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TITLE: ALIGNMENT AND FOCUSING DEVICE FOR A MULTIBEAM LASER SYSTEM

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ALIGNMENT AND FOCUSING DEVICE FOR A MULTIBEAM LASER SYSTEM*

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Abstract

Large inertial confinement fusion laser systems have many beams focusing on a small target. The Antares system is a 24-beam CO_2 pulse laser. To produce uniform illumination, the 24 beams must be individually focused on (or near) the target's surface in a symmetric pattern.

To assess the quality of a given beam, we will locate a Smartt (point diffraction) interferometer at the desired focal point and illuminate it with an alignment laser. The resulting fringe pattern shows defocus, lateral misalignment, and beam aberrations; all of which can be minimized by tilting and translating the focusing mirror and the preceding flat mirror.

The device described in this paper will remotely translate the Smartt interferometer to any position in the target space and point it in any direction using a two-axis gimbal. The fringes produced by the interferometer are relayed out of the target vacuum shell to a vidicon by a train of prisms. We are designing four separate "snap-in" heads to mount on the gimbal; two of which are Smartt interferometers (for 10.6 µm and 633 nm) and two for pinholes, should we wish to put an alignment beam backwards through the system.

Introduction

A device is described that will aid in the alignment of the Antares laser system.[1] Antares is a pulsed CO_2 laser, which is being built to study inertial confinement fusion. It has 24 beam lines, which deliver 40-kJ total energy. These 24 beams must be focused on the target with a minimum amount of aberration. This is the purpose of the device explained here. It consists of a Smartt point diffraction interferometer[2] that can be inserted into the target volume on the target insertion track. The Smartt interferometer is centered on a 2-axis gimbal so it can be pointed at any one of the 24 beams. The gimbal is mounted on a 3-axis translation stage (' mm travel) so it can be moved to any point in the target volume. The system has been designed so that either a 633-nm or a 10.6-µm Smartt interferometer can be used. This allows a tremendous range in sensitivity. Figure 1a is a schematic of the system.

As an alignment sequence, the Smartt is inserted into the target-vacuum shell and located where 1 of the 24 beams is supposed to focus. It is then pointed at the beam to be adjusted. The interference fringes seen when it is illuminated with an alignment laser show defocus, tilt, and aberrations. The focus can be adjusted by translating the focusing parabola. The tilt can be corrected and the aberrations minimized by an appropriate combination of tips and tilts of the parabola and the preceding flat mirror.

Using the Smartt interferometer will be a lengthy process (estimated 4 hours); so the pointing of the first few beams could change slightly before the last ones are finished. Fortunately, minor pointing corrections have an insignificant effect on the aberrations, hence a scheme that quickly corrects small pointing errors alone could be quite useful. The following scheme is one possibility.

This gimbal system can also be used in the reverse direction. The vidicon can be replaced with a laser and the alignment laser can be replaced with an alignment telescope. The Smartt interferometer would be replaced with a pinhole. The result is a point source of light that can be located at any point in the target volume where a beam should focus (Fig. 1b). The pointing error will be seen by the alignment telescope so it can be zeroed.

In this paper, the optical and mechanical design of the system will be discussed. The gimbal is presently being fabricated. The prototype should be under test early in 1981.

Design

The device must be moderately small, so it can fit through the target insertion air lock. This makes it difficult to install a vidicon on the gimbal. Also, cooling a vidicon in an evacuated region would be hard. Therefore, the vidicon has been located outside the vacuum shell, and the image of the Smartt interferometer is relayed out by a system of mirrors and prisms. If the image is transferred out through the gimbal axes, the image rotates but does not translate. The prisms shown in Fig. 2 accomplish this. (The image is derotated using the "K" prism shown in Fig. 1a.) The prisms are being made out of zinc selenide (ZnSe), one of the few materials that will transmit both 633 nm and 10.6-µm radiation. The advantages of

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prisms over mirrors are: (1) Two prisms are easier to mount than six mirrors; (2) The relative orientations of reflecting surfaces within each prism are maintained; and (3) ZnSe is a high index material (n = 2.4 to 2.6), which reduces the apparent optical path length between the interferometer and the outer bearing race. This means that the beam will have expanded by about half as much at the bearing race as it would while traveling an equal distance through air; so the bearing race, and therefore the whole global assembly, can be made smaller.

Figure 3 is a diagram of the unfolded optical design of the Smartt interferometer system. It shows two positions for the vidicon. The vidicon should be located at the rear (right) position during the crude alignment phase. At this position the Smartt plate is imaged on the vidicon (rather than on the fringes). The mirrors can be tipped and tilted until the beam focus is superimposed on the pinhole in the coating of the Smartt. Using visible light, the fringes should be resolvable at the other focus position when the focus is within ±0.4 mm of the pinhole (or ±3.5 mm for 10.6 μm). The sharpest fringes are obtained when the aberrating element, in this case the parabola, is imaged on the detector, so a small imaging lens has been sandwiched with the Smartt.

The optics from the Smartt plate, up to and including the vidicon, are all designed 10% larger in aperture than required. Hence, small barometric pressure and temperature changes and small assembly and prism errors will not move the image off the vidicon. When the system is being used as a beam projector, small tilt errors can move the focused beam off the pinhole. The pointing error could be remotely monitored if a quadrant detector were built around the pinhole,[3] as shown in Fig. 4. One of the flat mirrors just behind the gimbal can be remotely tilted to correct any minor pointing errors.

The gimbal system can handle 10.6-μm and 633-nm light, and both the Smartt and the pinhole; one gimbal will be made with four interchangeable heads. This concludes the optical description. The following paragraphs describe the mechanical design.

The mechanical tolerances for the gimbal system are fairly demanding. The total tolerance budget for the position of the Smartt interferometer and the pinhole is ±10 μm from the desired position. This includes:

1. ±1-μm accuracy for the encoders on the translation stage;
2. Non-intersection of the two rotation axes (~3 μm);
3. Tolerances on the bearings and races (~2.5 μm);
4. Mislocation of the pinhole or Smartt, relative to the the removable head (~2 μm);
5. Replacement tolerances for the pinhole and Smartt heads (~3 μm).

It is felt that this error tolerance can be met, although it will take some very sophisticated machining and measuring. The lenses, lasers, vidicons, etc. all have to be interchangeable, too; but the tolerances range from moderate to loose.

Summary and Prognosis

The device described has four configurations. The Smartt point diffraction interferometer using visible light will yield the most information. The interferometer fringes will show defocus, aberrations, and pointing errors to a part of a fringe (~λ/2) at 633 nm. This means that errors can be sensed to much better than λ/20 at 10.6 μm. One possible problem is that there may be too much information; so, if some of the optics are of much poorer quality than expected, the interference patterns may be too complex to be useful. If this unlikely situation were to arise, the 10.6-μm Smartt interferometer could be used with 17 times less sensitivity.

The Smartt interferometer allows the focus and aberrations to be optimized in addition to the pointing. This process is not painfully slow, but a faster final pointing scheme is desirable. For this scenario, the beam projector mode was developed. It can produce a point source of light at the correct location in the target volume that can be centered by the automatic alignment system. The final pointing should take about 20 minutes. The 10.6-μm beam projector will be used to calibrate out the dispersion errors experienced by the visible alignment system.

The device has been designed and the parts are on order. A prototype will be finished and under test in early 1981. The first Antares beam line will be ready to be aligned a year later.

Acknowledgments

The mechanical design is being done by Robert Day and Richard Lujan of Los Alamos Scientific Laboratory.

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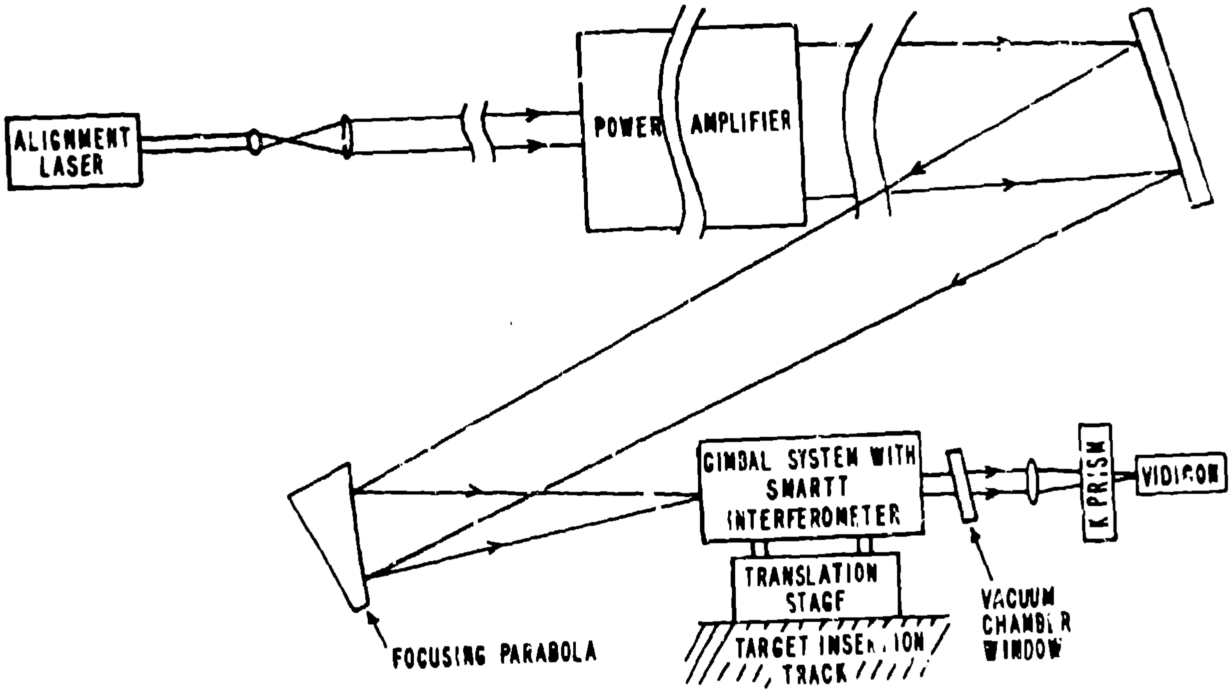

Fig. 1a. System schematic for Smartt interferometer.

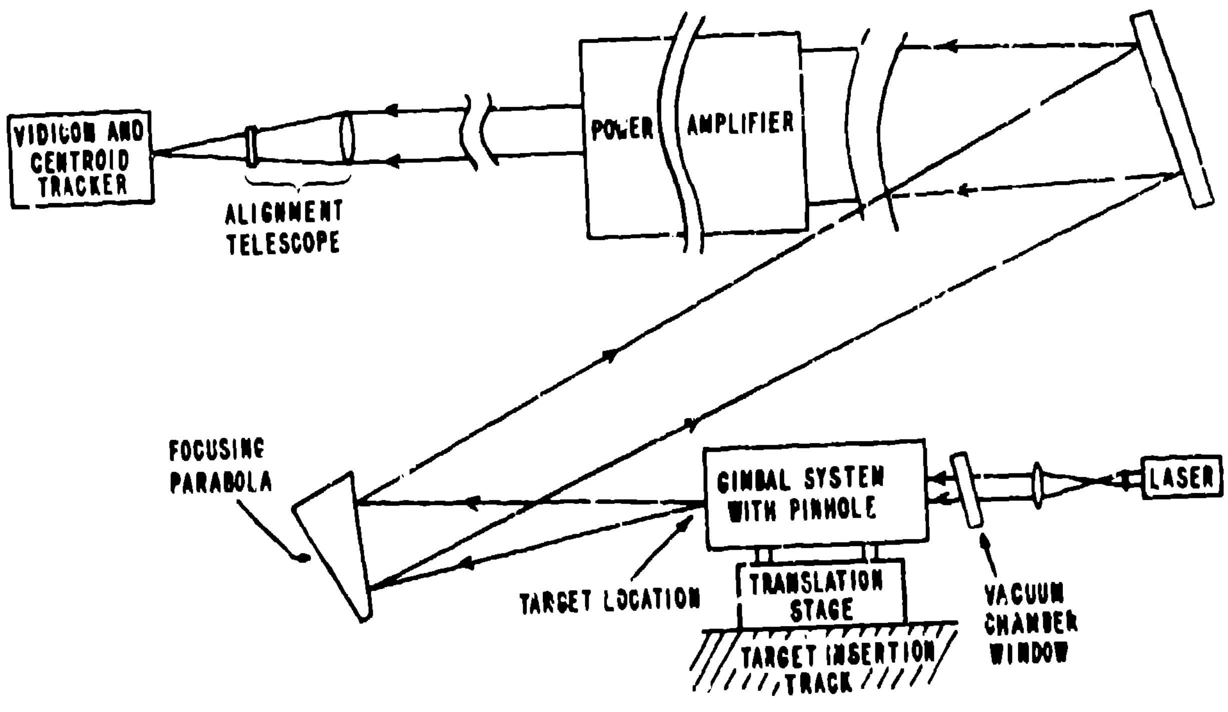

Fig. 1b. System schematic for beam projector.

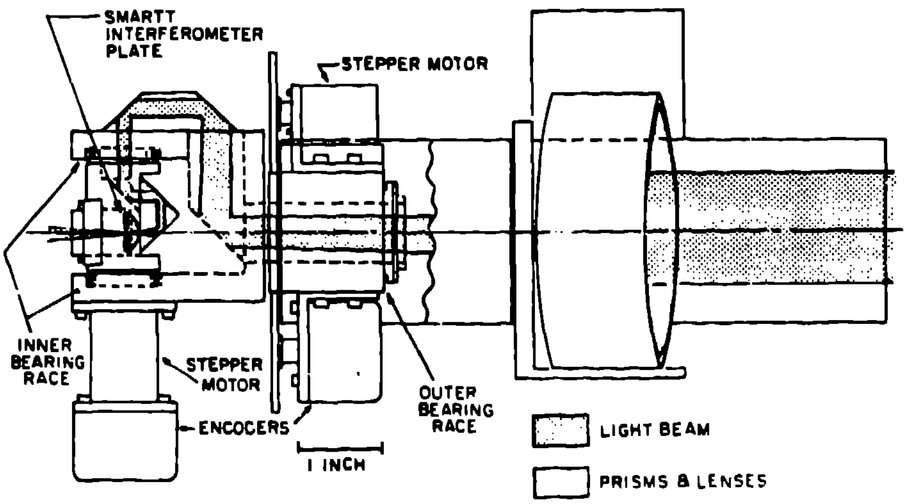

Fig. 2. Antares Smartt interferometer positioner.

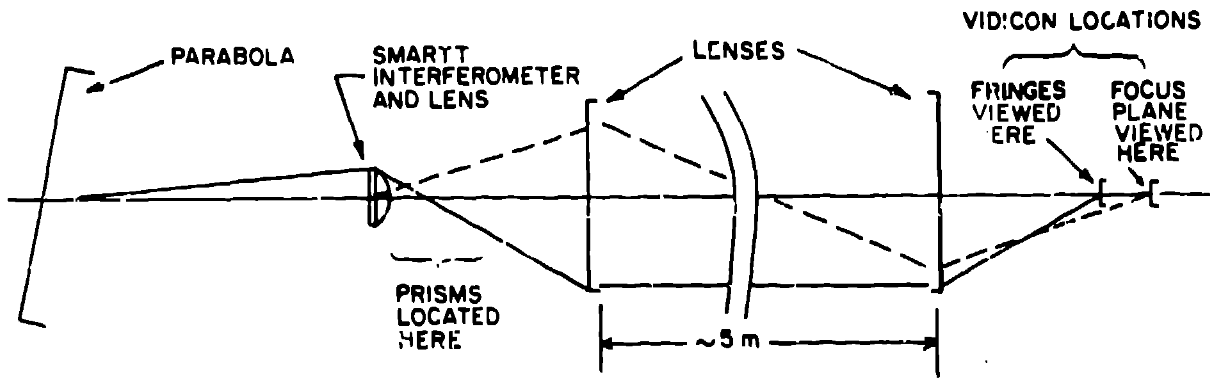

Fig. 3. Unfolded optical layout of Smartt interferometer.

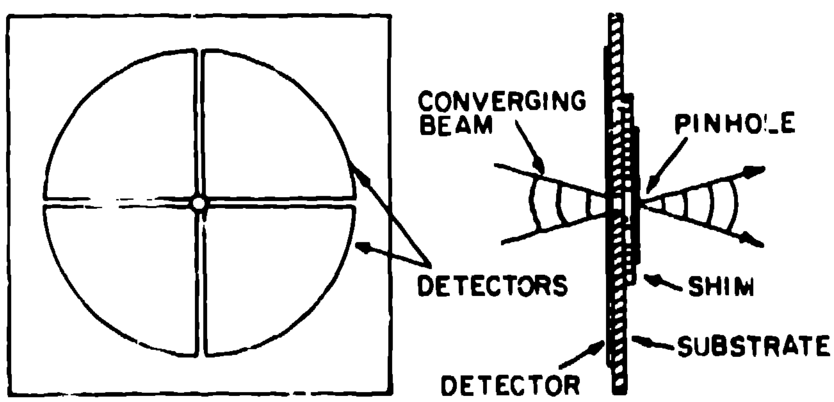

Fig. 4. Pinhole/quadrant detector for beam projector.