A major purpose of the Technical Information Center is to provide the broadest dissemination possible of information contained in DOE's Research and Development Reports to business, industry, the academic community, and federal, state and local governments.

Although a small portion of this report is not reproducible, it is being made available to expedite the availability of information on the research discussed herein.

1

LA-UR -83-1666

LA-UR--83-1666

DE83 014178

CONF-830425--27

MASTER

TITLE: ANTARES REFERENCE TELESCOPE SYSTEM

AUTHOR(S): V. K. Viswanathan, P-5
E. Kaprelian, Questar Corp.
T. Swann, P-5
J. Parker, P-5
P. Wolfe, P-5
G. Woodfin, P-5
D. Knight, Questar Corp.

SUBMITTED TO: Los Alamos Conference on Optics '83
Sweeney Convention Center
Santa Fe, New Mexico
April 11-15, 1983

Los Alamos Los Alamos National Laboratory

380157

Antares Reference Telescope System

V. K. Viswanathan, E. Kaprelian,* T. Swann, J. Parker, P. Wolfe, G. Woodfin, and D. Knight*

University of California, Los Alamos National Laboratory
P.O. Box 1663, MS E523, Los Alamos, NM 87545

Abstract

Antares is a 24-beam, 40-TW carbon-dioxide laser-fusion system currently nearing completion at the Los Alamos National Laboratory. The 24 beams will be focused onto a tiny target (typically 300-1000 μm in diameter) located approximately at the center of a 7.3-m-diameter by 9.3-m-long vacuum (10^{-6} torr) chamber. The design goal is to position the targets to within 10 μm of a selected nominal position, which may be anywhere within a fixed spherical region 1 cm in diameter. The Antares Reference Telescope System is intended to help achieve this goal for alignment and viewing of the various targets used in the laser system. The Antares Reference Telescope System consists of two similar electro-optical systems positioned in a near orthogonal manner in the target chamber area of the laser. Each of these consists of four subsystems: 1) a fixed 9X optical imaging subsystem which produces an image of the target at the vidicon; 2) a reticle projection subsystem which superimposes an image of the reticle pattern at the vidicon; 3) an adjustable front-lighting subsystem which illuminates the target; and 4) an adjustable back-lighting subsystem which also can be used to illuminate the target.

The various optical, mechanical, and vidicon design considerations and trade-offs are discussed. The final system chosen (which is being built) and its current status are described in detail.

Introduction

The Antares Reference Telescope System is a complicated electro-optical-mechanical system whose main purpose is to enable targets used in Antares Laser System to be positioned within 10 μm of a selected nominal position. The nominal position may be anywhere within a fixed spherical region 1 cm in diameter, centered on the center of the target chamber. The optical subsystems and the vidicon system have been manufactured and tested. They conform to the requirements. The mechanical system is currently under manufacture. In this article, the optical, mechanical, and video designs are discussed along with the various trade-offs. The reasons for the choice of a particular design to reach optimum system performance are given. The experimental results obtained so far are stated and the current status is described.

Description of the system

Figure 1 shows the optical schematic of the Antares Reference Telescope System. The basic subsystems are: a) the 9X optical relay system which produces a 9X magnified image of the target at the vidicon photo-cathode plane, b) the front illuminator which is capable of illuminating the target from the front side with variable size and intensity, c) the reticle projector which superimposes a reticle on the image of the target, and d) the back illuminator to backlight the target. The front and back illuminators are capable of being operated either separately or together. In addition, there is a shutter which prevents target shot debris from reaching the optical system and a light trap which prevents the light passing through the beam splitter from the front illuminator returning to the focal plane of the system, thereby reducing the contrast or even flooding the vidicon. Figure 2 shows the locations in the Antares Target Chamber area where the reference telescopes are to be installed.

Mechanical design considerations

The three general classes of requirements imposed on the mechanical design of the Reference Telescope System are:

1) Optical requirements consisting of optical element mounting, structural stability, and precision positioning;
2) Physical and environmental constraints resulting from the existing design of the Antares Target Vacuum Chamber and the "space frame" mirror support structure; and
3) Constraints as to how remote-control operations can be implemented based on compatibility with established Antares Controls System standards and procedures.

* Questar Corporation, P.O. Box C, New Hope, PA 18938

Opto-mechanical requirements

In addition to the obvious requirements to provide mounting for all the optical components of the telescope system, manual (setup) adjustments were needed in several instances. Remote precision adjustments were needed for the following cases: 1) focus adjustment for the large 9X optical relay assembly; 2) three axis adjustments for the vidicon camera/reticle projector assembly; 3) azimuth, elevation, and focus adjustments for the lens pair in the back illuminator; and 4) focus adjustment for the front illuminator. In addition, the mechancial structure had to be of sufficient stiffness so that motor activators, target vacuum chamber motion during pump-down, etc. do not appreciably degrade the optical performance.

Physical and environmental requirements

The telescope system was required: 1) to be attached to the existing "space frame" mirror support structure inside the Antares target vacuum chamber; 2) to be decoupled from the chamber wall as much as possible (to limit the forces on the telescope system which would act to push it out of alignment due to the relative motion between the "space frame" and the target chamber wall during the vacuum pump-down); 3) to exit the target vacuum chamber at two specific ports of several pre-existing ports in the chamber wall; and 4) to have the minimum profile in order to provide maximum solid angle available for the other target diagnostic systems.

The vacuum environment of 10^{-6} torr necessitated the use of low outgassing materials and an optical-quality vacuum window. Due to generation of debris during actual shots on target, a "blast" shutter to protect the optical elements of the telescope system was also required.

Controls requirements

The complex Antares controls system, used for precision remote adjustments and other controls functions like the closing of the shutter, turning on and off the light sources, etc., imposed certain guidelines, which had to be followed to ensure compatibility between the telescope system and the controls system computer. For example, these guidelines limited the choice of types of motors used, established the need for feedback/verification of various operations, etc.

Description of the major mechanical subassemblies

Figure 2 shows the relative locations of the subassemblies in the target vacuum chamber. These subassemblies are discussed below.

9X optical relay assembly

The 9X Optical Relay Assembly is shown installed in its housing in Figure 3. The 9X Optical Relay Assembly itself consists of an aluminum tube 20.5 cm in diameter and 240.0 cm long. In one end are mounted the two doublet objective lenses and in the other end is the negative doublet (Barlow) lens. This negative lens is mounted so that it can be manually adjusted to be on-axis with the objective lens. At a distance 95.25 cm from the front of the tube, at approximately the center-of-gravity, is a mounting flange which is precision machined to be perpendicular to the optical axis within ±0.5 milliradian. This mounting flange attaches to a stiffened structure which mounts open pillow block bearings at four planes to a 1-inch diameter precision linear shafting.

Focus positioning of the 9X Optical Relay Assembly is achieved by actuation of a 200-step/revolution stepper motor driven through a 10:1 right-angle worm-gear screw-jack. A step resolution of 3 μm results. Lateral movement of focus due to tolerances in straightness of the shafting, mounting, and alignment have been estimated at 3.5 μm per cm of travel.

Telescope housing

The telescope housing is also shown in Figure 3. It consists of a vacuum-tight welded aluminum box with a removable access cover surrounding the 9X relay optics focus adjustment mechanism with aluminum flanged pipe attached to both ends for enclosing the remainder of the 9X relay optics assembly. The forward tube (closest to the target) supports an optical-quality vacuum window and its protective shutter. The rear tube extends through the vacuum chamber wall and provides for attachment to the Instrument Package Assembly. This tube is sealed to the target vacuum chamber (TVC) through a welded bellows assembly. The flanged joint approximately two-thirds of the way along the rear tube is a feature to aid in installation and servicing of the telescope.

"Space-frame attachment"

The central box structure of the telescope housing assembly attaches to the existing mirror support "space frame" assembly through a welded and bolted structure. Coarse manual positioning adjustments are provided to aid in initial setup positioning of the telescopes.

Instrument package

The instrument package which is shown in Figure 4, attaches to the rear flange of the telescope housing assembly (external to the TVC). It consists of a welded aluminum structure to which are attached the vidicon camera, reticle projector, front illuminator (and its light trap), and two beam splitters.

The tube face of the vidicon camera is mounted at the focal plane of the telescope. The reticle projector is mounted on the same structure as the vidicon camera. These items are, in turn, mounted to a motorized X,Y,Z translator assembly to provide remote positioning of the camera and reticle projector in the focal plane of the telescope.

The front illuminator xenon arc light source is able to fill the pupil of the telescope for front illumination of the target. The light is inserted through a 50/50 beamsplitter. Transmitted light is reflected into a light trap to minimize light return to the vidicon camera. The front illuminator is mounted on a translation stage for remote focus adjustment capability.

Rear illumination system

The Rear Illumination System consists of two light projectors, shown in Figure 5, mounted external to the TVC. Light from these projectors passes through windows in the chamber and is reflected off mirrors which direct the light through the target location into the two nearly orthogonal telescopes.

The light projectors themselves consist of a high-intensity projector bulb and lens pair for directing the light to the target. The lens pair is mounted in a motorized positioner permitting control of azimuth, elevation, and focus so that target illumination can be optimized remotely.

Description and analysis of the optical and video designs

1. Basic considerations

The specification calls for an optical system which produces a 9X (-9X) linear magnification with the constraint that the short conjugate distance shall be about 40 inches and that the apertures of the system shall not exceed about 7 inches in diameter. This immediately establishes the numerical aperture at the object to be about .0875.

To meet a resolution requirement of 5 μm at the object plane, we have set a goal of 30 percent response at the spatial frequency of 200 mm^{-1}. Hence, we are dealing with a diffraction limited system with cut-off frequency about 5/3 times 200 mm^{-1}, or 333 mm^{-1}. The following table shows the cut-off frequency and the 30 percent response frequency for an f5.72 diffraction limited system as a function of wavelength λ:

TABLE 1

λ(μm)	Cut-off Frequency	30% Response at
0.9	194 mm^{-1}	117 mm^{-1}
0.8	218	131
0.7	250	150
0.6	291	174
0.5	349	210
0.525	333	200

This suggests that we should not permit the system to pass much light with wavelength in excess of .52μm - .53μm.

The television criteria can be summarized as follows: The required resolution at the vidicon is 45 μm, the maximum spectral sensitivity to be available in the 0.5-μm region, the image region of interest to be 1.8-cm diameter, and the system to have standard 525 line 2:1 interface for compatibility with the Antares video system.

380157

2. Selection of vidicon:

a) Resolution requirement:

For a resolution element size of ε mm, the resolution N in line-pairs/millimeter is $N = 1/\varepsilon = 1/45 \times 10^{-6} = 22.2$ line-pairs/mm at the vidicon photo-cathode. This is equivalent to 200 line-pairs/mm at the object plane.

b) Available vertical resolution:

About 35 of the 525 scan lines are used for controlling the raster, and the remaining do not provide continual coverage of the image space. The ratio of the minimum vertical resolution to that of the line spacing is usually about 1.4 (the reciprocal of 1.4 or 0.7 being known as the Kell factor). The vertical resolution, then, is about 340 lines for monochrome TV, regardless of the size of the vidicon used.

However, the available resolution in lp/mm will depend on the vidicon size, as will be shown. A standard raster has a height-to-width ratio of 3:4. The raster diameter d will be 8, 16, or 24 mm for a 1/2-, 1-, and 1 1/2-inch vidicon respectively. The available vertical resolution, for a 525-line system would be:

d_v (mm)	N (lp/mm)
8	71
16	35
24	24

All these cases meet the resolution requirements.

c) Available horizontal resolution:

Recalling[1] that one line-pair is 2 TV lines, and the television industry custom of rating vidicons in "TV lines/picture height," we have for a 3:4 raster, the relation,

$$N\ (\text{lp/mm}) = N(\text{TV})/1.2\ d\ .$$

Thus we can tabulate for a 1000-TV/ph line vidicon, the following resolution values:

	N (lp/mm)	
d_v (mm)	3 percent M.T.F	50 percent M.T.F
8	104	45
16	52	22
24	35	15

Recalling that a "1000-TV line vidicon" would typically have 3 percent MTF at the cut-off resolution values, the more meaningful values for 50 percent MTF at 430 TV lines/picture height for resolution are also tabulated.

d) Conclusions:

From the above considerations, we can conclude that a 1-inch vidicon capable of 1000 TV lines/picture height is preferable for the current application. Figure 6 shows the expected MTF in the object plane for the optical system, the 1000-line vidicon, and for the combined system.

The Chalnicon by Toshiba (available from Hammamatsu as vidicon N1453) has a high responsivity of 0.38 amp/watt at 4950Å. This vidicon is available in a medium-high resolution version, rated at 800 TV lines/picture height. However, the rating is very conservative. The rated MTF is 50 percent at 430 TV lines/picture height or 22 l.p./mm. Hence, this is the tube of choice.

The picture size of the vidicon tube planned for use with this system is 9.6 mm by 12.7 mm. At 9X reduction, this means that the largest spherical object that could be wholly encompassed in the field of view of a single picture is one with 1.067-mm diameter. However, the mechanical system can scan a 5-mm-diameter object field, and the optical system design provides good image quality over this field.

3. Optical Design Analysis

Relative to the various design approaches considered, we should first mention refractors vs reflectors. The trouble with refractors is, of course, secondary color. We have already mentioned what we consider to be a fairly severe limitation on the permissible wavelength band given by the resolution requirement. This alone makes an all-reflector system much less attractive than it would be for a non-imaging requirement, for example. Further, the configurational constraints (the system must fit totally inside a 7 1/2-inch-diameter pipe) militates against an all-reflector system, because such a system would necessarily have a central obscuration of the pupil.

A system using some refractory elements and some reflecting elements was also considered. A refracting element would be placed as close to the object as possible to gather light from the object at the largest possible numerical aperture. This element would then feed light to a reflector system in some way, possibly with other refractor elements, to provide the required 9X magnification and the required overall length. This is a feasible approach, but it presents a very small advantage with regard to secondary spectrum because most of the power in the system must be put in the first refracting element. Further, the reflecting elements introduce higher light losses and also have an obscuration in the pupil. The disadvantages of this system, particularly its extra complexity, are substantial, and the advantages marginal. so we ruled it out.

An all-refracting system was selected. If all of the power in such a system is concentrated at one group of lenses near the window at the closest allowable distance from the object, we do not get anywhere near the required 9X magnification. It is necessary to use a "telephoto" approach to get -9X linear magnification in the space given.

Our design consists of a cemented doublet of 1425.8-mm focal length located approximately one meter from the object. This doublet does not quite collimate the light and is followed by a second cemented doublet of 1613.9-mm focal length. This second doublet strongly converges the light toward the telephoto element which weakens the convergence of the light to that required for 9X magnification and the desired image location.

We now examine the matter of secondary color using what we consider to be the preferred design approach. We do not consider it practical to use an apochromat approach. It requires three different glass types, at least one of which must be "unusual" and consequently costly, and the individual element powers are much larger than for achromatic correction wit. consequent increase in spherochromatism (unless one of the glasses is very unusual and very expensive, fluorite for example, and not at all practical for a large diameter system).

If consideration of performance and cost turn us away from full apochromatic correction, then the only advantage of partial apochromatic correction - such as would be provided by the use of an unusual glass, a short flint, or a phosphate crown, in a simple doublet - would be to allow a somewhat larger bandwidth region for illumination and imaging. The secondary color expressed as a wave aberration varies as the fourth power of the wavelength difference from the design wavelength. If a certain wave aberration specifies the allowable limit of secondary color, then if we halve the value of the secondary color by using a special glass, we could increase the spectral bandwidth of our system by only 19 percent. This hardly seems worth it. We have, therefore, chosen to use common glasses in our design.

The question of the usable wavelength band is estimated by the following calculations. For a diffraction limited system, the secondary color expressed as a wave aberration varies with wavelength as the fourth power of wavelength difference from the design wavelength,

$$P(\lambda) = a(\lambda - 4950)^4 \text{ wavelengths} \quad .$$

We will show later the performance data on our system, and at λ=4750Å and λ=5150Å, the secondary color is approximately 1/2 wavelength. The MTF for many incremental wavelength bands is found by adding the responses (averaging) for each small interval,

$$\bar{M} = \frac{1}{\lambda_1 - \lambda_0} \int_{\lambda_0}^{\lambda_1} M(\lambda)\, d\lambda \quad .$$

Secondary color is a defect of focus, and the MTF for an out-of-focus condition varies at six-tenths of cutoff approximately as

$$M(\lambda) = .29 - P^2(\lambda), \; P \text{ in wavelengths} \quad .$$

This is not a derived formula, it is merely estimated from published graphs of the MTF of a perfect system with focus error in varying amounts. We may then write:

$$P(\lambda) = .29 - (3.125 \times 10^{-10}) (\lambda - 4950)^4$$

$$\bar{M} = \frac{1}{(\lambda^* - 4950)} \int_{4950}^{\lambda^*} [.29 - (9.766 \times 10^{-20} (\lambda - 4950)^8] \, d\lambda$$

$$= .29 - (1.085 \times 10^{-20}) (\lambda - 4950)^8 \quad .$$

If we allow our system to be degraded by secondary color to 0.8 of its theoretical maximum, i.e. to 0.23, then we find λ = 220Å ; or, since we have approximate symmetry of these arguments around the design wavelength, a 440Å band is acceptable. Using all the same approximations, a spectral bandwidth of 370Å would degrade the performance of the system only to .95 of its theoretical maximum, truly negligible.

4. Illumination requirements

It is necessary to design the system in order to have the data for a reasonable lamp choice, condenser design, and illumination calculations. The aperture stop of our system is located at the surface of the lens element nearest the object. The exit pupil of the system (also the entrance pupil, at least for the illumination system) is located 1497 mm from the image (vidicon target) and has a diameter of 24 mm. This must be filled with light, as must a 45-mm-diameter plane at the image. The condenser system is placed in the vicinity of the image point (actually a point conjugate to the image with respect to a beam splitter plane mirror), and an image of the light source formed at the pupil in the conventional manner for projectors. We want to avoid very large magnifications for the condenser system, and yet we must have a very high radiance source - incompatible requirements. We have selected an Osram short-arc xenon lamp of 450 W rated power. The average luminance is given as 350 cd/mm^2 and the arc size as 0.9 by 2.7 mm. We use only about 2/3 the length of the arc alongside itself to yield an effective source size of about 1.8 mm diameter. This requires condensers giving 13 1/3 times magnification. We were unable to find a stock condenser system which was sufficiently well corrected for the necessary conjugates. A two-element pyrex condenser was designed for this purpose.

We have estimated the radiance of the lamp that we selected by using the average luminance figure given by OSRAM, 350 cd/mm^2 and performing a numerical integration to arrive at a radiance figure for the arc within the visible spectral band. The xenon arc has a relatively constant radiance per unit spectral band throughout its entire emission band. What we did with this numerical interpretation was to estimate the value of this constant. Within our 440A region we estimate the average raniance of the arc to be 20 W/cm^{2}sr. Our actual source consists of the arc and an image of the arc. The image of the arc cannot be as bright as the arc because of reflection losses and because of self absorption effects. It may be 60 percent as bright, so our net average radiance figure for the source is 16 W/cm^{2}sr. On the way to the target we estimate the losses as follows: the condensers have four air-to-glass surfaces which we assume to be coated with single-layer MgF_2 anti-reflection coatings, 0.9224 transmittance. A dielectric beam splitter has 0.5 reflectance The elements of our telescope system have high efficiency coatings, and there are eight air-to-glass surfaces, 0.9607 transmittance. The net transmittance of the system illuminating the object is 0.44. The numerical aperture at the object is .09, so the irradiance of the object by the illuminating system is

$$\pi * (.09)^2 * .44 * 16 = 0.18 \text{ W/cm}^2 \quad .$$

The reflectance of the object we have taken as .05, so the radiance of the object is (if we pretend it is a plane surface) is

$$0.18/\pi * .05 = .0029 \text{ W/cm}^2\text{sr} \quad .$$

Coming back through the system, we have the same eight air-to-glass surfaces with 0.9607 transmittance, the dielectric beam splitter with 0.5 transmittance, a second beam splitter for the reticle projectors with 0.96 transmittance, and a band-pass filter with 0.8 transmittance. The net transmittance is 0.37. The numerical aperture at the Hamamatsu N1453 vidicon is .01, so the irradiance of the target is

$$\pi * (.01)^2 * .37 * 0.0029 = 337 \times 10^{-9} \text{ W/cm}^2 \quad .$$

380157

tivity of the detector is .38 A/W in the spectral band of interest, so for a of 1.22 cm², the signal current will be 156 nA. This is well up on the er characteristic of the vidicon. It may be compared to a dark current of 1 slow the "typical" operating characteristics of 200 nA.

iance requirement was also calculated in a separate fashion. At the limiting MTF = .03 to .05 typically. Here, the SNR (signal to noise ratio, > 1.2. The idicon TV system is established by the video input system. A very good video have an equivalent noise input of about 6 nA. If SNR limiting = 1.2, then = 1.2 x 6 nA = 7.2 nA. Then, for MTF = 1.0, i_{sig} = $i_{limiting}$/.04 = 180 ire σ = .38 amp/watt, A = 1.22 cm² . Then

)-9 W/cm².

e that both methods result in values which are in reasonable agreement with

ierformance data

7 are shown the relationships between the design field (5 mm diameter at vidicon field (which can mechanically scan the design field), and the three for which ray-trace data are presented.

8 are shown the lens aberrations based upon ray-tracing. The data are for eld points mentioned and for the three wavelengths, 4750Å, 4960Å, and 5150Å. in the form of wave-aberration curves. It is reasonable to say that the aberration except secondary color and a small amount of primary color.

is calculated on the basis of three colors of light. A 370Å band centered at considered to be adequately represented by the data for λ = 4950Å. This was the previous section. Bands from 4730Å to 4765Å and from 5135Å to 5170Å were be sampled by data at wavelengths of 4750Å and 5150Å, respectively. The was weighted .84 and the other bands .08, corresponding to their respective n consideration of the constancy of the light source spectral content. The re calculated using D. S. Grey's "Quick MTF" features in his optics program.

shows the MTF amplitude at 200 mm⁻¹ for various focal positions. The solid to field point 1, the short-dash curve to the tangential response at field the long-dash curve to the tangential response field point 3.

shows the MTF calculated as described above. The full curve is for the axial dashed curve for the tangential field at field point 3 - the worst case.

l speculations

e nature of the entire "scene" that the 9X magnification system will be s been a matter of some concern. There are few natural objects with s low as 5 percent. This in itself is of no concern. We may still have a trast scene if the background has zero radiance and if the optical system has ight. An optical system with 5 percent veiling glare, however, is a fairly nd quite acceptable for most purposes. We know little about the background the 5 percent reflectance object is to be viewed, but from what we see overall configuration, the object is inside a body which may assume some of es of an integrating sphere into which a rather intense light is being must do all we can to minimize stray light within the optical system. If d is too bright, we will observe the object as dark against it, presumably. sume, in any event, that we will be dealing with a very low contrast target

ability of random, low-contrast detail by an optical system is proportional e" under the MTF solid. There may be studies relating the MTF of an optical e ability of a human to point the system at the center of a low-contrast e know of none. It is quite possible that an image fairly badly degraded by or can be centered in the field of view just as well as a much superior is true only if the low-contrast object remains easily detectable. We show an estimate of what the MTF would look like with a 750A bandpass filter. ight would still be contained in a good core, so there is still some response (probably really a bit less than shown because the reduced cutoff at longer as not been taken into account in the estimate given). This bandwidth would con signal current above the "typical" operating value, so there is no point g larger spectral bandwidths. It seems advisable to try two or three different filters under experimental trials to determine the best spectral bandwidth under the actual conditions of use. The range of spectral bandwidths within which an optimum may lie is roughly 440Å to 740Å, centered at λ = 4950Å.

In observing Figure 9, note that the response at 200 mm^{-1} has a fairly sharp peak, i.e. the depth-of-focus is rather small. This means rather fine focusing may be required, but not necessarily, since the object itself is spherical and has a depth that is many times the dept-of-focus of the optical system.

The 9X lens system, which is properly classifiable as a microscope objective, is shown diagrammatically in Figure 12, together with construction data.

The optical system

The entire system is shown schematically in Figure 13. Light from the 450-W xenon lamp is collected by condenser 3 and reflected by beamsplitter 4 through the 9X lens system to the target (not shown). After reflection from the target, the light returns through the 9X lens system, through beam splitters 4 and 12 and through the wave-band filter 13 to the vidicon.

Light from the xenon arc which passes through beam splitter 4, is diverted vertically upward by a mirror 5 into a light trap 6 of the type described by Breneman.[2]

A bright-line reticle 9 illuminated by lamp 7 and condenser 8 is imaged via mirror 10, lens 11, and beam splitter 12 onto the vidicon. The reticle mount is provided with means for centering the reticle. Mirror 10 and beam splitters 4 and 12 are held on flexure mounts to provide for ready alignment along both axes, and condenser 3 is arranged to allow axial movement for focusing.

Current status and results

The manufacture of the optical and video systems is complete. We have mocked up these systems in the laboratory, in the exact scale as they would be used in Antares, and found that the system has a resolution of 2 μm over the instantaneous field and works very close to the nominal design parameters. Figure 14 and 15 show the actual photographs of the optical video system in the laboratory mock-up.

Conclusions and future work

From our experiments, we have concluded that the electro-optical system works according to the design. We are in the process of manufacturing the mechanical parts needed and hope to do the mechanical integration in the next three months. We hope to install the whole system in the Antares laser in the next six months in time for the target shots.

Acknowledgements

We would like to thank A. Saxman, V. Zeigner, and J. Dewitt for their suggestions during various discussions about this project.

References

1. Rosell, F. A., "Television Camera Tube Performance Data and Calculations," in Photoelectronic Imaging Devices, H. Biberman and S. Nudelman, Eds. (Plenom Press, New York 1971) V.2 Chap. 22 p. 536.
2. Breneman, E.J., Applied Optics, 20, (7), 1118-1119, 1 April 1981.

380157

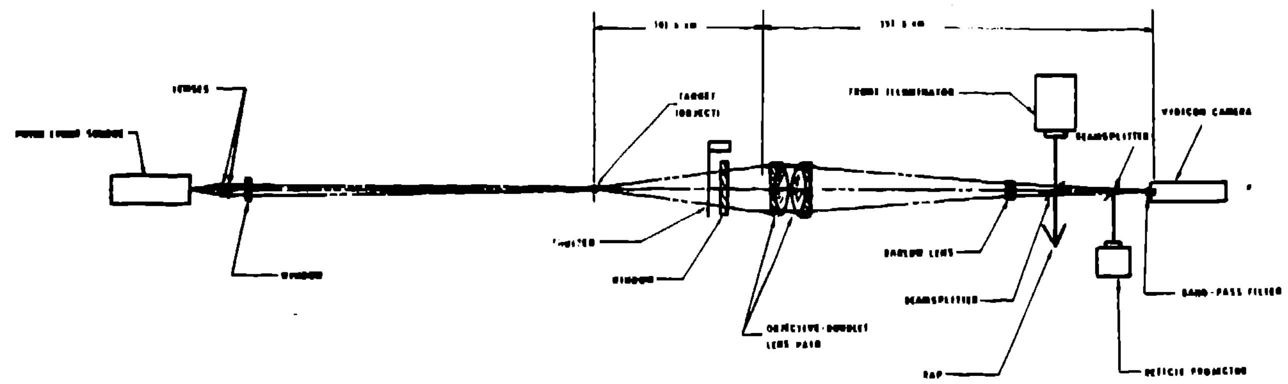

Fig. 1. Antares-Reference telescopes optical schematic

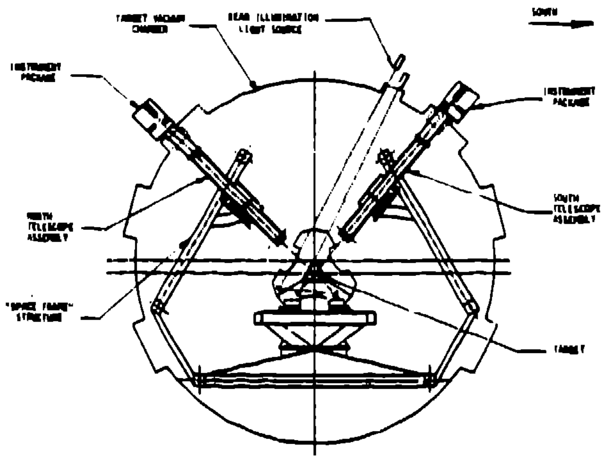

Fig. 2. Antares reference telescopes installation

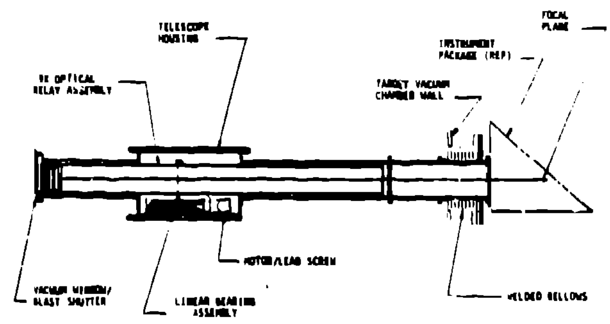

Fig. 3. Telescope assembly

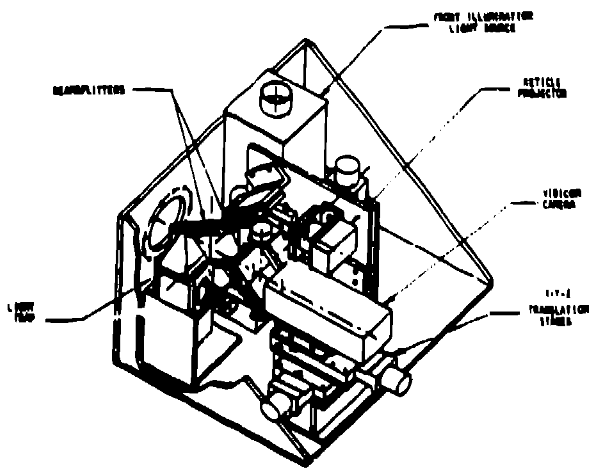

Fig. 4. Instrument package

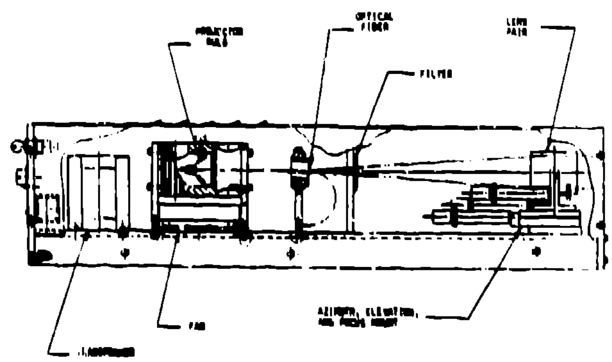

Fig. 5. Rear illumination light source

380157

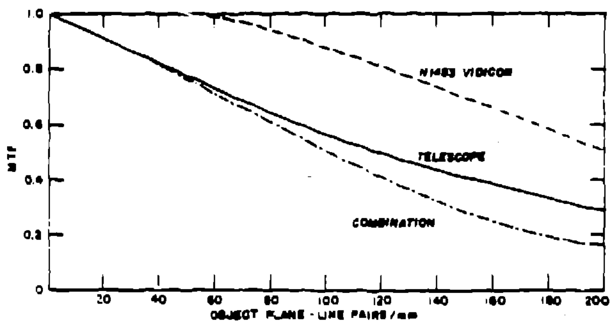

Fig. 6. M.T.F. of components and total system

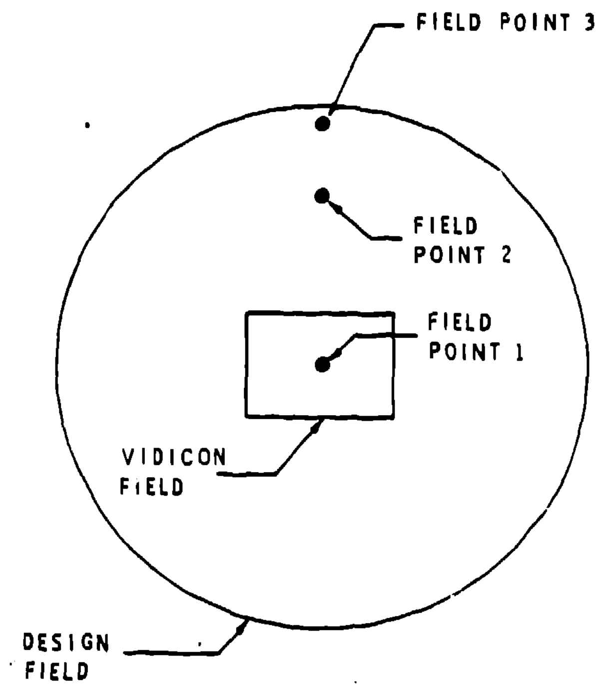

Fig. 7. Design Field/vidicon field relationship

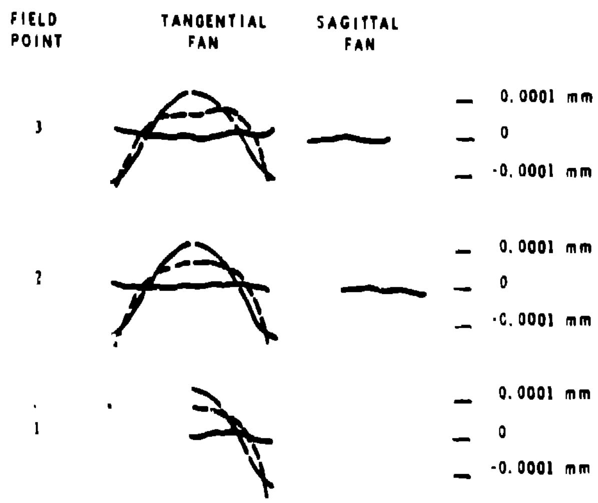

Fig. 8. Lens aberrations

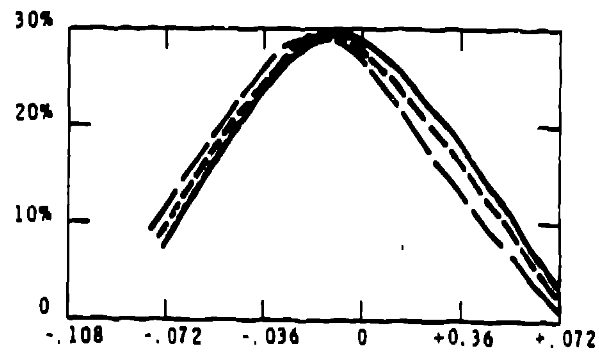

Fig. 9. Response at 200 mm through focus

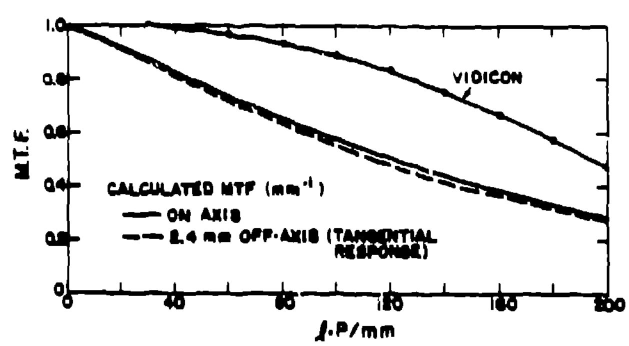

Fig. 10. M.T.F. calculations

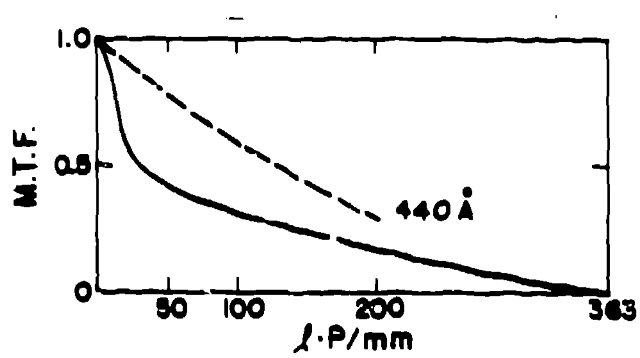

Fig. 11. M.T.F. with 740 Å bandpass filter

380157

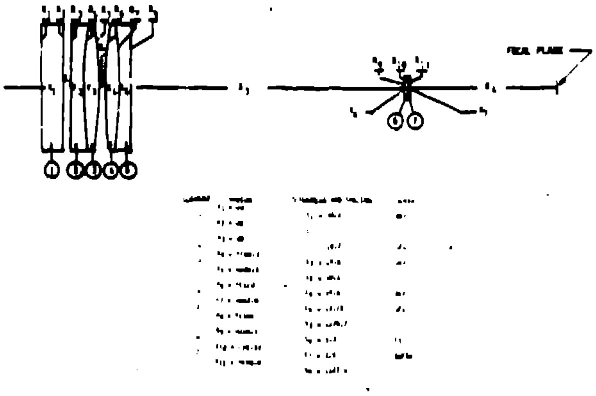

Fig. 12. Optical element definition

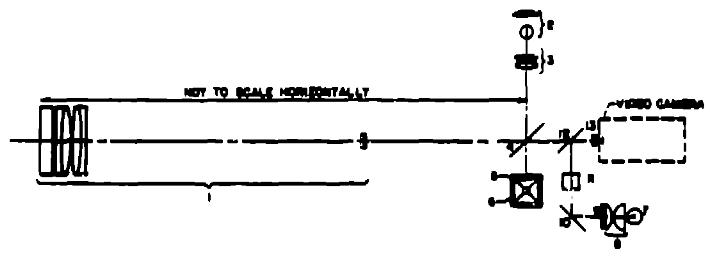

Fig. 13. The optical system

Fig. 14. Optical system

Fig. 15. Optical video system