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ARGUS TARGET CHAMBER

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MASTER

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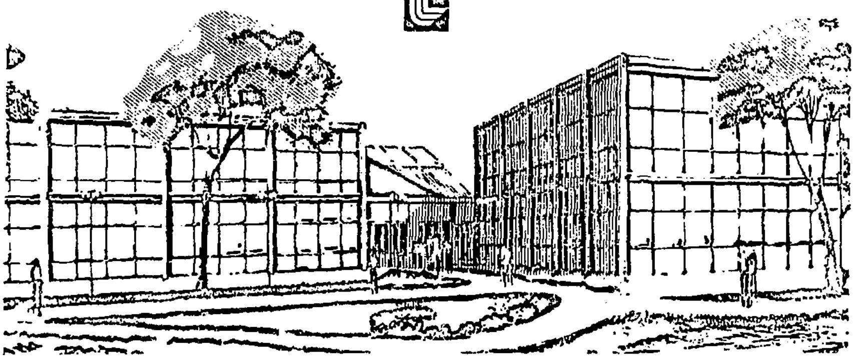

ARGUS Laser Target Chamber*

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SUMMARY

A target chamber for application in the laser fusion program must satisfy some very basic requirements.

- Provide a vacuum on the order of 10^{-6} torr.
- Support a microscopically small target in a fixed point in space and verify its location within 5 micrometers.
- Contain an adjustable beam focusing system capable of delivering a number of laser beams onto the target simultaneously, both in time and space.
- Provide access for diagnostics to evaluate the results of target irradiation.
- Have flexibility to allow changes in targets, focusing optics and number of beams.

The ARGUS laser which is now under construction at LLL will have a target chamber which meets these requirements in a simple economic manner. The chamber and auxiliary equipment are described, with reference to two double beam focusing systems; namely, lenses and ellipsoidal mirrors. Provision is made for future operation with four beams, using ellipsoidal mirrors for two-sided illumination and lens systems for tetragonal and tetrahedral irradiation.

1. Introduction

The laser target interaction program at LLL has as its major goal the attainment of "breakeven" fusion. The primary facility for pursuing breakeven experiments will be a 20 beam 1.06 μm system named SHIVA which has been designed to produce 10 kilojoules in 500 picoseconds and is due to be completed in 1978. For preliminary laser target experimentation, a number of facilities have been constructed. JANUS can deliver up to 20 J from each of two 8.5 cm diameter beams to a target in 100 psec. CYCLOPS will produce 50 J in each of two 20 cm beams and ARGUS, now under construction will delivery 150 J in each of two (four in the future) beams of 20 cm diameter.[1]

The power level in these short pulses is extremely high. As an example, 100 Joules in 100 picoseconds is equivalent to a power level of one terawatt. At this power, the index pf refraction of glass is not constant and causes problems with large and small scale self-focusing which produces damage to elements and non-uniform illumination of targets.

Simultaneity of pulse arrival is extremely important. We have shown that a delay of 40 psec severly degrades implosion symmetry and have established a limit of 10 psec error in pulse arrival. Since light travels 3 cm in 100 psec, the total length of a normal pulse, the corresponding allowable error in path length is 3 mm. This is the total allowable accumulation in the 65 meter path from the oscillator to the target. Final adjustments of path length is accomplished by translation of the beam turning mirrors.

Intensity of illumination must be held uniform over the target surface to within ± 10% to avoid instabilities during implosion. Since the beam profile is a modified Gaussian, a function of the focusing system is to re-distribute the energy evenly over the surface of the target.

Completely uniform illumination of the target requires irradiation of the entire surface. All rays must be normal to the spherical surface of the target within 15°. Early experiments have used extremely fast lenses to subtend as large a solid angle as possible, but a marginal ray angle of 45° is the maximum feasible with refractors alone. To increase the solid angle of illumination, we will use ellipsoidal mirrors in concert with fast lenses to achieve essentially 4π illumination, with power up to one terawatt over a pair of 20 cm beams.

As power increases, the thick lenses required with simple ellipsoids introduce an unacceptably long optical path through glass. The nonlinear index introduces a phase retardation, resulting in wavefront distortion and non-uniform illumination of the target. To obviate this problem, we have in the ARGUS system used a pair of relatively thin f/1.25 lenses coupled to ellipsoidal mirrors to illuminate the main inner ellipsoids with the large solid angle which they require. Targets are as small as 50 μm (.002 in.) diameter. They must be placed in the focus region of the lens system and held to within 5 μm of absolute position. The extreme precision needed in these large systems requires that the target be isolated from air pressure, temperature and vibration effects, and be positioned by very rigid, accurate translation systems. The targets must be introduced into the target chamber without damage and without destroying the high vacuum necessary for exposure. Positioning must be remotely controlled.

2. Design Objectives

With the foregoing considerations, plus considerations of versatility and economy, the design objectives for the target chamber may be stated:

- Support lenses and targets in stress-free space frame isolated from vibration, temperature changes and vacuum load.
- Position all elements while at full vacuum to within 1 μm of optimum and translate lenses to defocus the beam a specified amount which will vary for different targets.
- Set up and align the optics system in a laboratory and install the pre-aligned system into the chamber as a unit.
- Provide versatility to accomodate different focusing systems, change orientation and move

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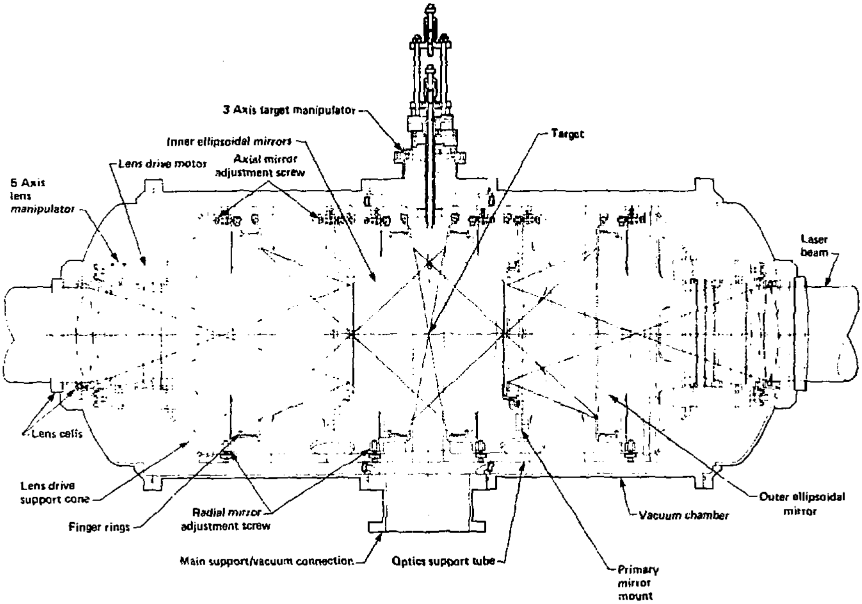
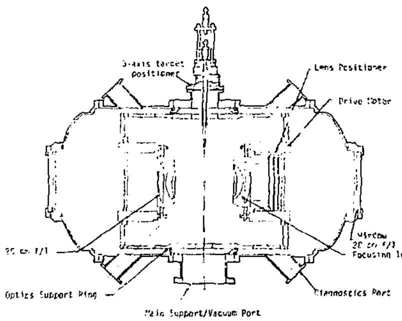
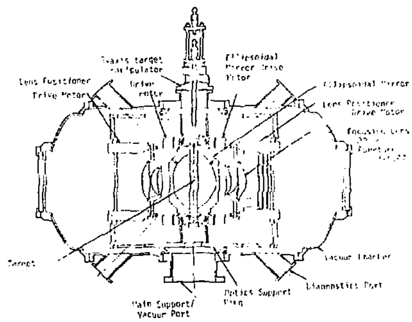


ARGUS Target Chamber - Baseline Design with Compound Ellipsoids



ARGUS Target Chamber Simple Lens Focusing Configuration



ARGUS Target Chamber Simple Ellipsoidal Mirror Configuration from one laser facility to another.

3. Space Frame (Optics Support Cylinder)

All optical components, target manipulator and target alignment optics are supported on a rigid framework which is freely supported within the vacuum chamber.

The entire optical system is thus isolated from variables such as deflection due to vacuum loads and temperature changes. The floor pad is a 3 foot thick concrete slab which is carefully isolated from vibrations due to vacuum pumps, air conditioning machinery, vehicular traffic and microseisms.

As an added advantage, the optical system can be installed into the space frame and aligned in an optical laboratory before being placed into the target chamber. *Different space frames allow a variety of* optical configurations to be installed into the basic vacuum chamber without interruption of the experimental program.

4. Vacuum Chamber

The primary function of the vacuum chamber is to provide an environment in which the experiments can be conducted. A pressure of 10^{-5} torr or better is required to avoid air breakdown from the intense laser beam, allow unobstructed paths for electrons, ions, and low energy x-rays to their respective detectors, and to avoid electrical arcing within the detectors.

In addition, the vacuum chamber serves as the main support for the space frame and diagnostic equipment. The center section is the backbone of the system, upon which can be fastened various focusing units, diagnostic spools and heads, and which can be easily moved from one facility to another by simply unbolting the main support flange which is also the vacuum pumpout port.

5. Target Manipulator

The target manipulator is a device for positioning targets precisely inside the vacuum chamber with 4 degrees of freedom (three translations and one rotation about vertical axis) as follows:

Axis Motion	Range
Translation X, Y	± 7 mm
Translation Z	
Coarse extension	280 mm
Fine extension	± 4 mm
Rotation	± 15°

The axis motions X, Y and coarse Z are powered by stepping motors for remote operation. The axis motion Z fine and rotation Θ_z are manually adjusted. All translations (X, Y, Z) can be adjusted to within .5 μm.

The target positioner is mounted directly to the optics support tube and is decoupled from the chamber by a bellows. The X and Y translation stages are mounted to a base spool. The target entry tube is mounted to the top of the X and Y stages. The vacuum interlock linkage is part of the base spool structure. The Z translation stage consists of a target rod, shield tube, mounting flange, and actuating mechanism. The Z stage is inserted into the target entry tube and clamped to the top of the X and Y stages.

In order to insert a target into the chamber the vacuum interlock is closed at the bottom of the target entry tube. A target is installed on the target rod of the Z translation stage. A special alignment fixture is used for target installation and pre-alignment. Once the target is installed on the target rod it is retracted into the shield tube. The Z translation stage is then inserted into the target entry tube at the top of the X and Y stages. The vacuum interlock is then opened and the motorized Z axis extends the target rod and target into the chamber for positioning. The target is then viewed through target alignment optics, and fine alignment of the target is done remotely to within 0.5 μm.

The unit was designed for maximum rigidity at the *target, precise alignment to within 0.5 μm, with the* capability of inserting and removing the target into and out of the chamber without breaking the vacuum.

6. Target Alignment Optics

The target alignment optics (TAO) is an optical device which is used to aid in the alignment and positioning of targets inside the vacuum chamber.

Its optical system consists of a positive relay lens combined with an achromatic Barlow lens. The system relays the image of the target out of the chamber and onto a reticle at 5X magnification. The image on the reticle is then viewed through a 20X microscope for alignment or with a camera for recording.

The TAO is mounted directly to the space frame (optics support tube) and is decoupled from the chamber with a bellows. Two TAO's are normally used on the chamber, mounted 90° apart, to aid in the positioning of the target.

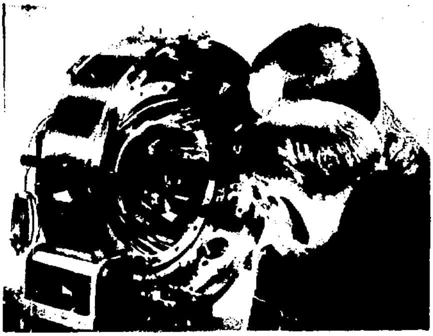
The TAO's are pre-aligned to the theoretical center positon of the system by viewing a 250 μm steel ball suspended by the target manipulator and illuminated by the focused laser beam. The 250 μm ball is then removed and the target proper is inserted and positioned in the chamber using the reticle in the TAO as a reference.

7. Lens Micro Positioner

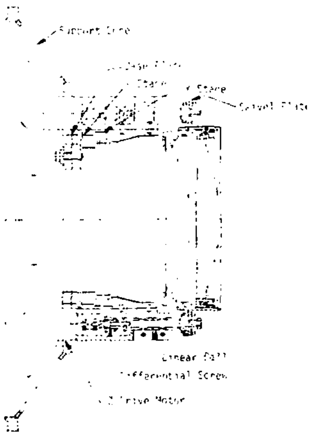
The lens micro positioner is a device for positioning lenses precisely within a vacuum chamber with five degrees of freedom (three translations and two angular rotations) as follows

Axis Motions	Range
Translations X, Y, Z	
Coarse	± 8 mm
Fine	± 0.7 mm
Angular Rotations Θ_x, Θ_y	± 2°

The axis motions are actuated by stepping motors which drive differential screws. Single steps of the motors translate into 0.5 μm incremental movements at the output of the differential screws. The positioner has a clear aperture of 250 mm, and each axis motion is spring-loaded and free of backlash.



Simple Ellipsoidal Mirror As-Machined Silver Surface



Lens Manipulator

The unit consists of three stages (x, Y and Base) mounted on precision roller slides which nrovide the X and Y translations. The top (Y) stage serves as a mount for three actuators that control the Z, θ_x, and θ_y motions. A lens housing is supported by three swivel plates which are attached to the ends of the three actuators. To provide the Z translation, the three actuators are simultaneously moved in and out. The majority of the component parts are made of aluminum and stainless steel.

8. *Ellipsoidal Mirror Mounts*

The ellipsoidal mirrors are fabricated from beryllium substrates which are copper plated, precision *machined at Oak Ridge by single point diamond turning* to prodice the optical surfaces, electroless nickel plated and lapped to reduce scattered energy, and dielectric coated to increase reflectivity and damage resistance. *The fabrication process is described more* fully in a paper by S. Glaros.[2]

The mirrors are supported around their periphery by segmented finger rings, elastically pre-loaded to provide uniform support and eliminate distortion due to mounting. These finger rings are suspended in a stiff support ring which, in turn, is mounted to the space frame in completely adjustable mounts.

The ellipsoids can be positioned manually in five dimensions, as follows:

Motion	Range
Translation in x, y, and z	± 5 mm
Angular rotation θ_x and θ_y	± 1°

All adjustments are manual, to be accomplished with the space frame in the laboratory. In addition, a motorized drive is provided for fine adjustment of tne axial drive Screws. This will allow fine tuning of focus and tilt while under vacuum over a range of ± 55 μm, with a resolution of better than 0.1 μm.

9. Vacuum System

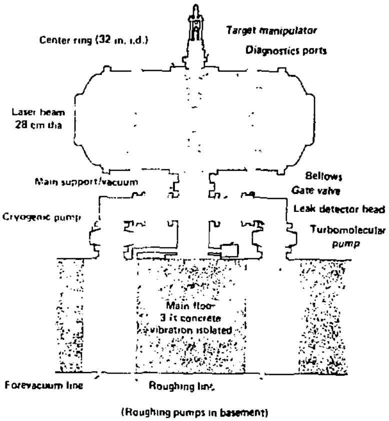
In addition to the obvious function of providing a working pressure in the range of 10^{-6} Torr, the vacuum system must embody a number of attributes.

First, it must be simple and foolproof. We have avoided diffusion pumps and instead used turbomolecular pumps which will withstand occasional accidental *excursions to atmospheric pressure without damage* and without contaminating the system. A dual pump arrangement provides fast pumpdown and gives a backup in case of breakdown. Cryogenic pumps remove condensable *vapors and greatly increase pumping* speed. *This* is necessary because of the large amount of plastic insulation on motors, wires and detectors. The cryogenic pumps and all cold traps are automatically filled with liquid nitrogen as required.

Control of all vacuum pumps and valves is remote, and functions are interlocked to prevent errors. In the event of a power failure, all valves close and the roughing pumps are vented to prevent backstreaming. On resumption of power, the system must be manually restarted.

Vibration and noise from the roughing pumps are isolated by placing the pumps on a mezzanine in the *basement of the building. Vibration from the turbo*molecular pumps is small and is minimized by flexible bellows which are arranged in opposition so that no net lateral air pressure loads are placed on the support pedestal.

Base pressure of the system is 1×10^{-7} Torr, and is expected that we will reach less than 1×10^{-5} Torr within 20 minutes. Operation will be from 10^{-5} to 10^{-6} Torr.



ARGUS Target Chamber Baseline Configuration

10. Diagnostics

A large number of ports are available for mounting diagnostic equipment and for electrical feed throughs. Accuracy of alignment is important, to allow rigid installation of equipment with small angles of acceptance.

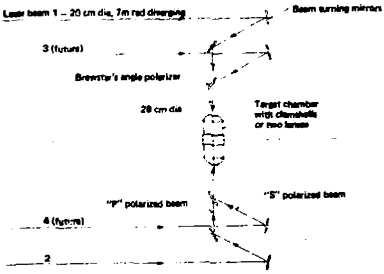
All flanged faces are flat, to avoid the cost of machining o-ring grooves in the chamber. O-rings are captured between aluminum retainer rings and sandwiched between the flat flange faces. Both patterns are compatible with high vacuum flanges manufactured by Varian, Huntington and others. Adapters allow use of equipment provided with pinch gasketed flanges.

11. Versatility

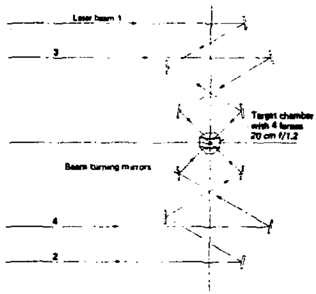
The basic target chamber and optics support tube can accomodate a variety of two beam focusing systems as discussed earlier. In the future, we expect to increase the total power by adding two more amplifier lines. The new beams will be polarized orthogonally to the existing and will be combined in polarizer as shown in the illustrations.

Four beams in a plane can be accomodated by adding new vacuum chamber heads, equipped with focusing lenses as fast as f/1.2.

Transfer of the chamber from one laser facility to another is easily accomplished by providing a standard base at each facility and merely unbolting the entire chamber from its support flange. The CYCLOPS facility at LLL is presently being modified to allow this flexibility.



ARGUS Target Chamber Layout Two-Four Co-Linear Beam Configuration



ARGUS Target Chamber Layout Four Beam Tetrahedral Configuration

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References

1. Laser Program Annual Report, 1974, UCRL 50021-74.
2. Glaros, S., and Glass, A., "Compound Ellipsoidal Focusing System for Fusion Lasers," UCRL 77249, November, 1975.