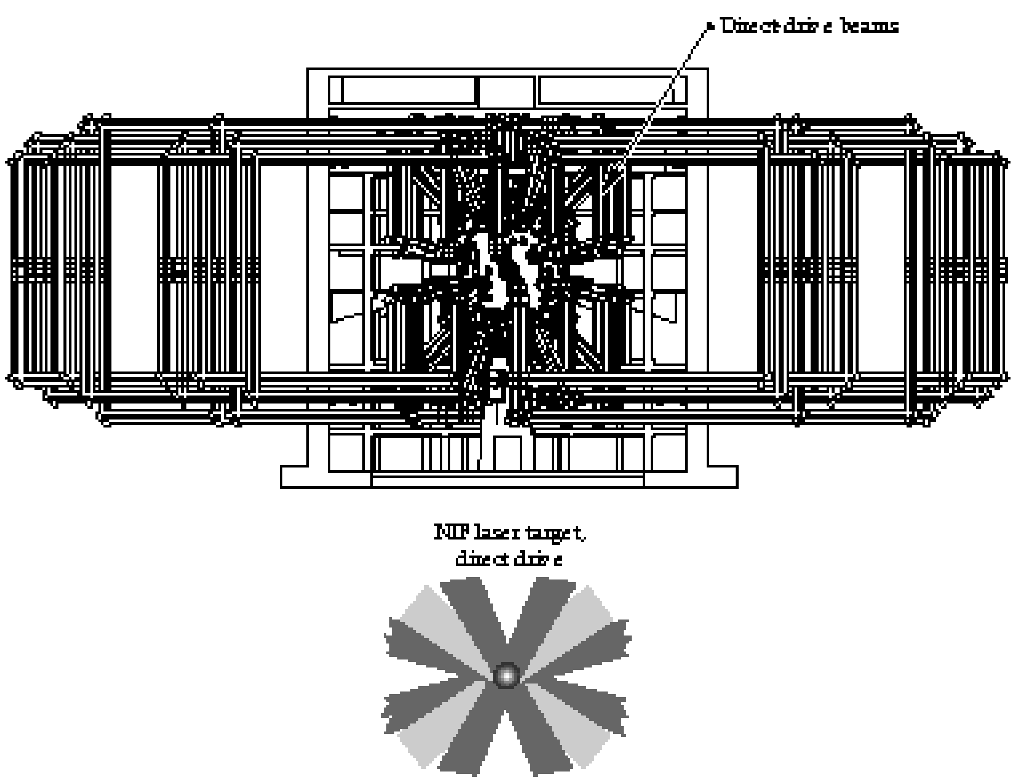

FIGURE 4. Beam transport layout for direct-drive experiments (end view).
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