NOVA/BEAMLET/NIF UPDATES JANUARY–MARCH 1997

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Nova

Nova Operations performed 201 full system shots, resulting in 213 experiments during this quarter. These experiments supported efforts in ICF, defense sciences, university collaborations, laser sciences, and Nova facility maintenance. The Nova shot rate continues to be impacted by facility funding reductions. The process of moving Nova Operations personnel into National Ignition Facility (NIF) related positions will continue, eventually resulting in Nova operating 1.5 shifts per day. Also impacting the shot rate for the quarter was a three-week period during which the first shift of each day was dedicated to facility maintenance. The Nova Operations personnel efficiently used the added maintenance time to perform deferred maintenance tasks and to expedite progress on system upgrades and additions.

The first series of implosion experiments was performed with kinoform phase plates (KPPs) on all ten beamlines. We were successful in maintaining the accuracy of precision pointing and power balance with the KPPs at levels sufficient to produce symmetric implosions. The first target-shot series with smoothing by spectral dispersion and KPPs on all ten beamlines was also successful. We achieved the desired bandwidth (2.4 Å at 1ω) with acceptable levels of temporal and spatial modulation on all beamlines.

The Petawatt Project efforts concentrated on preparing for the first series of shots into the new Petawatt target chamber in late April. The target chamber was cleaned, assembled, and installed early in the quarter. By the end of the quarter, the target chamber had been integrated into the Nova vacuum system with new hardware and software, then pumped down to a satisfactory vacuum level. The parabolic mirror, beam alignment, target insertion, target alignment, and target diagnostic systems were installed. Tests of these systems will be performed in early April.

The 4ω probe beam was successfully installed on the ten-beam target chamber. Off-line testing of the frequency conversion system has been completed. On-line testing and tuning will commence early next quarter. Plans are being formulated to use this beamline, which uses light taken from the center obscuration of beamline 8, as a probe beam for experiments in the Petawatt target chamber.

The preparations for decommissioning the Nova two-beam target area continue. The system will continue to operate until mid-November to allow for the completion of 100-TW and equation-of-state experiments. The area will be clear by mid-January, when we will begin work to convert it into a NIF optics processing area.

Beamlet

Beamlet continues to provide a testbed for validating the laser physics foundations of the National Ignition Facility (NIF) and for evaluating laser engineering concepts and components proposed for the NIF. During the second quarter of FY 1997 activities on Beamlet included the following:

1. Characterization of beam quality at the output of the Beamlet front end to validate noise propagation models and to support the development of optical specifications for the NIF preamplifier module.
2. Optimization of the laser wavefront using the Beamlet adaptive optics system to gauge compliance with NIF focusability requirements and to provide a baseline for testing a prototype NIF deformable mirror.

3. Successful testing of a 40-cm NIF prototype deformable mirror inside the main amplifier cavity.
4. Propagation of full system shots with angularly dispersed bandwidth to test the 1.06-μm laser requirements for producing 1D beam smoothing at NIF targets.

Modifications to the facility included a safety upgrade to dual-camera inspection systems for all four spatial filter lenses, as well as the removal of the frequency converter enclosure at the output of Beamlet to make way for installation of the final optics test mule.

The measurements performed on the Beamlet front end confirmed that the beam injected into the main amplifier is of high quality. In the absence of active wavefront correction, the injected beam is near-diffraction limited, with 80% of the power contained inside a divergence half angle of 4.3 μrad (for a 34-cm beam). The distortion of the measured wavefront is 0.1 wave rms, and the calculated Strehl ratio is 0.7. Amplitude modulation in the near field was measured to have an irradiance contrast of 5%, confirming model predictions that the small amount of modulation observed in the output beam at low power is driven by contributions from the front end.

Beam divergence at the output of the laser was characterized with the Beamlet adaptive optics system (AOS) optimized to correct for wavefront distortions incurred in the main amplifier. Emphasis of the tests was on establishing best attainable divergence at low power in the angular regime below 20 to 30 μrad to help ascertain wavefront gradient requirements for NIF optical components. Performance was monitored with radial shearing interferometers that measured near-field wavefront at the input and output of the main amplifier with a spatial resolution of 1 cm, and with cameras that measured the corresponding intensity distributions in the far field with an angular resolution of 0.3 μrad. Test results show that pumping the Beamlet amplifiers induces 1.8 waves of long scale-length distortion over the 34-cm beam that is fully correctable with the Beamlet AOS. Passive distortions in the system total ~2 waves peak to valley and are only partially correctable, resulting in a residual error of 1 wave peak to valley, 0.2 wave rms. The resulting output beam has 80% of the power contained inside a divergence half angle of 10 to 11 μrad, and a Strehl ratio of 0.5.

A prototype 40-cm deformable mirror and controller were provided by the NIF Wavefront Controls and U-AVLIS Adaptive Optics groups. The mirror was installed and tested in the multipass cavity at an end mirror position adjacent to the amplifier modules. No evidence of coating damage or degradation to the actuator assemblies was observed for the 11 shots in which the mirror was exposed to flashlamp radiation. Output wavefront was not as good as that obtained with the Beamlet deformable mirror because of a figure error of 1 wave peak to valley in the large mirror that was incurred during fabrication. The advantages of distributing large wavefront correction over two passes of the cavity were addressed by examining the pass 2 focal spot in the cavity spatial filter. With 3 waves of correction, an approximate 25% reduction in spot size was observed over the case where the correction is applied in the front end, although the irradiance level at the edges of the pinhole was not measured.

1D beam smoothing by spectral dispersion (SSD) was successfully tested for the 1.06-μm part of the laser at output powers up to 3.5 TW in 1-ns pulses. Bandwidth of 2 Å was generated with a 6.7-GHz phase modulator and angularly dispersed in the Beamlet front end to produce an output divergence of 25 μrad, consistent with NIF indirect-drive requirements. Testing was performed with the pinhole in the transport spatial filter removed to better observe nonlinear growth of beam modulation in the laser. For B integrals in the booster amplifier stage of 1.4 rad corresponding to the maximum power tested, measurements showed a high-quality output beam with no increase in near-field modulation over the non-SSD case.

National Ignition Facility

The primary focus of the NIF Laboratory Project Office for the second quarter of FY 1997 was to complete the revision of the project baseline in accordance with the directives of the DOE Headquarters (HQ) Level 1 Baseline Change Control Board (BCCB1). This activity, namely in the form of the FY 1998 Project Data Sheet, was approved and forwarded to the Secretary of Energy in December 1996; it culminated in a proposed new baseline to be documented in an updated *Project Execution Plan*.

Critical Decision 3, Approval to Begin Construction, was signed by the Acting Secretary of Energy on March 7, 1997. This top-level milestone for the NIF Project was achieved ahead of schedule, allowing the Project to proceed with construction activities at the selected site, Lawrence Livermore National Laboratory (LLNL).

The Notice to Proceed for the first Construction Subcontract Package, Site Preparation, was given on March 18, 1997. After the notification was issued, site work began on March 31, 1997, with preparation of the construction laydown area (Kirschbaum Field) for the installation of the construction management trailers.

Key activities supporting construction and completed as scheduled include the following:

- Execution of the NIF Project Labor Agreement, a key to the construction strategy.
- Implementation of a Project-specific *Construction Safety Program*, which was included in the first construction package.
- Completion of a traffic survey.
- Approval of an Owner Controlled Insurance Program.
- Award of a broker contract.

The final *Independent Cost Estimate Report* was completed and released, and all action items were completed.

Revision 1.6 of the *Primary Criteria and Functional Requirements* was completed in accordance with the Level 1 Baseline Change Control Action, and a description of the process for developing the ES&H criteria using DOE's *Work Smart Standards* was prepared.

At the request of the BCCB1, the NIF Laboratory Project Office prepared and submitted to DOE's Oakland office (DOE/OAK) the *NIF Project Completion Criteria*. This document specifies the criteria for completion of the NIF Project and for achieving Critical Decision 4 in September 2003, consistent with the Project baseline revision effort. The overall strategy for completion enables the ICF Program to begin experimental operations in support of Stockpile Stewardship and other programmatic missions at the earliest possible date, as NIF performance capability is building up toward the eventual goals set out in the *Primary Criteria and Functional Requirements*.

The NIF *Mitigation Action Plan* (MAP) has been formally transmitted by DOE/OAK. The MAP's purpose is to describe how to mitigate environmental impacts identified in the *Record of Decision* and the *Final Programmatic Environmental Impact Statement for Stockpile Stewardship and Management*. The first MAP action was placing public notices of the start of construction in all local papers and the *San Francisco Chronicle*.

Working with the NIF System Integration team and DOE/OAK and using the DOE guidelines for Necessary and Sufficient (Work Smart) Standards, the NIF Project Assurances team developed the final draft of a document describing the process for preparing the *Primary Criteria and Functional Requirements*. This and revision 1.6 of the *Primary Criteria and Functional Requirements* were signed at DOE/HQ.

Site and Conventional Facilities

The Project began the transition to the construction phase for the NIF Conventional Facilities. The first construction subcontract package was awarded as scheduled, and construction began on Construction Subcontract Package 1: "Duct Bank Relocation and Parking Lot Relocation." The construction laydown area where the construction management complex is located (Kirschbaum Field) was prepared for construction management trailers.

In addition, the Title II design for Conventional Facilities saw the completion of several design review packages:

- The "Target Building Mat and Laser Bay Foundation" (Construction Subcontract Package 3) was received for Title II 100% review.
- The "Target Area Building Shell" (Construction Subcontract Package 6) 65% review comments were received.
- The "Laser Building Buildout, Site, and Central Plan" (Construction Subcontract Package 9) was received for Title II 65% review.

Special Equipment

- The optomechanical layout of the pre-amplifier module (PAM) has been updated to reflect the optical component design currently under analysis. The beam size in the multipass amplifier section has been increased from 23 mm to approximately 27 mm. As a result, several of the 50-mm optics will need to be increased to 75 mm.
- The 50-mm Nova rod amplifier head has been installed and activated in the preamplifier integration testbed. Gain, gain uniformity, and birefringence measurements under full loading have been completed. The 4-pass amplifier cavity has been set up and extraction experiments begun. Results will be available for the Technical Management Plan review scheduled in April.
- The impact of the optomechanical layout for the 1:4 beamsplitting assembly following the PAM and the location of the separate PAM power conditioning unit (PCU) with respect to the preamplifier support structure (PASS) in the beam transport system were evaluated. The PAM PCU will now be located on the Laser and Target Area Building floor beneath the PASS.
- After careful comparison between air and nitrogen, the amplifier cooling gas working group recommended that the amplifier flashlamp cooling gas be changed from air to nitrogen.
- The Power Conditioning development team worked to validate the NIF system design and answer Title I issues. Effort was concentrated on switch testing. The first full-energy, 1000-shot run was completed on the prototype module at Sandia National Laboratories (SNL) using the Physics International switch in self-break mode. Results showed that the 6-mm spark-gap erosion observed in initial tests grew to 18 mm after 1000

shots. Although the gap erosion rate exceeded that predicted by the manufacturer, this experiment demonstrated the feasibility of using the spark-gap switch in the NIF application.

- The Beam Transport design team concluded that a graded approach on spatial-filter interior surface finish should be used. This means that polished plate will be used for end and center vacuum vessels (near optics) and that bead-blasted surfaces will be used in the vacuum beam tubes. This decision allows the placement of the long-lead mill order after the vessel configuration is frozen.
- The Integrated Computer Controls System (ICCS) team developed the *Hardware Control Emulation Plan* to help guide the planning for the first of the ICCS software prototypes. Prototype frameworks for the configuration, system manager, generic front-end processor, status monitor, message log, and sequence control will be demonstrated in May. Four design reviews on these framework components were held in March. The object-oriented models for the prototype are complete, and coding of the associated software packages has commenced.
- The ICCS team developed a first-draft software test package that contains the essential elements of a full-scale benchmark test. The plan is to subject the NIF components, software tools, and networks (in a repeatable fashion) to simulated performance stresses expected during operation. A 'client' within the test package can exercise CORBA services that are used in the ICCS framework. Scale testing of the software is accomplished by operating any number of objects in any number of servers on any number of computers. Timing, memory usage, and results of sample calculations are measured. Initial tests of functionality and speed of performance were made.
- After problems associated with the behavior of an updated version of a third-party-supplied module were corrected, the two-way time transfer system was shipped to Jet Propulsion Laboratories (JPL). Measurements made at the supplier indicate that the timing performance meets expectations. Following JPL evaluation, the unit will be further evaluated at LLNL, and efforts to enhance performance to meet integrated timing system precision requirements will begin. The master clock source, which will serve both as a two-way time transfer system timing input and a network time server, has been ordered.
- A decision has been made by the Diagnostics design team that a set of four output sensors will not share the input of quads (of four beams) from adjacent bundles. The decision not to share was made due to the concomitant complexity of the relay optics and the lack of space that would be available for installation and alignment. Other methods of data sharing between the quads of adjacent bundles are being considered.
- A proposal was made by the Diagnostics design team to use each output sensor diagnostic camera simultaneously for two beams. Options for beam sizes and beam combination techniques were evaluated. A preliminary analysis was made of the performance of the 1ω diagnostic near-field camera with the required larger aperture. Options for 1ω diagnostic tower and relay beam layouts were considered; a layout was chosen as a compromise between minimizing potential damage problems and equalizing relay lengths. This new configuration eliminates the crossover beams, simplifying the component mounting requirements under the TSF vessel and improving access.
- The prototype large-aperture deformable mirror (DM) was tested on Beamlet this quarter. The purpose of the Beamlet tests was fourfold: (1) Assure that the DM survives flashlamp exposure with no adverse prompt effect due to electromagnetic interference (EMI) or thermal expansion and with no structural or cleanliness degradation due to flashlamp ultraviolet exposure to the epoxy. (2) Acquire data from which a Beamlet propagation model can be validated for wavefront and focus spot performance. This validated model can later be extrapolated to the NIF configuration and beam size. (3) Investigate the focus spot performance in the early cavity pinholes. (4) Test the NIF wavefront controller prototype on Beamlet. The DM was inspected after 12 Beamlet shots and showed no apparent degradation or discoloration. Also, the DM showed no evidence of adverse prompt effects due to EMI or thermal expansion.
- The target chamber Request for Proposal was released on January 27, 1997, to five potential offerors. Updating of drawings is ongoing through the Title II engineering phase, with the goal of releasing the package to the successful bidder in June. Vendor bids are due April 23, 1997.
- Further redesign of the target chamber has been done to accommodate last-minute requests for more diagnostic ports and an access port for the first-wall-servicing robot.
- Continuing work was done on assessing the cost and performance of hot-pressed B_4C and Al-B_4C cermet (metalized ceramic) for the first wall. A small R&D contract was developed

with a potential cermet manufacturer to develop a cermet that meets NIF cost and performance criteria. X-ray fluorescence analysis was done on new cermets and hot-pressed B_4C to quantify whether they would meet performance specifications.
- We completed a preliminary investigation into the effects of the proposed new color separation grating on beam dumps. The current locations for the beam dumps appear to be satisfactory, and a nominal size of 1 m × 1 m (possibly just over 1 m in one direction and just under 1 m in the other) should handle the first five orders of 1ω and 2ω light.

Optics Technology

- Schott Glass Technologies completed the construction of a 13,000-ft^2 building to house the NIF-size prototype of the continuous melter and installed melting and annealing equipment. A melting campaign is scheduled to begin in late April, with results available in the summer. A full-size BK-7 analog, continuously melted and formed, met NIF specifications.
- Hoya Optics completed fine annealing of continuously melted laser glass formed at half-scale; all properties except homogeneity met NIF specifications. Hoya received a building permit from the city of Fremont for its NIF laser glass facility and is moving ahead with the design. Facility construction will begin this summer and will be completed in FY 1998.
- LLNL grew a 51-cm KDP boule using rapid growth technology, demonstrating the size needed for the NIF second-harmonic generation crystals (i.e., Pockels cell crystals demonstrated in FY 1996). Improved platform design to improve crystal quality and minimize stresses is continuing and will be demonstrated in July.
- The Optics Technology group demonstrated new coating source material at each of the coating vendors, which will improve the spectral performance of polarizers. The damage threshold has been qualified on subscale parts; full-scale parts will be tested beginning in late April.

Upcoming Major Activities

During the third quarter of FY 1997, the NIF Project will begin its transition from strictly design to the initiation of Conventional Facility site work, the start of Special Equipment procurement, and the start of vendor facilitization in Optics. Site Preparation work will begin in April and should be completed in July, and the Site Excavation contractor was mobilized in June. In Special Equipment, the selection of the contractor for the Target Chamber should be completed, and award is planned for early August. In Optics, the facilitization contract for the amplifier slab fabrication facilitization should be awarded. Plans are also taking shape for the NIF Groundbreaking Ceremony, which will be held in May to mark the beginning of construction on the NIF site.