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INERTIAL CONFINEMENT FUSION

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A target plane imager for inertial confinement fusion*

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P. O. Box 5508, L-492, Livermore, California 94550Abstract

The Nova laser, completed in December 1984 at Lawrence Livermore National Laboratory, is being used to conduct inertial confinement fusion experiments.¹ It is capable of focusing more than 100 kJ of energy on small fusion targets. This paper discusses an optical system called the target plane imager that is used during the beam alignment phase of these experiments.²

The TPI includes a three meter long periscope with a wide field of view, F/3 objective. The telescope relays images of the target focal plane to viewing optics and a video sensor located outside the target chamber. Operation of the system is possible at three wavelengths: 1.05μ , 0.527μ , 0.351μ . These are the three wavelengths at which the ten Nova laser beams can irradiate targets. Both nearfield and farfield images of the ten beams can be viewed with the TPI. This instrument is used to properly align the laser to the target before each target irradiation.

Introduction

Inertial confinement fusion experiments have been in progress at LLNL's Nova laser since December 1984. This facility is capable of focusing 60-100 kJ of energy on fusion targets at wavelengths of 1.05μ , 0.527μ , or 0.351μ . Figure 1 is a simplified diagram of a portion of the laser system, the target chamber and related subsystems. One of Nova's ten beams is shown focused onto a target in the chamber. Alignment of the beams onto the target is performed using the target plane imager (TPI) shown in the figure. It views alignment beams at the three operating wavelengths, allowing the operator to correctly position focus lenses at the chamber and other optics. The TPI works in conjunction with the other harmonic alignment systems shown in Figure 1.

Optical Design

The TPI is an optical periscope, three meters long, weighing 900 kg that relays images of the laser alignment beams formed at the center of the chamber. These images may be from surfaces of the experimental target or from a reference reticle replacing the target at the chamber center or from a small mirror that can be manipulated at the chamber center. Figure 2 shows the optical layout of the instrument. The input section is an eight element F/3 objective lens with a magnification of 5. This lens and all the others are corrected to minimize aberrations at the three operating wavelengths but focal shifts are mechanically compensated for.

The first image in the system is formed at the first field lens which reduces clear aperture requirements for subsequent optics. Section 2 is a 1:1 relay which reimages the beam at the next field lens three meters from chamber center. Since this relay is so long, the design is achromatized to make the 1 ω and 3 ω image planes coincident. This eliminates the need for a cumbersome mechanical focus adjustment in this section. The optical design of the 1:1 relay is simple because the input beam is only F/15. In addition, the field lenses are also achromatic to preserve pupil plane relaying properties. Several fields of view can be selected in the viewing module. When a lens cell identical to the input section is inserted between the last field lens and a CID video camera (as shown in Figure 2), the system is symmetrical and has a field of view of 1 cm. Other optics can be selected to give increased magnification with resulting field of view of 3 mm and 1 mm. Resolution is approximately 1% of the field of view in each case.

Figure 3 is a photograph of an F/4 beam at a wavelength of 0.527μ focused on a diffuse reticle as viewed by the target plane imager. The circle diameters are increments of 1.0 mm with a line thickness of 20μ . The focal spot is about 25μ in diameter and the resolution is limited by the graininess of the diffuse reticle.

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Figure 1. Nova output alignment subsystems.

Figure 2. Target plane imager.

Mechanical Design

Figure 2 also shows the mechanical assembly. There is a small mirror (13 mm diameter) mounted at the input to the periscope. This mirror can be manipulated to intercept the beam or fold back out of the field of view. When in the beam it can be rotated in such a way as to reflect any one of the ten Nova beams directly into the TPI. In this mode, the focal spot can be viewed or other optics can be introduced in the viewing module that allow viewing nearfield images of the laser beam at the plane of the 74 mm diameter

target chamber focus lens. When this mirror is out of the field of view, the TPI is used to view and align focused beams from all ten Nova arms that are incident on a ground glass reference reticle at the center of the chamber.

Figure 3. Target plane imager video data - medium field of view.

In addition to the mirror manipulator, the TPI has several other mechanical motions. The entire periscope and optical viewing module are mounted on a stepper motor driver X,Y translation stage. This allows the operator to survey an area of 25 cm² at chamber center by sending computer controlled scan commands. In addition, the periscope will zoom in and out in the Z-axis ± 25 mm to focus on various planes near the target chamber center. Optics in the viewing module track these motions to preserve focus. At shot time (when the target is imploded by a high power laser pulse), the periscope is retracted approximately one meter and a vacuum gate valve closes to protect the optics.

Three wavelength operation is achieved by adjusting the spacings between the reference reticle and the first objective, between the second field lens and the field of view optics and the final focal distance to the CID camera focal plane. All these motions are controlled by the operator through the computer interface. These various motions are coordinated by the computer control to achieve the desired viewing and to avoid damage caused by conflicting motions.

Operation

Since the Nova laser is capable of irradiating targets at three wavelengths and since the focusing optics are refractive, it is necessary to align the beams at the wavelength planned for each experiment. Low power alignment laser beams at each wavelength are introduced into the main laser beamlines and these are used to align the output of the system to fusion targets. A typical procedure is to use the TPI in order to view each of the alignment beams in nearfield at the target chamber lenses and then center the beams on these lenses. At this point, a reference reticle is aligned to chamber center at the exact location that the fusion target will be during implosion. The images of the alignment beams on this reticle are then viewed by the TPI. Each target chamber focus lens is adjusted to properly align and focus the beams onto the reference reticle. This procedure is followed prior to each target experiment.

Conclusion

The target plane imager, in conjunction with other subsystems, provides the capability to align the Nova laser on target prior to fusion experiments. It functions at the three harmonic wavelengths used in the Nova system and provides the accuracy necessary for these experiments.

References

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