UCRL-JC-124520

NIF/LMJ prototype amplifier mechanical design

John Horvath

This paper was prepared for submittal to the Solid-State Lasers for Application to Inertial Confinement Fusion (ICF) 2nd Annual International Conference
Paris, France
October 22-25, 1996

October 1996

Lawrence Livermore National Laboratory

DISCLAIMER

NIF / LMJ prototype amplifier mechanical design

John Horvath

University of California
Lawrence Livermore National Laboratory
Livermore, California 94550

ABSTRACT

Amplifier prototypes for the National Ignition Facility and the Laser Megajoule will be tested at Lawrence Livermore National Laboratory. The prototype amplifier, which is an ensemble of modules from LLNL and Centre d'Etudes de Limeil-Valenton, is cassette-based with bottom access for maintenance. A sealed maintenance transfer vehicle which moves optical cassettes between the amplifier and the assembly cleanroom, and a vacuum gripper which holds laser slabs during cassette assembly will also be tested. The prototype amplifier will be used to verify amplifier optical performance, thermal recovery time, and cleanliness of mechanical operations.

Keywords: amplifier, cassette, guillotine, blastshield, flashlamp, slab, maintenance, vehicle, cart, AMPLAB.

2. MECHANICAL DESIGN

2.1 Prototype amplifier

Prototypes of the National Ignition Facility (NIF) and Laser Megajoule (LMJ) amplifiers will be tested at Lawrence Livermore National Laboratory (LLNL). The prototype amplifiers are shown in Figures 1. and 2.

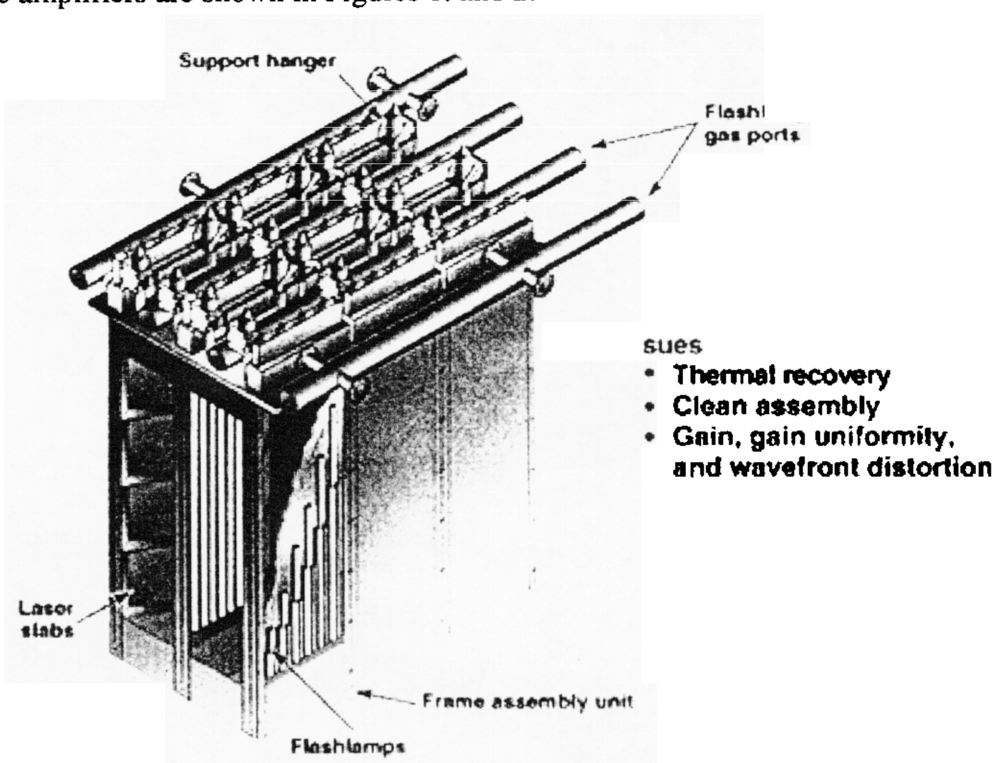

Fig. 1.

The amplifier design uses cassettes that are loaded into the amplifier by a maintenance transfer vehicle (MTV). The amplifier is suspended 3.2 meters above the floor, thus allowing the MTV which is 3.1 meters tall to move beneath the amplifier for insertion or removal of cassettes. Utilities such as flashlamp power cables and cooling gas pipes are located above the amplifiers. This makes the space below the amplifiers available for the movement of cassette maintenance vehicles and other laser equipment and personnel, a feature that reduces the need for tunnels and bridges in the laser building.

The prototype amplifier is composed of three modules. The central module is being built by Centre d'Etudes de Limeil-Valenton (CEL-V). The two end modules are being built by LLNL. The arrangement is shown in Figures 1. and 2.

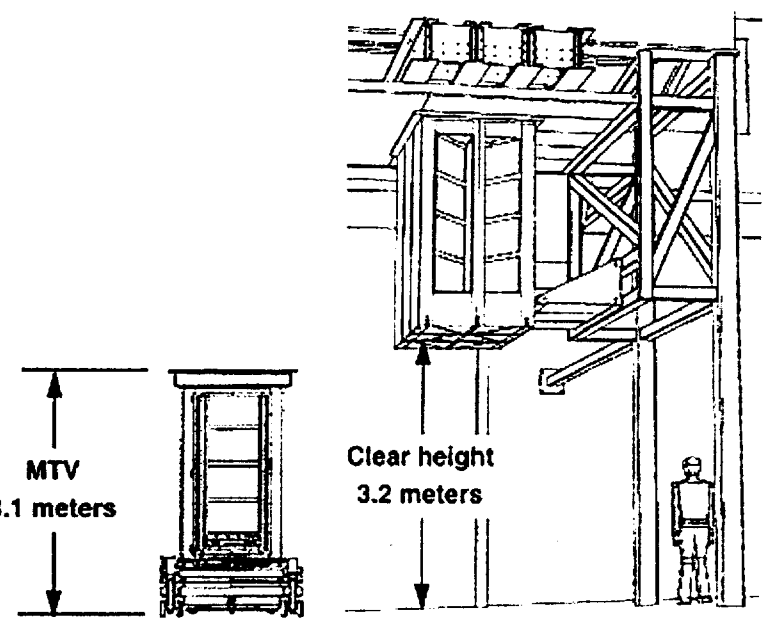

Fig. 2.

The bottom-access amplifier design provides a configuration that is compatible with in-situ cleaning, a process that has potential cost benefit for amplifier system maintenance operations. The cleaning process can be used to drive heavy particles downward more easily than upward. The use of bottom-access also allows the overhead crane in the laser building to be available for other tasks, thus reducing the need for additional building cranes.

2.2 Amplifier module

An module is here defined as the smallest assembled amplifier segment that can be removed. The module size for the prototype amplifier is 4x2x1, which was dictated by the size of existing cleaning and plating facilities. This module can be visualized as a one-slab long slice of a 2x4 laser beam bundle taken normal to the beam direction. The module size for NIF or LMJ may differ in size from the prototype.

Each module is a mechanical assembly of cassettes, also called a line-replaceable units (LRU), which contain optical components and reflectors in a form that is compatible with rapid replacement in the laser bay. Each 4x2 amplifier module contains two slab cassettes and three flashlamp cassettes supported by a frame assembly unit (FAU). Cassettes are inserted into FAUs from below using a sealed maintenance vehicle. Latches at the base of the cassettes lock them to the FAU. Each set of cassette latches is capable of resisting loads in all directions. A cross-section view and an exploded view of a 4x2 amplifier module are shown in Figure 3.

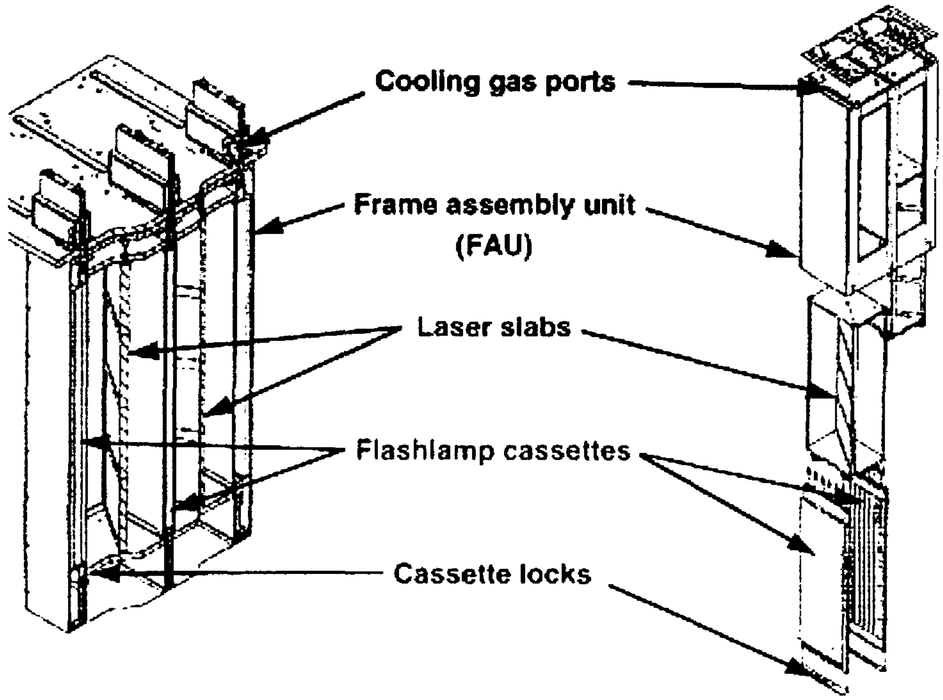

Fig. 3.

Cooling gas flows through the flashlamp cavities to reduce the amplifier thermal recovery time. Cooling gas enters and exits through the flashlamp cable connector blocks at the top of the amplifier. It circulates down one flashlamp and returns up the two neighboring cavities.

2.3 FAU

The FAU supports the slab cassettes, flashlamp cassettes, blastshields, flashlamp electrical connections, and cooling gas plumbing for amplifier components, and gives mechanical rigidity to the amplifier assembly. All amplifier components that are likely to need periodic replacement are designed to be removable from the FAU. Laser slabs, flashlamps and reflectors are contained in cassettes. The blastshields that separate the pump cavity from the flashlamp cavities are also removable.

FAUs are bolted to an external support structure through a top mounting plate which serves as an inverted bench for accurately positioning the FAUs. The prototype amplifier uses insulated connections between the top mounting plate and the external structure for electrical isolation. The use of in-situ cleaning could enable FAUs to remain in place for the life of the laser system.

2.4 FAU Guillotines

The interface between 4x2x1 amplifier modules will contain guillotine assemblies. The guillotine system, which was designed and manufactured by CEL-V, permits a sealed FAU to be removed from an amplifier assembly without contaminating neighboring modules.

A 3.2 cm space exists between each FAU module in the prototype amplifier. This allows the removal of an FAU module without completely disassembling the prototype amplifier. CEL-V has designed and built a guillotine system that fits into this 3.2 cm space. The guillotine design as it would appear when implemented on both amplifier columns is shown in Figure 4.

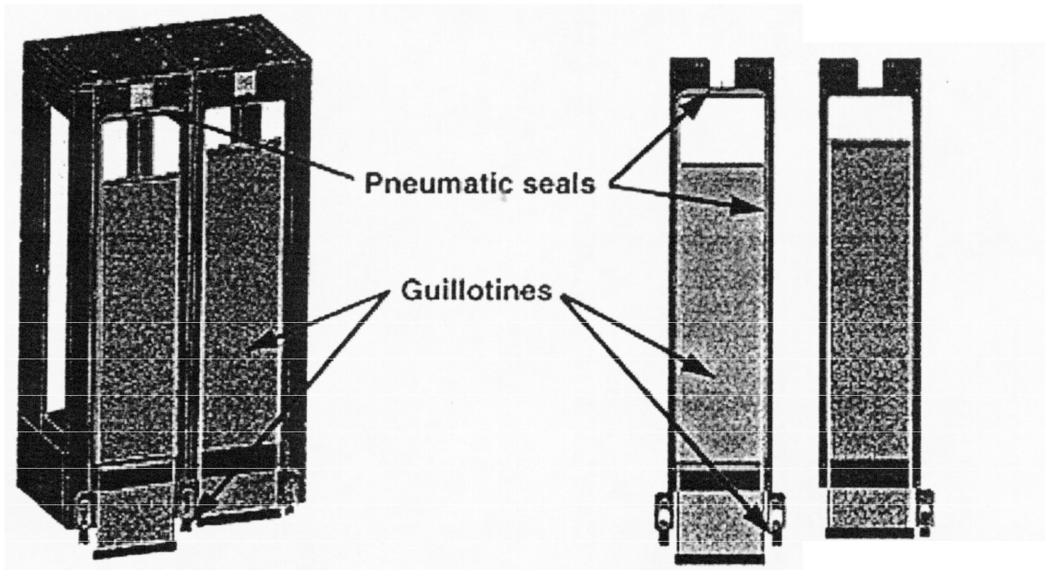

Fig. 4.

Guillotines will be installed on both ends of one column of the central amplifier module. The neighboring amplifier column will use expandable pneumatic spacers without guillotines. Since the blastshields form a barrier between the two neighboring columns, cleanliness tests of the guillotine system can be performed.

2.5 Slab cassette LRU

Slab cassettes are LRUs that contain four laser-glass slabs and their associated pump cavity reflectors. The components of a slab cassette are shown in Figure 5.

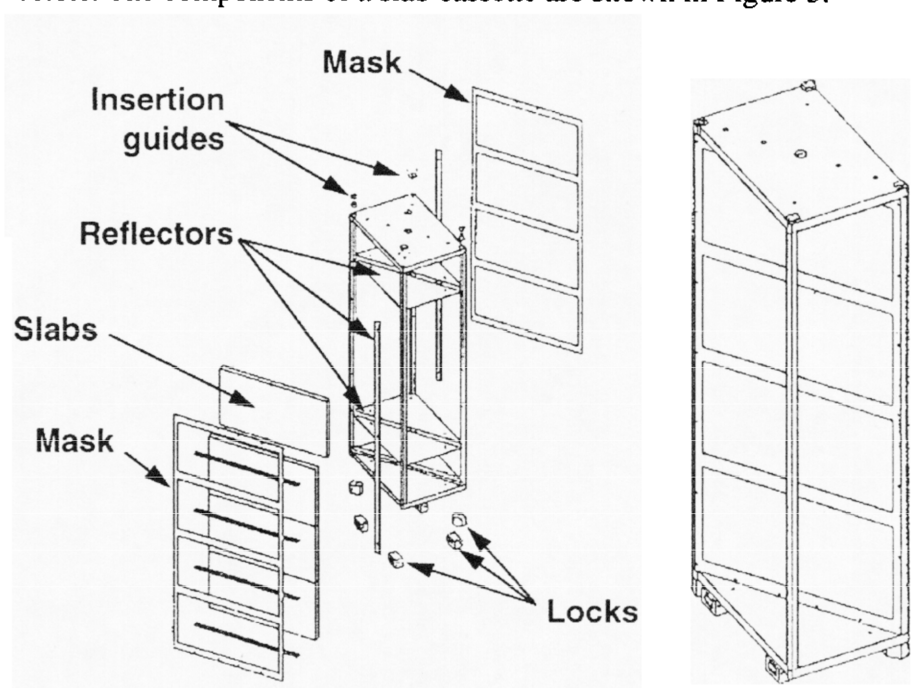

Fig. 5

The four slabs are stacked on edge with corrugated steel Marcel springs separating them. The springs have a corrugation cycle of 0.6 cm which distributes the load along the slab edges. Slabs are held in a vertical position by masks. A small clearance between the masks and the slabs prevents any mechanical load which may introduce non-uniform stress fields in the glass.

Guide buttons composed of ultra-high molecular weight (UHMW) polymer glide along nickel-plated FAU surfaces during cassette insertion and removal. Particulation tests have been used to identify a combination of materials, normal force, and speed that does not produce particles during a cassette replacement. The use of UHMW polymer and nickel, a normal force of less than 45 Newtons, and a speed of less than 25 cm per second did not produce particles harmful to the slabs during simulated insertion tests. This combination of parameters is incorporated in the prototype cassette, FAU, MTV designs.

2.6 Flashlamp cassette LRU

Each 4x2 amplifier module contains three flashlamp cassette LRUs, one in the center and one on each side. Central cassettes hold eight flashlamps and have vertical reflectors between flashlamps. Side cassettes hold six flashlamps each and incorporate shaped reflectors. A side flashlamp cassette is shown in Figure 6.

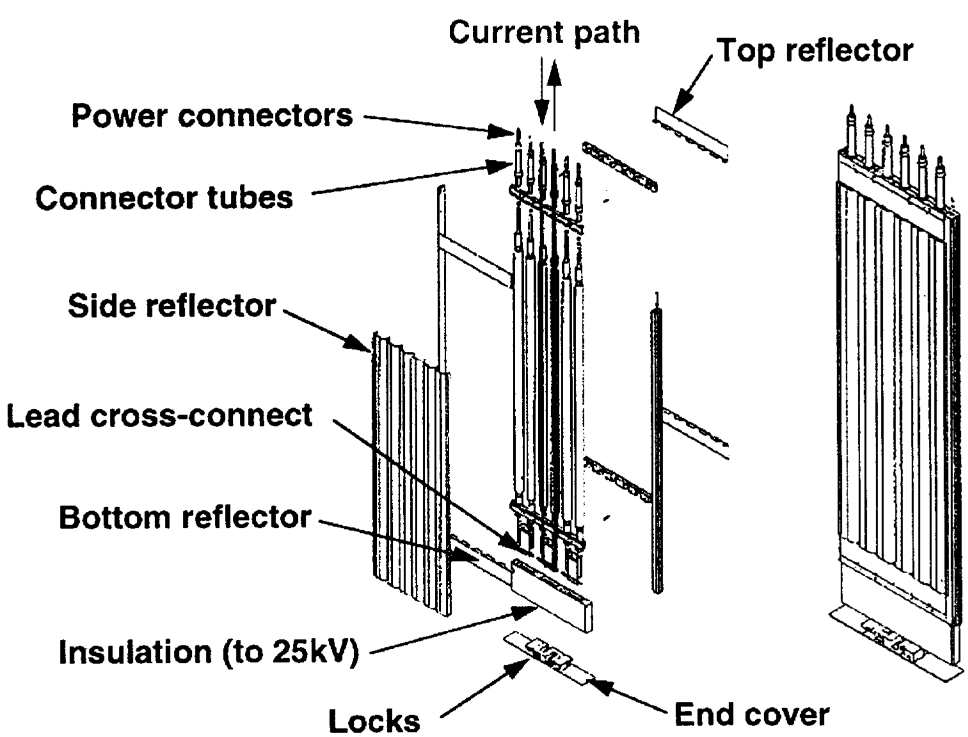

Fig. 6.

All flashlamp cavity reflectors are mounted on the cassette for ease of maintenance. These include the shaped side reflectors, the vertical reflectors between central cassette flashlamps, and the vertical and horizontal reflectors that cover the edges of the flashlamp arrays.

The prototype cassettes will use silver plated reflector surfaces, however alternate surface treatments are under consideration. Cassettes without flashlamps installed are shown in Figure 7.

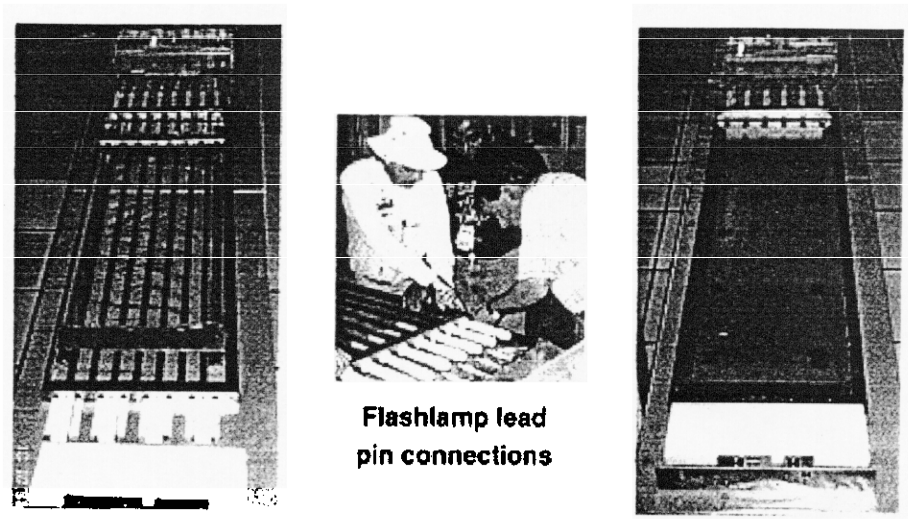

Fig. 7. **Central cassette** **Side cassette**

Pairs of flashlamps are connected in series. Electrical current enters the top of the amplifier module through coaxial cable. The core of the coaxial cable and the braided wrap provide the current supply and return paths for a pair of flashlamps. In addition to the flashlamp electrical power leads, each cassette has an external connection for the reflector ground which provides a separate current path in the event of a flashlamp explosion.

3. ASSEMBLY AND MAINTENANCE

3.1 AMPLAB

Assembly, maintenance, and performance tests will be conducted in the Amplifier Module Prototype Laboratory / Laboratoire Amplificateur (AMPLAB / LABAMP) located at LLNL. The facility is designed to test full-size prototype NIF and LMJ amplifiers. The testing of a full-size amplifier requires cleanrooms for slab cassette assembly, and a means of transferring cassettes to the prototype amplifier. AMPLAB provides the required ceiling height for the elevated amplifiers and cleanrooms. The physical arrangement of AMPLAB is shown in Figure 8.

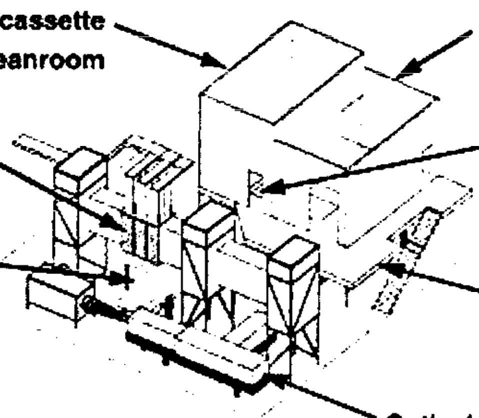

Fig. 8.

Amplifier performance will be measured using a Large Aperture Diagnostic System (LADS). This diagnostic system is contained on five optical benches in AMPLAB. The probe beam is expanded to full-aperture size and directed into any of the eight beam paths in the amplifier by full-aperture translation-stage mirrors. The mirrors and translation stages are housed in towers that provide the required stability.

The AMPLAB facility construction was completed in June of 1996. Amplifiers, pulsed power, assembly equipment, and optics are now being installed. Cleanliness tests will begin in December, 1996, and optical performance tests will be conducted in 1997.

3.2 Mechanical tests

All prototype amplifier parts undergo a series of mechanical tests. The mechanical fit of flashlamp and slab cassettes was verified during inverted vertical insertion tests such as those shown in Figure 9.

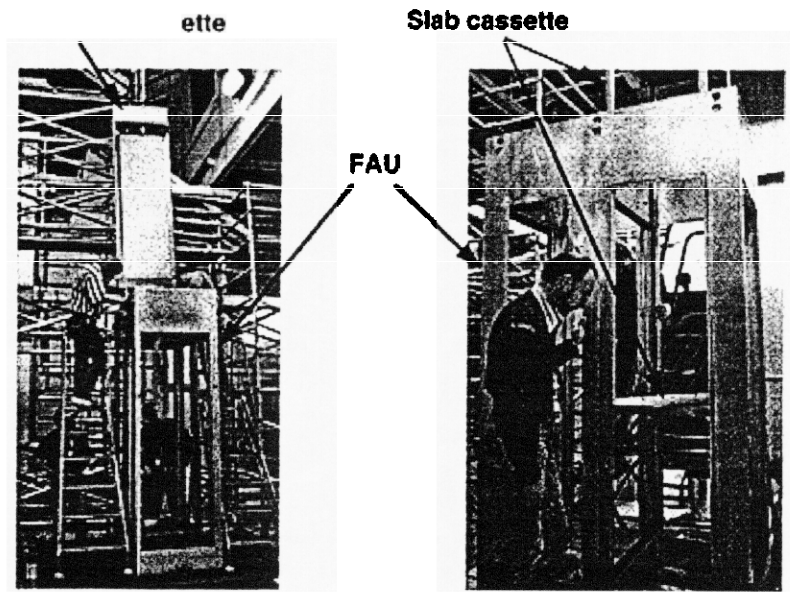

Fig. 9.

Load tests were conducted on the slab cassette locks using an overhead crane. A pair of slab cassettes were inserted and locked into an inverted FAU as shown in Figure 10.

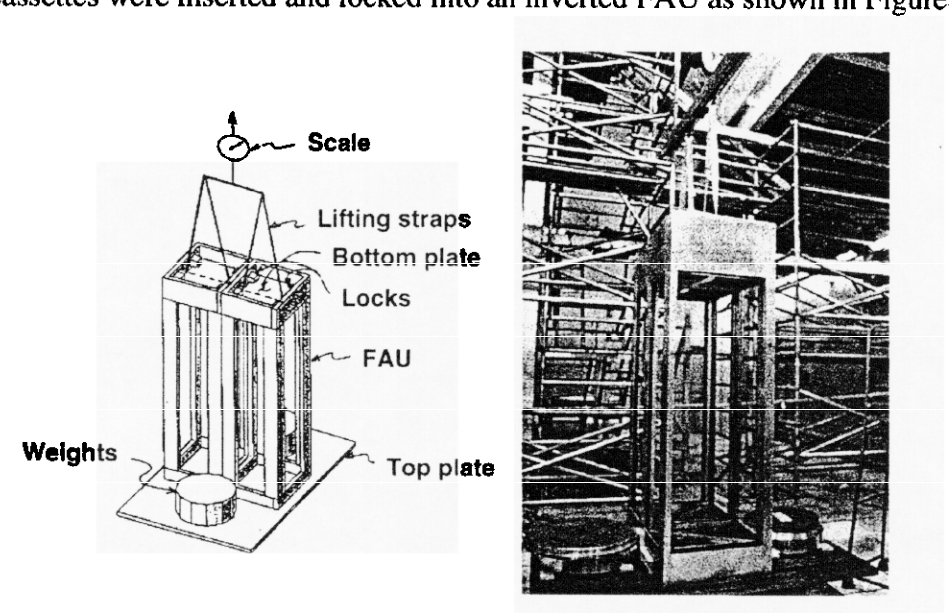

Fig. 10.

The FAU was bolted to the top mounting plate which provided a platform for holding additional weights. The cassette bottom plates of the two slab cassettes were held by lifting straps and pulled to a load that was 50% higher than a normal latch load. Cassette lock verification will become a part of the MTV operating procedure. Each newly-inserted cassette constitutes a potential overhead hazard to personnel if it is not securely locked into the FAU. This can be accomplished by lock position sensors, remote CCD cameras, a verification pull test, or a combination of these prior to MTV undocking.

After mechanical fit has been verified, components will be disassembled, cleaned, and reassembled for clean insertion tests. Particulation will be monitored by mounting silicon wafer witness samples at various locations and orientations. Particle measurement systems will be used to quantify the size, distribution, and composition of particles. When the slab cassette assembly process has been certified as acceptably clean, laser glass will be installed and performance measurements will begin.

3.3 Slab cassette assembly tools

Prototype slab cassette assembly occurs in Class-100 cleanrooms located in AMPLAB. All slab cassette parts are first cleaned in another facility, bagged, and moved to the AMPLAB cleanrooms for final assembly. The cleanrooms contain a suite of tools composed of a vacuum slab gripper, a clean crane, and a cassette assembly fixture. The ensemble of AMPLAB cassette assembly tooling is shown in Figure 11.

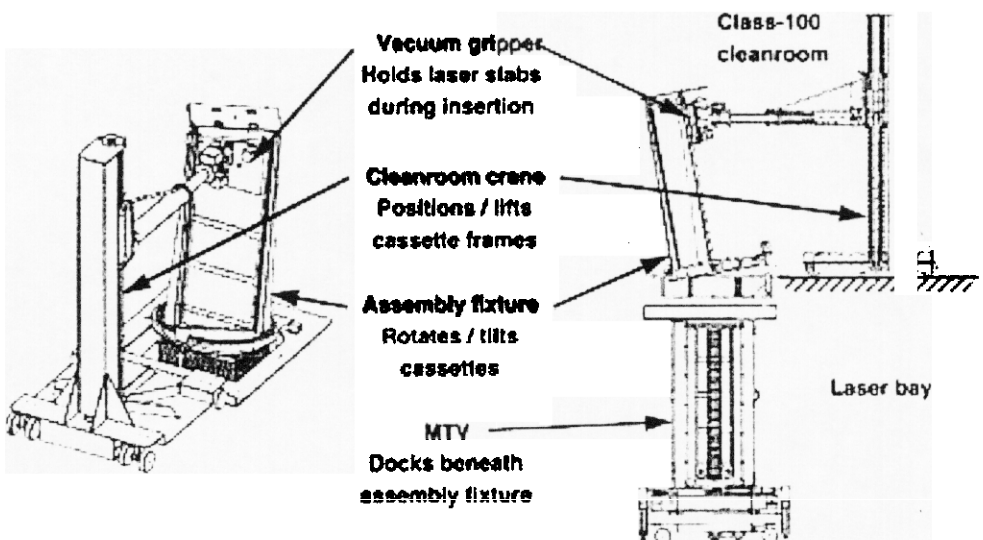

Fig. 11.

Laser slabs are mounted in the slab cassette using a vacuum slab gripper which contacts the face of the laser slabs on the edges beyond the clear aperture. This permits the slabs to be inserted into the cassette while maintaining precise control. The gripper has a motorized tilt degree-of-freedom to match the angle of the cassette frame. It also has a motorized extension degree-of-freedom that performs the slab insertion or retraction with extreme precision and control.

The slab gripper is connected to a clean crane arm using a standard robotics wrist connector. The clean crane arm can extend and retract, move vertically, and rotate about the crane vertical axis. All motions except the latter are motorized.

The slab cassette is held in position by an assembly fixture which is mounted to a docking port in the floor of the elevated cleanroom. This opening provides a docking location for the MTV.

The assembly fixture has an actuator that tilts the cassette so that gravity holds the slabs in position while the slab mask is removed. The entire fixture rotates on a vertical axis to permit optimum positioning of the cassette with respect to the gripper for slab insertion and removal. All particulation sources on the clean crane, gripper, and assembly fixture are isolated from the cleanroom environment by bellows. The docking port below the assembly fixture presents the same mechanical interface to the MTV as does an FAU. The vehicle alignment, docking, and cover removal procedure at the assembly fixture is identical to that at the FAU.

3.4 MTV

The amplifier/MTV system design is based on “isolation technology”, a technique used in the microelectronics assembly industry to prevent contamination of silicon wafers. Isolation technology employs small, clean glove boxes separated by areas containing personnel and other contamination sources. Clean parts are moved from one clean compartment to another using small transport containers that dock and seal to the glove boxes.

The MTV, called a vehicule de transport et de transfert (VTT) by CEL-V, is a larger adaptation of isolation technology that will be used to cleanly transport LRUs in NIF and LMJ. This vehicle, combined with a modular laser design, permits rapid replacement of optical components without requiring a clean environment in the laser building. The partially-assembled prototype MTV is shown in Figure 12.

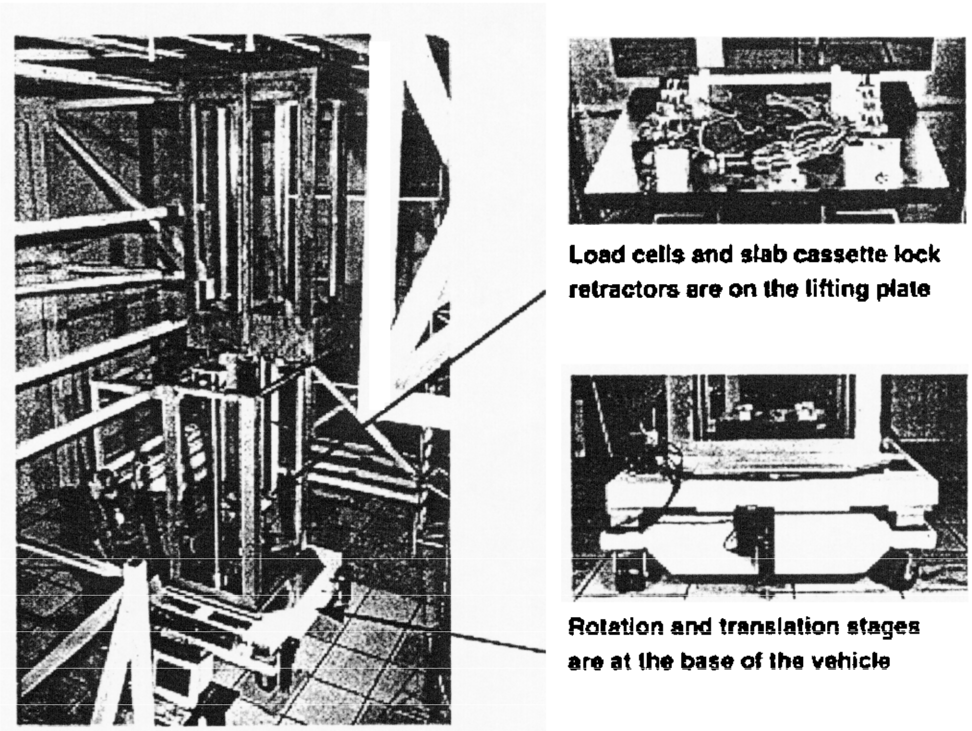

Fig. 12.

The prototype MTV being tested at in AMPLAB at LLNL will demonstrate the ability to perform assembly and maintenance tasks on slab cassettes in a clean manner. The AMPLAB prototype will also investigate the unique problems encountered in scaling the size up from the smaller systems now in use to the larger versions needed for NIF and LMJ.

The slab cassette was selected as the first LRU for the MTV test because of the critical need for maintaining clean slab surfaces. Contamination on slabs causes glass damage due to the flashlamp environment and the high energy fluence.

A major source of contamination in an assembly operation is the presence of personnel. The use of LRUs and a sealed MTV employing isolation technology to transfer LRUs without direct human contact limits particle generation sources to those of mechanical origin within the MTV/amplifier system. MTV motors and drive mechanisms are enclosed in bellows or are located outside of the clean interior compartment. The MTV and the clean crane use the same enclosed lead screw design for isolating particle sources. The sliding surfaces that guide cassettes during insertion or removal are potential particle sources that have been eliminated by careful selection of material combinations, normal force, and insertion rate. Selection of these parameters was achieved using calibrated bench tests.

4. ACKNOWLEDGMENTS

The following people contributed to the design, assembly, and testing of the hardware described here: T. Alger, W. Davis, A. Erlandson, J.D. Fisher, J. Hall, T. Lee, R. McCracken, E. Moor, B. Pedrotti, S. Rodriguez, D. Silva, D. Swort, F. Tulloch (LLNL), T. Adjadj, J-C Fornerod, J-L Guinet, X. Maille, P. Manach, S. Seznec (CEL-V), P. Bosch (SICN).

*This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

Technical Information Department • **Lawrence Livermore National Laboratory**
University of California • Livermore, California 94551