Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

TITLE Installation Alignment of a Multi-beam ICF Target
Illumination System

LA-UR--85-2351

AUTHOR(S) Walter Bauke, P-5
David Stahl, P-5

DE85 015677

SUBMITTED TO Southwest Conference on Optics '85
Albuquerque Convention Center
Albuquerque, NM
March 4-8, 1985

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

By acceptance of this article the publisher recognizes that the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution or to allow others to do so for U.S. Government purposes.

The Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

Installation Alignment of a Multi-beam ICF Target Illumination System

Walter Bauke and David B. Stahl

University of California, Los Alamos National Laboratory
P.O. Box 1663, MS E523, Los Alamos, NM 987544
(505) 667-6065

Abstract

Target illumination systems for inertial confinement fusion (ICF) experiments require precise alignment of a multitude of mirrors, usually spherically arranged around the ICF target. The mechanical support structure for these mirrors generally consists of a large space frame with many voids. This makes direct alignment or boresighting impossible, since alignment instruments and references cannot be placed at the coordinate centers representing the mirror arrays or focal points. Nevertheless, the structural members must be accurately aligned during the assembly phase, to provide the focusing precision required by the completed illumination system.

This paper describes the techniques used to assemble and align the Antares Laser space frame, where a total of 48 mirrors fold and focus 24 laser beams onto the ICF target, with in a 7.3 meter space frame. The alignment procedures described use optical tooling and taut techniques supplemented by surveying instruments and auxiliary devices, as required by the unique geometry of the space frame.

Introduction

The Antares laser target illumination system is mounted in a space frame consisting of a large welded box beam structure located within a vacuum chamber as visible in Figure 1. The space frame moves in and out of the chamber on roll-out surfaces and air bearing pads and is locked into place inside the chamber on support planes to provide precise positioning within the global coordinate grid.

The space frame geometry is complex and difficult to visualize. Several objectives had to be met, the major ones being a clear and unobstructed view of the target from all optical elements, and structural integrity and stability of the frame to support the optics and associated hardware. These requirements are somewhat contradictory as satisfaction of one may interfere with the other, i.e., by adding more or larger members to the frame, one may obscure the visual access to the target.

Since drawings alone could not satisfy the problem of proper visualization, an exact scale model of the space frame was built and its dimensional accuracy was verified within an optical tooling dock.

The reference grid of the tooling dock was oriented to the target location representing $X, Y, Z = 0$, and was applied in correct scale dimension to the model.

The full scale global coordinate grid was used throughout the assembly for positional control of the Antares laser components and for the manufacture of the space frame. This grid was developed using optical tooling as described in Reference 1.

Various deviations from the traditional tooling dock had to be employed at times as dictated by the size of the assembly and the difficult field conditions.

The optical system

Two beamlines of 12 beams each enter the target chamber 180° opposed from the east and west (Fig. 2). The beams are quasi-trapezoidal in shape with a footprint of a little less than 1,000 cm². The optical elements are made of diamond-turned copper reflectors shaped and oriented to the proper beam pattern.

The beams are positioned in annular symmetry around the Y axis as they leave the turning chamber and are deflected by the turning mirrors into a symmetrical pattern of three arrays of four beams each as they arrive at the fold mirrors. These are located in the central region of the space frame (Fig. 3) and reflect the beams to the focus mirrors, the last optical elements in the path to the target. In this stylized view of the beam path,

the focus mirrors would be in a plane near the observer. The actual supports for the fold mirrors are visible in the central region of (Fig. 1).

The focus mirror array frames are located in 120° symmetry about the target, one each facing a fold mirror array.

The space frame

The space frame consists of a stainless steel box beam structure and provides the mechanical support for the target mechanism and the associated optical and diagnostic elements. The frame is about 6 x 6 x 7.3 meters in overall size and was welded in segments leaving some joints for separation during shipping and final assembly in the target hall of the Antares laser.

There are two major functional areas in the space frame, the central target region and the focus mirror support planes facing the target. Centrally located is a kinematic mount for the target which is inserted on an inclined track through a port in the target chamber wall. Surrounding the target is the fold mirror structure which is comprised of two half-shells holding three arrays of four fold mirrors each.

Target and fold mirror assembly are supported on an intermediate plane within the space frame, the central mounting plane. This plane is positioned at a specific -Z value below the target elevation and all central elements are treated as subassemblies to be installed and aligned after completion of the space frame.

The focus mirror supports consist of welded box beam frames within the network of the space frame, providing six flat planes facing the target. To these planes are mounted the focus mirrors in arrays of four each, with the mirror surfaces positioned in spherical symmetry about the target. Control of these structures during manufacture and assembly was achieved by assigning an "array plane coordinate center" to each group of mirrors and using these points as references throughout the alignment procedure.

The space frame model

To verify the accuracy of the space frame design, a model was built to 1/5 scale and placed into the center of our optical tooling dock (Fig. 4). Two transits and one level identified the X, Y, Z, - 0 planes, the intersection of which determines the target location. Frame members and control points on the model were then measured in their actual position within the global coordinate grid.

The array plane coordinate centers for the focus mirror arrays represent important control points but could not be measured directly because they fell into an open space within the grid of the space frame. Using the optical tooling scopes, we identified the coordinates X, Y, and Z for each array plane center and stretched monofilament lines across the opening to determine the intersection of these planes in reference to the actual centerline of each array plane (Fig. 5). Adjustments were made to the model to bring each array plane center within design tolerance of the intersection of the coordinates for the respective plane.

The optical clearance requirements within the space frame were measured by projecting an optical tooling laser along the central ray of each beamline and, using small test mirrors, tracing the beams to the target location, identified by a small sphere suspended within the frame at the controlled center of the coordinate grid. Each structural member close to the laser beam could then be measured to assure sufficient clearance for the beam footprint to pass.

The major interface between the space frame and the target chamber consists of the mounting pads which must mate with the support surfaces within the chamber. In the tooling dock this was represented by a granite table, on which the model was placed and proper shimming and locating references were devised to assure accurate positioning of the frame within the target chamber.

Space frame assembly alignment

The assembly of the space frame was controlled by an optical tooling grid similar to the one used to check the scale model. However, because of the large size of the frame and the difficult working conditions in the assembly shop, the use of the tooling barn was not practical. The instruments were mounted on individual stands and tripods and

oriented to benchmarks identifying the $X, Y, Z = 0$ location of the (at this time still imaginary) target.

The frame was assembled around a temporary core support of crossed steel ribs (Fig. 6) and box beams were aligned and welded in place to form the exterior shell of the frame. Not visible in this illustration are the breaks provided to disassemble the frame for shipment. These bolted joints were designed to be welded in the final assembly to form an integral weldment structure prior to installation of the mirror arrays.

There are several surfaces which required precise control to provide matching interfaces with other components in the system, the major ones being:

- a) The base pads, which mate with the support surfaces in the target chamber and determine the location of the space frame within the Antares laser system.
- b) The central mounting plane, which provides the support surface for the centrally located target and folding mirror assemblies. This plane determines the actual position of the target within the center of the space frame.
- c) The focus mirror array planes which provide the support for the focus mirrors in spherical symmetry about the target.

The frame members in a and b are located in level planes and were aligned with optical levels related to $Z = 0$. Optical tooling scales were extended above or below the box beams to set control points as needed.

Alignment of the focus mirror array planes was based on the theory that each array plane coordinate center can be located from the system coordinate center (the target position) by two angles and the radial distance from the center. A theodolite located at the target position will reproduce the normal radius to each plane and if coupled with a precision distance measuring device and autocollimation eyepiece, can be used to set each array plane into the correct orientation within the space frame.

To apply this technique, a dummy frame was built to represent the support plane and mounting holes of the actual array box beam structure. An alignment fixture (Fig. 7) was set into this frame with a target in the position of the array plane coordinate center. This target (Fig. 8) consists of a combination centering/autocollimation target set into a universally adjustable holder to permit angular and linear positioning.

The target was aligned to the frame in a modified optical tooling dock, using a transit and a theodolite with autocollimating eyepiece (Fig. 9). The transit, visible in the rear, is used to orient the frame in vertical position. The theodolite facing the frame in front is used to level the frame and to align the target laterally to the coordinate center within the frame mounting hole pattern and, through autocollimation off the mirrored target face, to place the target into the plane normal to the line of sight of the theodolite.

The alignment fixture was now moved into the space frame to a focus mirror array plane and aligned using a centrally located theodolite in combination with a distance measuring rod. The theodolite (visible in the center of Fig. 6) was set to the source point of the global coordinate grid ($X, Y, Z = 0$) using the original external benchmarks defining this grid. The telescope was then tilted into the correct compound angle to duplicate the ray from the global coordinate center to the array plane coordinate center. The length of this ray was measured using calibrated end caps on the theodolite and the array plane target in conjunction with a linear micrometer rod (Fig. 10).

At this point, the array plane coordinate center target occupied the exact design position in space within the space frame. The plane was now tilted to be normal to the reference ray by using the autocollimation eyepiece of the theodolite to reflect off the mirrored surface of the reference target.

This setup was maintained during the welding procedure for each array frame. Corrections were made as required to assure that each array plane remained within the designed tolerance range in angular and linear orientation.

The space frame was then disassembled and shipped from the manufacturer to Los Alamos to be reassembled in the laser hall of Antares. The tooling setup was reproduced and the final position of each array plane was verified to be within design tolerance.

Summary

The Target System of the Antares laser presented unique alignment and assembly problems. Large structural support frames had to be manufactured to tolerances usually not associated with such structures. The optical, as well as mechanical system, is discussed in part to give a clear understanding of the problems, and the alignment procedures are described from the initial check of a scale model through the final installation.

Assembly and alignment of the spaceframe was completed using optical tooling instruments complimented by auxiliary fixtures as dictated by the intricate structure of the space frame. The accuracies obtained were limited by the inherent precision of the optical tooling equipment. Angular values can be set within an error cone of 1 arc second and linear dimensions can be verified to ± 0.025 mm over short viewing distances. This precision satisfied the design requirements and the space frame was installed and the optical elements aligned for successful target shots within the allotted time.

Acknowledgements

The authors are deeply indebted to Vernon Zeigner of the Mechanical Design Group at the Los Alamos National Laboratory for his creative support in developing the alignment theory and in designing the auxiliary alignment fixtures.

References

1. W. Bauke, A. Saxman, and N. O'Kay, "Optical Tooling for Antares," Proceedings of the Los Alamos Conference on Optics '81, ed. D. H. Liebenberg, SPIE 288, pp 154-161 (1981).

Fig. 1 : Antares target system spaceframe is being aligned inside the target chamber.

ANTARES TARGET SYSTEM - OPTICAL SCHEMATIC

Fig. 2

Fig. 4 : Spaceframe model located in tooling dock for dimensional check

Fig 5 : Array plane coordinate center in spaceframe model: the coordinates and the actual center are identified with monofilament lines.

Fig. 6 : During spaceframe assembly, a centrally located theodolite is being used for alignment of focus mirror array planes

Fig 7 : Alignment fixture for the focus mirror array planes

Fig 8 : Alignment target for the focus mirror array planes

Fig 9 : Alignment of the focus mirror array plane fixture, using a transit and autocollimating theodolite.

Fig 10 : Alignment of a focus mirror array plane, using the centrally located theodolite and micrometer rod.