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SHIVA OPTICAL DIAGNOSTICS

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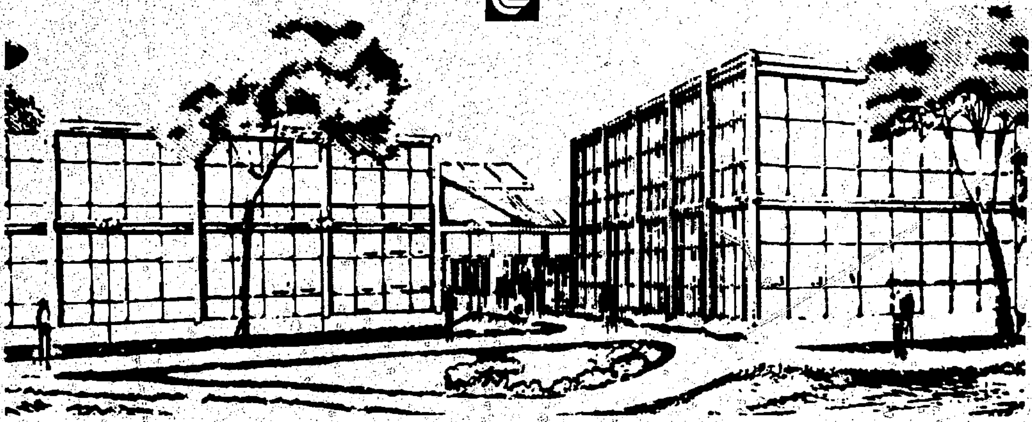

Abstract Submitted

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Shiva Optical Diagnostics. F. RIENECKER, M. KOBIERECKI, R. CZARSKI, L. SEPPALA, K. MANES and B. MERRITT, Lawrence Livermore Laboratory**-- In the laser fusion program at Lawrence Livermore Laboratory, no target experiment is complete unless it is complemented by careful measurements of the laser pulse that irradiates the target. For this purpose, an incident beam diagnostics (IBD) package has been designed for the Shiva laser. The package will furnish data on items such as the total energy and the focusable energy out of the laser chain, and the spatial and temporal energy and power distribution at the target plane. Understanding laser-plasma interactions requires knowledge of the amount of 1.06 μm light energy that is scattered in various directions from the target. The light energy that is scattered toward the beam focusing lens is analyzed by a reflected beam diagnostic (RBD) package containing a calorimeter, a multiple image camera and a TV camera. This paper describes the detailed design and operation of the IBD and RBD packages as tools to align spatial filters and targets, as well as to diagnose the laser beams and target reflectivity.

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REA

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INTRODUCTION

The Shiva facility[1, 2] at Lawrence Livermore Laboratory is a 20 beam Nd: glass laser which is capable of delivering 10 kilojoules of 1.06 μm light to a fusion target in less than 1 ns, with a peak power of over 20 terawatts at ∿ 100 ps. The building which houses the facility has two main rooms; the laser bay contains the oscillator and all amplifiers, and in the target room are the final turning mirrors, target chamber, beam diagnostics packages and target diagnostics detectors. Fig. 1 shows a model of the laser, target chamber and their support frameworks.

As the laser beams enter the target room, they are steered by a series of turning mirrors to form two bundles of ten beams each, entering the top and the bottom of the target chamber. The final turning mirrors are 98% reflecting, 2% transmitting to "leak" a portion of the beam for analysis by the IBD package (see Fig. 2). Light reflected from the target during a shot is collimated by the focusing lens and is partially transmitted through the final mirror to the Reflected Beam Diagnostics package which is integral with the PFC sensor. The function of the computer controlled PFC system is to center the beam onto the main lens, point the beam through the lens to the target and to focus the beam on the target.[3] After the beams are aligned and focused, a remotely powered mirror is inserted to steer the return beam to the RBD package for analysis.

Included in the laser chains are numerous spatial filters to remove the high frequency components of the beam which would otherwise build up local intensities to the damage level.[4] Figure 3 is a schematic diagram of a typical chain, showing the locations of the spatial filters, beam diameter, power and break-up integral at various locations.

One of the functions of the beam diagnostics equipment is to view the images of the spatial filter pinholes to aid in their alignment. The image is focused on a silicon target TV camera in the Incident Beam Diagnostics package, using a remotely inserted cross-hair as a reference center.

INCIDENT BEAM DIAGNOSTICS PACKAGE

A complete laser fusion experiment requires an extensive array of diagnostics monitoring the laser-target interaction phenomenon. However, an essential part of the philosophy of the LLL laser-plasma interaction effort has been that no target experiment is complete unless it is complemented by quantitative measurements of the characteristics of the laser pulse that irradiates the target. In keeping with this tradition, an incident beam diagnostics (IBD) package (Fig. 2) has been designed for the Shiva laser. The package will furnish data on items such as the total energy and the focusable energy out of the laser chain, and the spatial and temporal energy and power distribution at the target plane.

Each IBD package samples about 3% of the 1.06 μm light that is transmitted through the final beam turning mirror. The diagnostics included in IBD are:

- A Galilean telescope to focus the beam through a pinhole and onto the other diagnostic elements.

- A calorimeter to measure the total integrated energy contained in the pulse.
- A focused fraction calorimeter to measure the energy passing through a pinhole corresponding to the target in size and position.
- A fast photodiode to record pulse shape on long (greater than 1 ns) Gaussian and shaped pulses.
- An array camera to record on film the time-integrated spatial energy distribution at various equivalent planes near the focal point.
- A TV camera to view alignment of the beam into the IBD and also to aid in aligning spatial filter pinholes.
- An emerging beam that can be focused onto a streak camera to record the temporal power distribution.

A separate IBD package will be provided for each of the 20 beams. Remote focusing of the telescope will allow an "equivalent plan to be imaged onto the pinhole, the TV camera, and the array camera. The equivalent plane is defined as the plane in the IBD that corresponds to the plane in the actual beam focal region where the target is placed.

Initially, the IBD packages will be mounted on the laser space frame to aid in spatial filter pinhole alignment and to verify the milestone goal of 10 KJ in less than 1 ns. They will then be moved to their permanent positions on the target room space frame.

REFLECTED BEAM DIAGNOSTICS PACKAGE

Understanding laser-plasma interactions requires knowledge of the amount of 1.06 μm light energy that is scattered in various directions from the target. The light energy that is scattered toward the beam focusing lens is analyzed by a reflected beam diagnostic (RBD) package containing a calorimeter, a multiple image camera (MIC) and a TV camera (Fig. 5).

The TV camera verifies alignment of the target and aids in imaging the correct focal plane onto the MIC. This focal plane will vary with the size and type of target and generally will not coincide with the best focus point.

The MIC is a simple film holder equipped with an IR transmitting black-glass filter to prevent fogging of the film by ambient light. A remotely adjusted lens system focuses the desired focal plane onto the film. A pair of beam splitters produces a series of images on the film, each reduced in exposure by one-half of the previous image.

Part of the beam is split off to a calorimeter that measures the total integrated energy that has been forward- and/or backscattered into the RBD. A portion of the pulsed beam can be split off and focussed into a streak camera to record reflected energy as a function of time.

The RBD package is mounted to the pointing, focusing and centering (PFC) package as an addition, to take advantage of the existing PFC focusing lens and TV camera. A total of 20 RBD packages are provided, one for each beam.

PRESHOT ALIGNMENT

Spatial Filter Pinholes

To center and focus the spatial filter pinholes, a diffused CW YAG beam is propagated down the line to back-illuminate the pinholes in sequence starting from the oscillator. To set up, all pinholes are remotely moved out of position to allow the CW beam to propagate down the chain. The beam is centered on a crosshair in the IBD package by steering the Beam Diagnostics Routing Mirror (BDRM), while viewing the image via the TV camera.

A rotating diffuser is placed in the beam to back-illuminate the pinholes which are centered in sequence around the crosshair. Focusing is done by moving the pinhole axially until its image is sharpest on the TV screen. All pinhole movements are powered by stepping motors which are energized from the control room.

CW Energy Distribution

The beam is focused onto the TV tube to evaluate alignment and possible aberrations. By focusing through the near and far fields, energy distribution can be subjectively evaluated and the various beams may be compared. In addition, a single frame may be stored on disk and an individual scan line may be analyzed digitally for energy distribution.

Pointing, Focusing and Centering

Each beam is steered to pass through the center of its focusing lens and pointed and focused on the target by a pair of turning mirrors which are under computer control. The Pointing, Focusing and Centering (PFC) system is described fully by E. Bliss.[3]

In general, the target is not placed at the best focus point of the beams, but in the intermediate field so that the marginal rays are tangential to the target. To view various planes around the focal point, the Return Beam Diagnostics (RBD) package has a remotely controlled focusing lens. The RBD will image the opposing beam and also the target in that beam to verify target alignment. Fig. 6 shows the tangential focusing method and a TV view of the target in the CW beam.

SHOT DIAGNOSTICS

Incident Beam Diagnostics (Fig. 4)

The IBD contains two calorimeters - one to measure the total energy in the beam by sampling a small fraction of the energy passing through the first turning mirror, but integrating over the entire beam; the second collects that fraction of the incident energy that passes through a pinhole which is located at the focus of the Galilean telescope. As the energy density is extremely high at the focal point, the beam must be attenuated to avoid air breakdown. The atteruator wheel contains a number of partial reflectors which will transmit from 1% to 5% of the beam, in addition to an antireflection coated window which is used during preshot alignment.

Energy distribution is evaluated by a time-integrated series of exposures on film in an array camera. This camera images various planes in the vicinity of the focal point and provides a series of exposure levels for each of those planes. A typical film record is shown in

Fig. 7 and an enlarged view of an image with its corresponding energy distribution is shown in Fig. 8a. The energy density profile is unfolded from the film density profile by a technique described by D. MacQuigg.[5]

Time resolved power is recorded by a high speed electronic streak camera,[6] which samples the residual light which passes through the array camera beam splitters. A typical record is shown in Fig. 8b. For slower pulses (greater than 1 ns FWHM), a fast photodiode will measure power vs. time, to be recorded on a fast oscilloscope or a transient digitizer.

CONTROLS AND READOUTS

All functions in the IBD, RBD and routing mirror are powered by DC stepping motors, which are controllable from a number of positions.

Local manual control is done by a universal stepping motor power supply which can be plugged directly into the unit. There is no readout associated with this mode, and it will be employed mainly in setup and debugging before installation.

Target room control is from a mezzanine in the target room, about 3 m lower than the target chamber. This location includes position readouts, safety interlocks and logic functions. Commands are entered through an elementary control panel with all processing and logic done by microcomputers.

Eventually, all control functions will be commanded from the central control room using microcomputer techniques. Links between the control room and target room will be electrically isolated by fiber optics to avoid electrical noise in the target room.

CONCLUSION

All 20 IBD packages have been built and aligned. Five of the units have been installed in the laser bay to aid in setup and initial operation of the laser chains. Controls have been completed and checked.

The RBD packages are starting to be assembled. Controls have been designed and are being built.

We expect all IBD and RBD packages to be operational for target experiments early in 1978.

References

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2. J. A. Glaze and R. O. Godwin, The Shiva Laser: Nearing Completion, SPIE Vol. 103, Systems Integration & Optical Design II (1977), p. 57 ff.
3. Ibid, p. 62. Also, E. Bliss, APS, 1977.
4. J. T. Hunt, J. A. Glaze, W. W. Simmons and P. A. Renard, Suppression of Self-focusing Through Relay Imaging and Low Pass Spatial Filtering, UCRL 79904, (Aug. 5, 1977).
5. D. R. MacQuigg, Film Calibration Method for Analysis of Laser Light Energy Distributions, UCRL 79121 (Jan. 20, 1977).
6. J. W. Houghton, S. W. Thomas, and L. W. Coleman, Ultrafast Streak Camera for Optical Pulse Measurements, ISA Transactions, Vol. 14, No. 3 (1975).

Captions for Figures

1. Model of the Shiva laser and space frame.
2. Typical Shiva Beam Routing.
3. Shiva laser chain, single arm.
4. Shiva Incident Beam Diagnostic package.
5. Return Beam Diagnostics package.
6. Tangential focusing on microshell targets.
7. Array camera - time integrated energy distributions.
8. Typical energy and power distributions at the target.

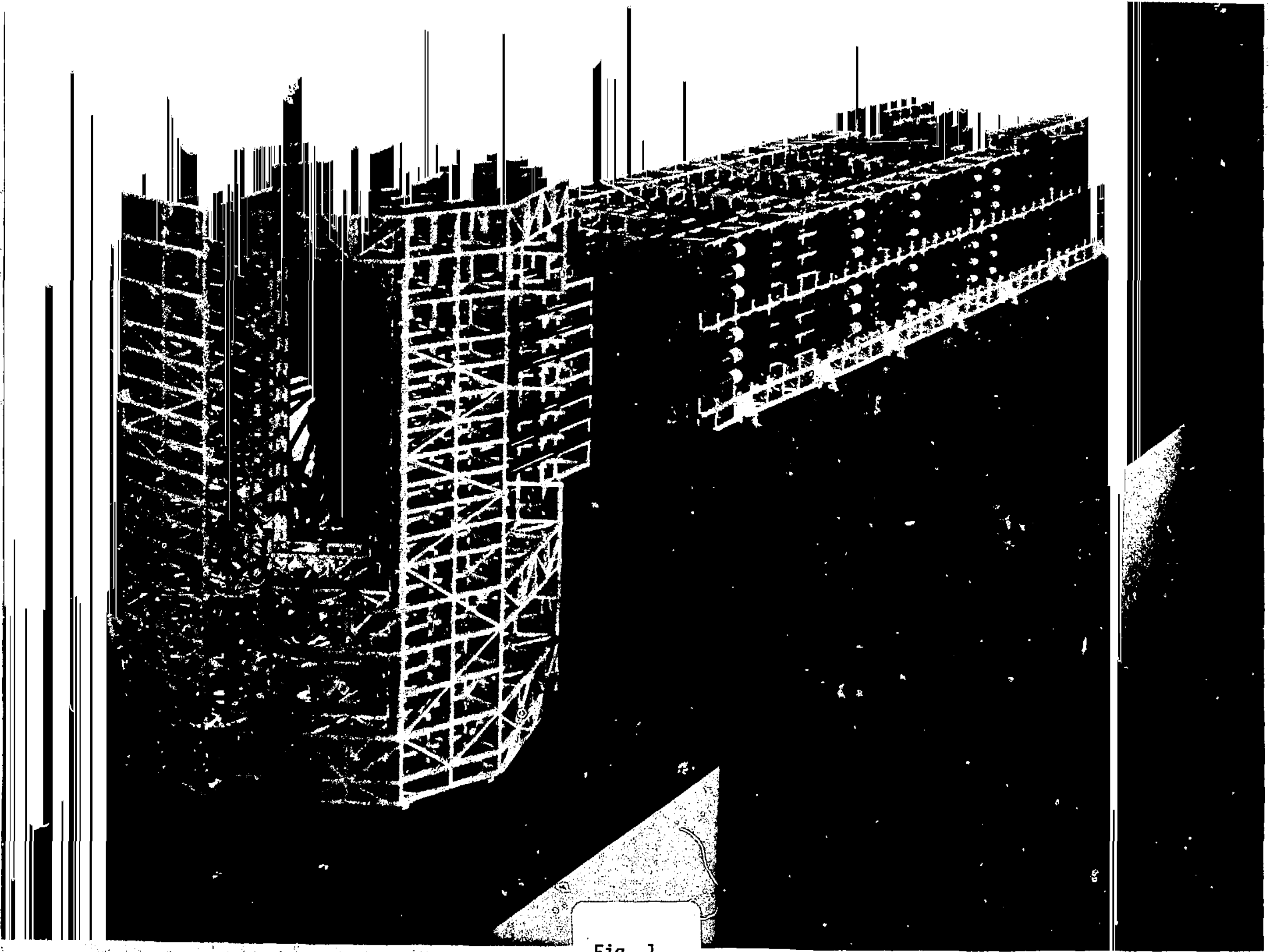

Fig. 1

TYPICAL SHIVA BEAM ROUTING

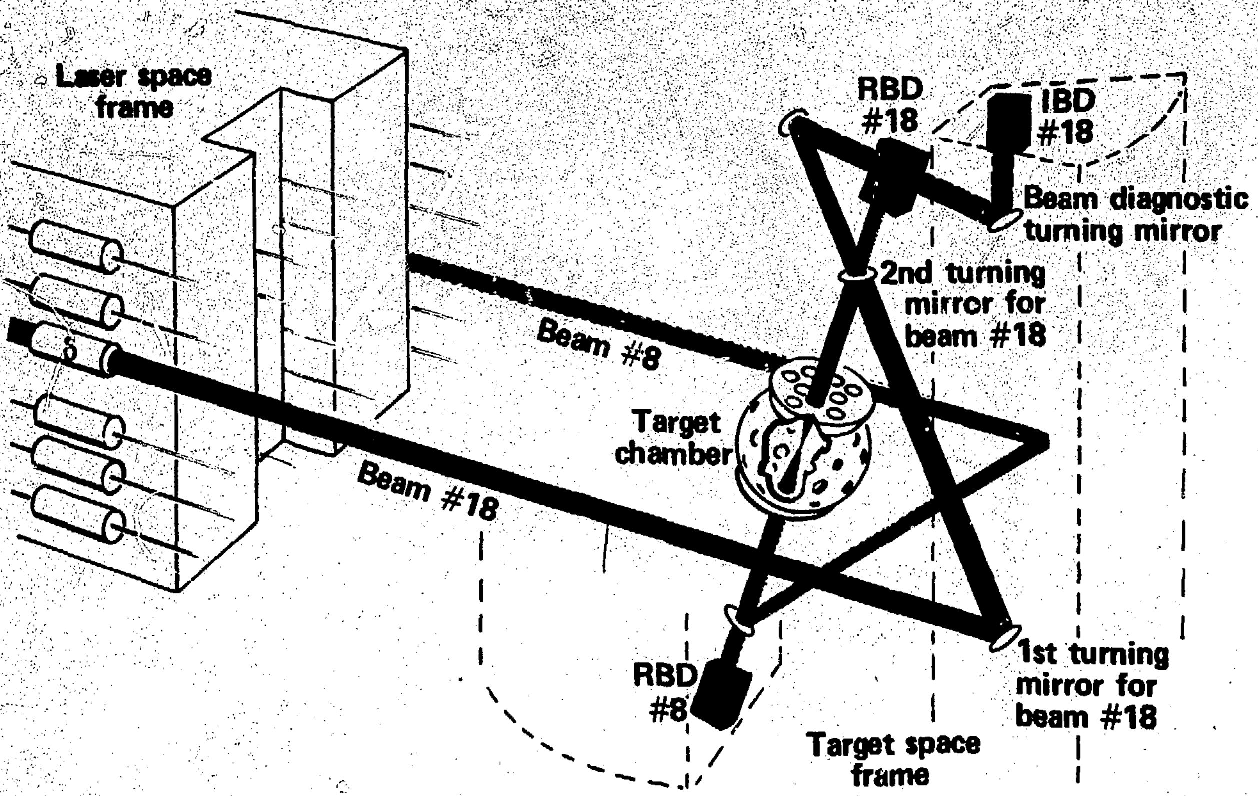

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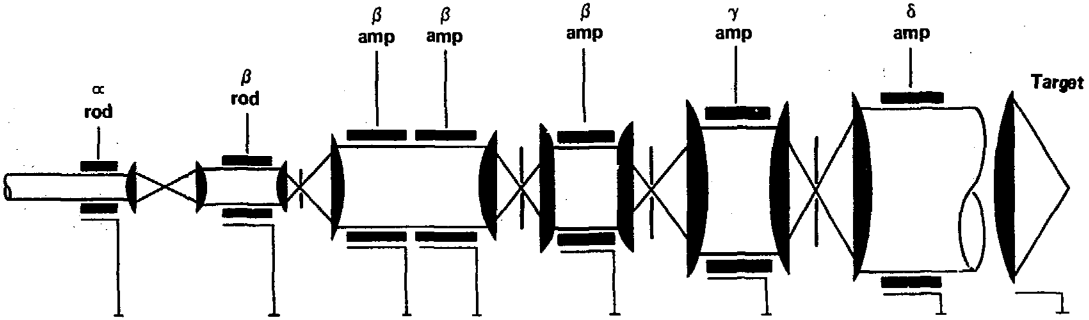
Figure 2

SHIVA LASER CHAIN, SINGLE ARM



Beam dia, mm	21	44	91	91	91	145	202	–
Power at 100 ps, TW	0.001	0.0091	0.031	0.11	0.37	0.90	1.4	1.35
Bank energy, kJ	30	40	150	150	150	220	280	–
Break up integral, nep	0.2	0.7	0.2	0.8	1.8	1.6	1.4	0.6
Whole beam phase, rod	0.2	0.9	1.1	1.9	3.7	5.3	6.7	7.3

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Fig. 3

SHIVA INCIDENT BEAM DIAGNOSTICS PACKAGE

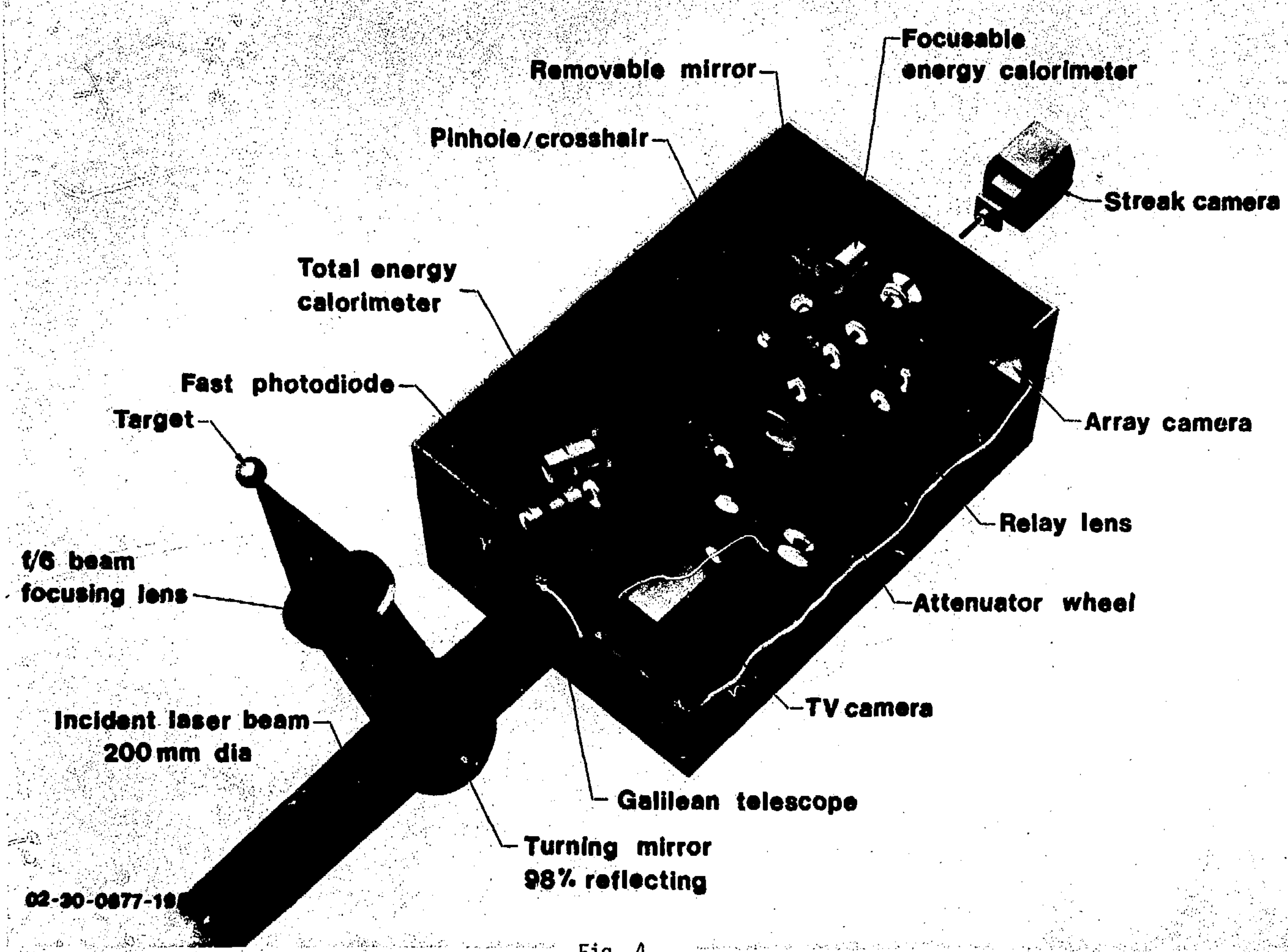

Fig. 4

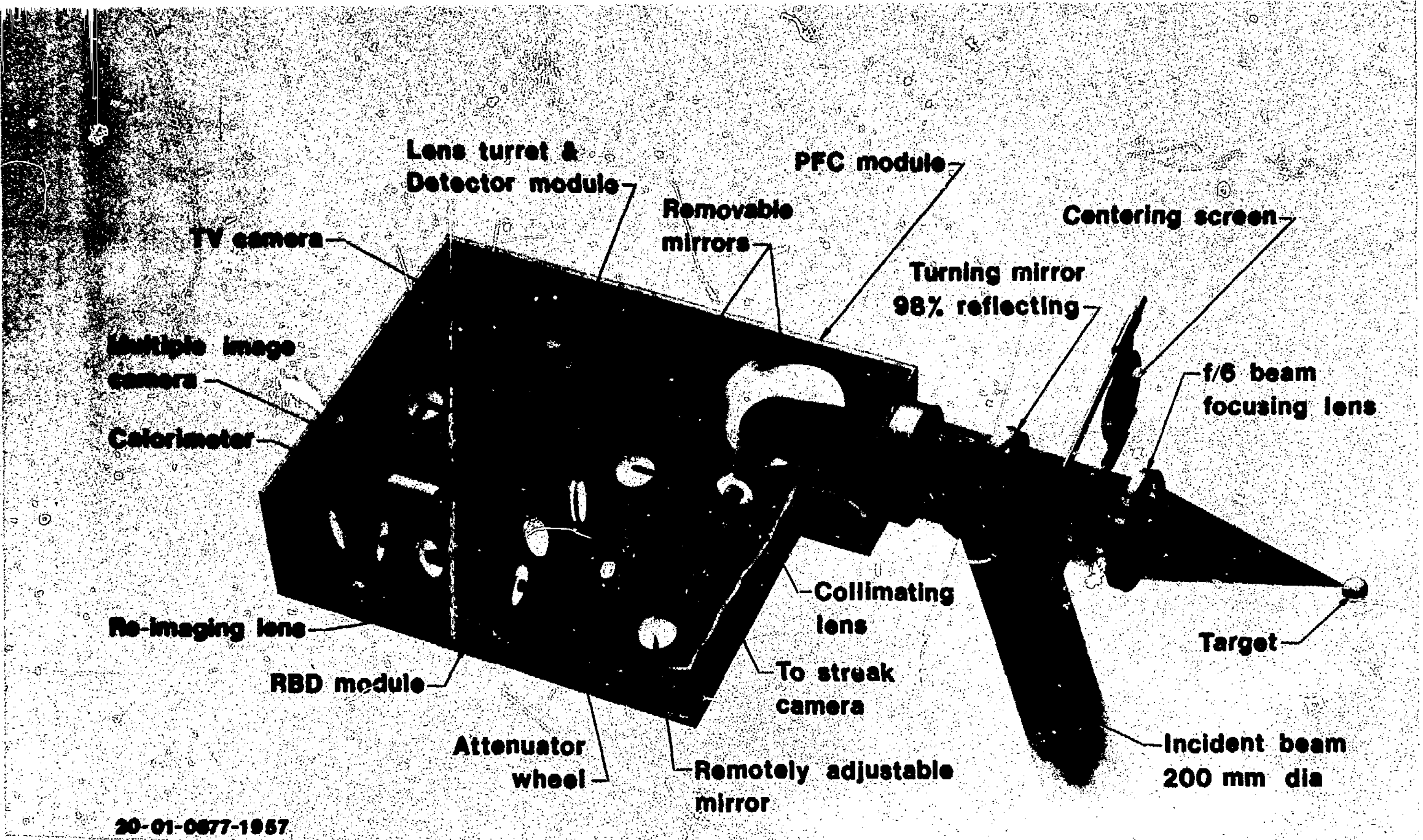
Lens turret &
Detector module
PFC module
Removable
mirrors
Centering screen
TV camera
Turning mirror
98% reflecting
Multiple image
camera
f/6 beam
focusing lens
Calorimeter
Collimating
lens
Re-imaging lens
Target
To streak
camera
RBD module
Incident beam
200 mm dia
Attenuator
wheel
Remotely adjustable
mirror
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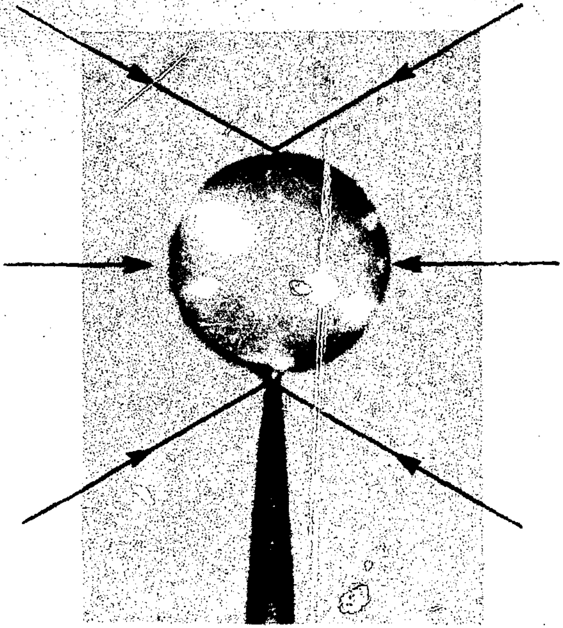
Figure 5

TANGENTIAL FOCUSING ON MICROSHELL TARGETS



Marginal rays of
focused laser beams
from f/1 lenses

Target diameter = 85.7 μm
Wall thickness = 0.64 μm
D-T fill = 2 mg/cc

Target aligned
in the beam

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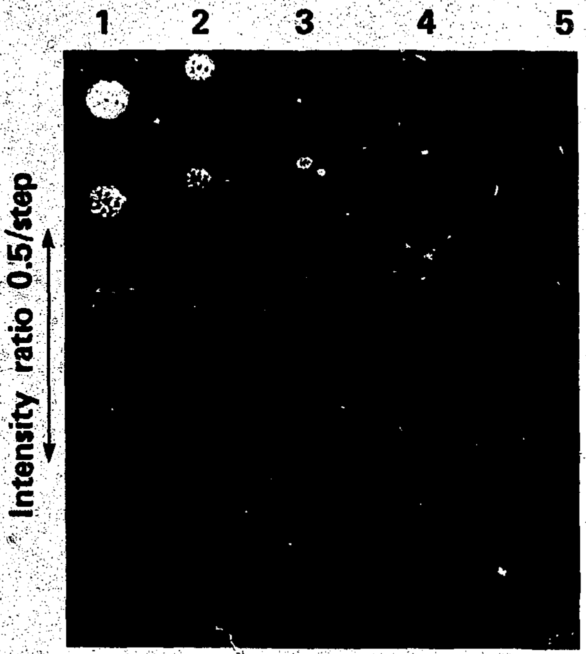
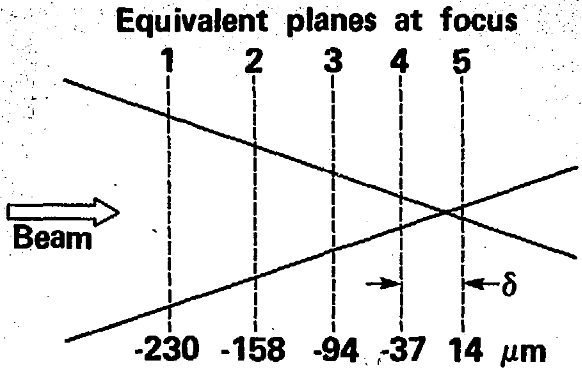
Fig. 6

ARRAY CAMERA – TIME INTEGRATED ENERGY DISTRIBUTIONS





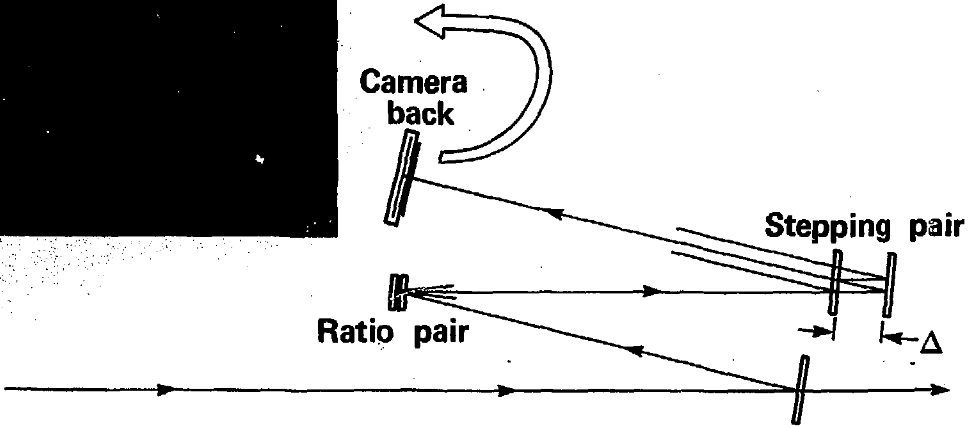


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Fig. 7

ARGUS NORTH BEAM – POWER ON TARGET 2.8 TW

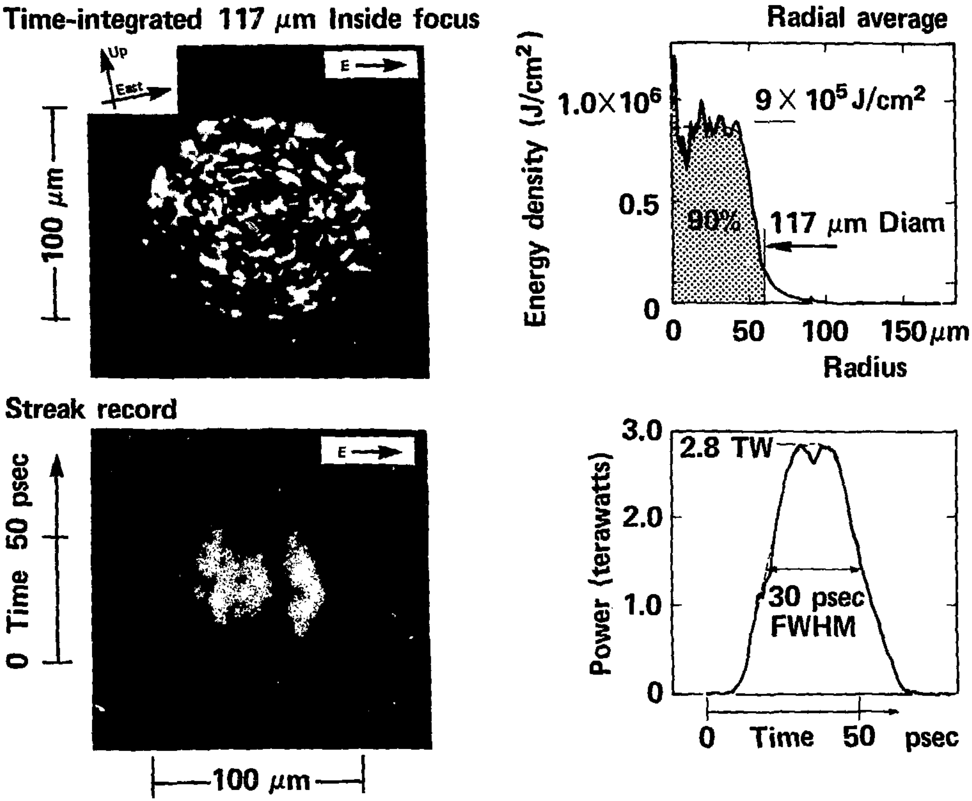

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Fig. 8