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WAVEFRONT FOLDING INTERFEROMETER

By

Robert L. Whalen

Contract No. AF 19(628)-3314

Project No. 8663

FINAL REPORT

Period Covered: September 1, 1963 thru February 28, 1965

Date of Report: January 25, 1966

This research was sponsored by the Advanced Research Projects Agency, ARPA Order No. 450, Project Code No. 3720, Task 2

Prepared For:

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
OFFICE OF AEROSPACE RESEARCH
UNITED STATES AIR FORCE
BEDFORD, MASSACHUSETTS

Prepared By:

Block Engineering, Inc.
CAMBRIDGE 39, MASSACHUSETTS

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ABSTRACT

Results of a design study of a wavefront folding interferometer were applied to the fabrication of a prototype interferometer which was experimentally employed to make angular diameter measurements of missile re-entries. The interferometer, based on a modification to Lloyd's mirror, displays the space frequency Fourier transform, including both amplitude and phase, of an incoherently illuminated object. Because the wavefront folding interferometer provides a direct positional reference, this instrument was used in the field to provide a measure of both apparent angular diameter and tracking error. The field instrument consists of a 14 cm collector telescope, a wavefront folding interferometer, and an 8 mm camera to record the fringe pattern. During the experimental program carried out on the Pacific Missile Range, the interferometer was installed on a Roti optical tracking mount. Because of the extreme pointing sensitivity of the instrument and the relatively crude tracking provided, difficulties were encountered which would be absent with more accurate tracking. Use of the folding interferometer to measure the apparent diameter of a time varying source such as a re-entry body is deemed a promising technique worthy of further investigation.

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SECTION I

PRINCIPLES OF OPERATION OF THE WAVEFRONT FOLDING INTERFEROMETER

1.0 General Description

To understand the wavefront folding interferometer, first consider Lloyd's mirror, shown in figure 1. The mirror forms a virtual image of a monochromatic point source. The source and its image then generate interference fringes in regions of common illumination, as illustrated. White light may be used, in which case the fringes are visible only near the plane of the mirror where zero order interference is located.

The spacing of the fringes is inversely proportional to the separation of the source from its image.

If several point monochromatic sources are present each gives its own fringe pattern, with space frequency proportional to the distance from source to mirror. Consequently the fringe pattern is related to the pattern of sources by Fourier transformation. The recognition of this relation prompted improvement of Lloyd's mirror.

Lloyd's mirror tends to be awkward because the interesting phenomena occur near grazing incidence. Its utility, however, only depends on its being an interferometer with an even number of reflections in one beam (zero reflections in the direct beam) and an odd number of reflections in a second beam. Such a characteristic is equally accomplished by a Michelson interferometer with a roof mirror replacing the flat mirror in one arm. Disadvantages of this configuration are that the interesting fringes occur near the roof edge, and the roof must be an extremely accurate right angle.

Further pursuit led to the configuration shown in figure 2, and then to the 3-D configuration shown in figure 3, which accepts more divergent beams. All of these configurations tend to prefer polarized light or some sort of a retardation plate in one arm to assure superposition of the fringe patterns of the two polarizations. Otherwise the fringes appear with unnecessarily low contrast.

Representative images of star patterns as formed through the interferometer are illustrated in figure 4. The image plane is the normal image plane of the telescope objective. The images are doubled because the interferometer has two alternative paths. A dashed line is included as a line of symmetry, although such line is not actually visible in the image. Each star image has a conjugate image equidistant on the other side of the dashed line, but with a specific vertical displacement. Each star image is coherent with its conjugate and forms Young's fringes, which may be viewed in the exit pupil. If a star is left to drift through sequential positions 1 through 5 as seen in figure 5a, then the fringes pivot as in figure 5b. Note that the intercepts of the fringes with the dashed line of symmetry remain fixed.

If the star had been double, occupying positions 2 and 4 of figure 5a, then the superimposed fringes form a checkerboard pattern as in figure 6a. If the star has an appreciable diameter and lies in position 3, the superimposed fringe (of all parts of the star) appear as in figure 6b.

Now it may be noted that for any vertical section of the fringe pattern, somewhere along that vertical section will be a maximum of fringe contrast. That contrast is a measure of the space frequency image component, with space frequency proportional to the distance of the section from the dashed line. The vertical position of maximum contrast fringe on the section is a measure of the phase of the space frequency component. The phase is referred to the dashed line in the image plane.

Thus the interferometer performs amplitude and phase Fourier transformation of an incoherent image pattern in one fell swoop. The monochromaticity of the light need only be as much as the per cent resolution desired in the Fourier transform.

Inasmuch as the entire transform is presented in one observation, rather than a sequence of observations, the interferometer might be beneficial for multiple source measurements. The resolving power will not exceed that of the diffraction limit of the telescope objective. The folding interferometer, like the Michelson stellar interferometer, is not severely affected by seeing. The principal image disturbance caused by seeing is of a phase character, and so the fringes exhibit vertical wandering (except at the dashed line where they remain fixed) and seem to flap like the strips on a flag. Any vertical section of null contrast maintains a fixed position (in the horizontal direction) during atmospheric seeing.

The utility of the interferometer for multiple source measures would only be if the interferometer proved to have experimental facility. In view of Finsen's extensive measurements with his version of a Fizeau interferometer (a Michelson stellar interferometer without the periscopic arms)[1], the folding interferometer may offer no practical advantage.

One of the considerations on utility is limiting magnitude. Experimentally, fringes were readily visible on third magnitude stars with a 25 cm telescope. A 2.5 meter telescope would have one hundred times the light gathering power and so fringes of 8th magnitude stars should be equally visible.

In addition to the first three preprototype folding interferometers which were built, two were built during the course of this research; one was adaptable to the eyepiece mount of an available 25 cm Cassegrain telescope and the other was built for

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1. W.S. Finsen, Astron. J., 69, 319(1964).

use with a 14 cm lens and a motion picture camera. The latter system was used in the field and is described separately.

The investigation subsequently diverged on two tacks. One involved two dimensional transforms, and the other concerned faint objects.

1.1 Investigation of Two-Dimensional Transforms

The motive for investigating modifications of the wavefront folding concept which would permit two-dimensional transformations was simply to ascertain space frequency content of typical scenes, using incoherent light. It should be quite clear that if the interferometer is arranged so that one image is rotated 180° with respect to the other, then two dimensional transforms are presented in the exit pupil. Such an interferometer is equivalent to a Michelson interferometer with a cube corner mirror replacing one flat mirror. Alternatively, if roof-mirrors replace each of the flat mirrors of a Michelson interferometer, then with suitable orientations of the roof mirrors, the rotation angle need not be 180° between the images but may be any angle. This is basically a theta shearing interferometer as proposed by M. J. Block in a private communication in 1960 and described by Armitage (Sydney, Australia meeting on interferometry, August 1964). The motive for reducing the angle from 180° to some much smaller angle is that the scale of the Fourier transform may be thereby altered. For typical scenes, most of the space frequency content is at characteristically low frequencies, rather than at high space frequencies near the diffraction limit.

The design of theta-shearing interferometers tends to be rather awkward. It turns out that a far more elegant design is available for a radial shearing interferometer. If the image plane contains two coherent images of differing magnifications, then the exit pupil also gives the desired two-dimensional transform. In this case the transform is rotated 90° from that which would have been obtained by theta shearing. The rotation occurs because for radial shearing, the separation produced on an input point is radial, whereas, for theta-shearing, it is tangential. Consequently, the respective Young's fringes are at right angles to one another.

For lack of obvious motive, this diversion of two-dimensional transform was not pursued further. The second tack of the investigation is toward fainter sources.

1.2 Investigation of Faint Sources

All of the angular diameter interferometer configurations present very few photons at the output. The real thing that is needed is a legitimate averaging procedure. Straight summing of successive outputs on a photographic plate is not legitimate because the fringe pattern is shifting. However, the character recognition procedure described by Armitage and Lohmann[2] may be adapted. Clearly their "shift invariant pattern recognition" is appropriate since it permits shifts of the fringe patterns. It is nothing more than the Fraunhofer diffraction pattern. For adaption to our problem, we would take movies of the fringe pattern. Individual frames would expose imperceptible images on the film. For summation, the "illumination" system of a projector would be replaced by collimated light, and the Fraunhofer diffraction patterns exposed sequentially and additively on a photographic plate. If imperceptible fringe patterns are actually on the frames, then the fringe will act as a weak diffraction grating and ± first order diffracted spots will eventually rise above the scattered light.

Probably a Fizeau interferometer would be more simple and appropriate than a folding interferometer for this experiment. It is certainly simpler in that we only have a motion picture camera

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2. Armitage and A.W. Lohman, App. Opt., 4, 461(1965).

in the focal plane of a large telescope, and a mash with two small (10 cm dia.) apertures over the telescope entrance aperture. The Fizeau is more appropriate in that all the light employed (albeit less than the folding interferometer) is concentrated in a small spot, and that the fringe pattern results from only one space frequency in the object. Thus no separation or discriminating procedure need be employed in the fringe pattern recognizer.

1.3 Comparison of the Fizeau and Wavefront Folding Interferometers

A comparison of the wavefront folding and Fizeau interferometers is in order. Both are two beam interferometers which display the coherence of light impinging on two portions of the telescope objective. As such they have the same resolution capabilities and any comparison will depend on convenience for a particular application.

The wavefront folding interferometer has the advantage of looking at all space frequencies of the object simultaneously, rather then depending on a succession of measurements. The Fizeau interferometer may be modified with a V slit on the objective and a cylindrical lens to partake this advantage.

The wavefront folding interferometer displays phases of space frequencies as well as amplitudes, and so yields an absolute position reference. The slope of the fringes is proportional to the absolute lateral displacement of the object from the telescope axis. If the Fizeau is used carefully so that absolute fringe positions are obtained, perhaps with reference to a third beam, then it also may yield absolute position.

The Fizeau interferometer concentrates the light of the object into a small group of fringes. Consequently it may be easier to use with multiple objects without undue confusion. It also means that there is less extraneous light adjacent to the fringes which might confuse the measurement.

Neither interferometer seems particularly adapted to photoelectric readout, although it is probably slightly easier with the Fizeau (not modified to give simultaneous measurement or phase) because of the last advantage mentioned.

1.4 Utility for Re-Entry Measurements

The practical utility of the wavefront folding interferometer has been demonstrated with the previously mentioned instrument designed for field experiments. Because the wavefront folding interferometer provides a direct positional reference, this instrument was used in the field to provide a measure of both apparent angular diameter and tracking error. Because of the extreme pointing sensitivity of the instrument and the relatively crude tracking provided, difficulties were encountered which would be otherwise absent with sufficiently accurate tracking. A detailed description of the instrument and the experiments performed is contained in the following section.

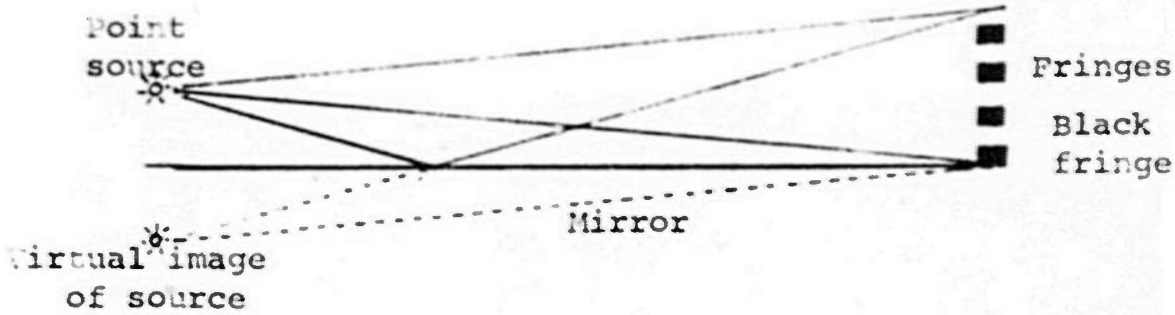


Figure 1 Lloyd's mirror.

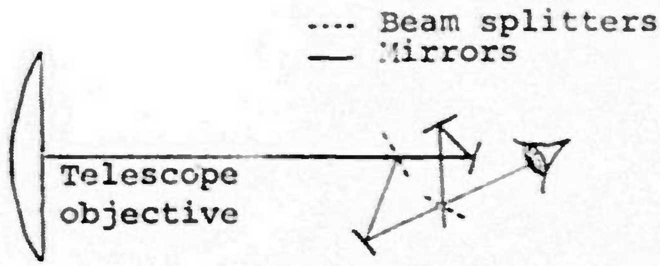


Figure 2 Wavefront folding interferometer.

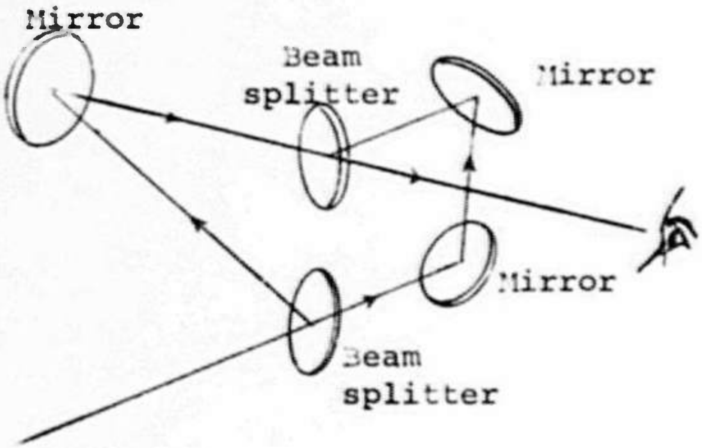


Figure 3 Wavefront folding interferometer.

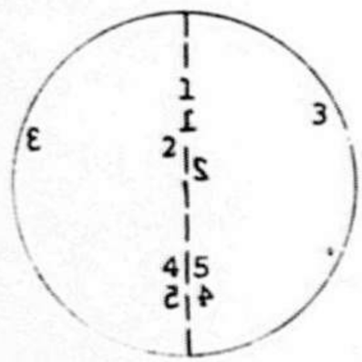


Figure 4 Image plane with reference-numbered star locations.

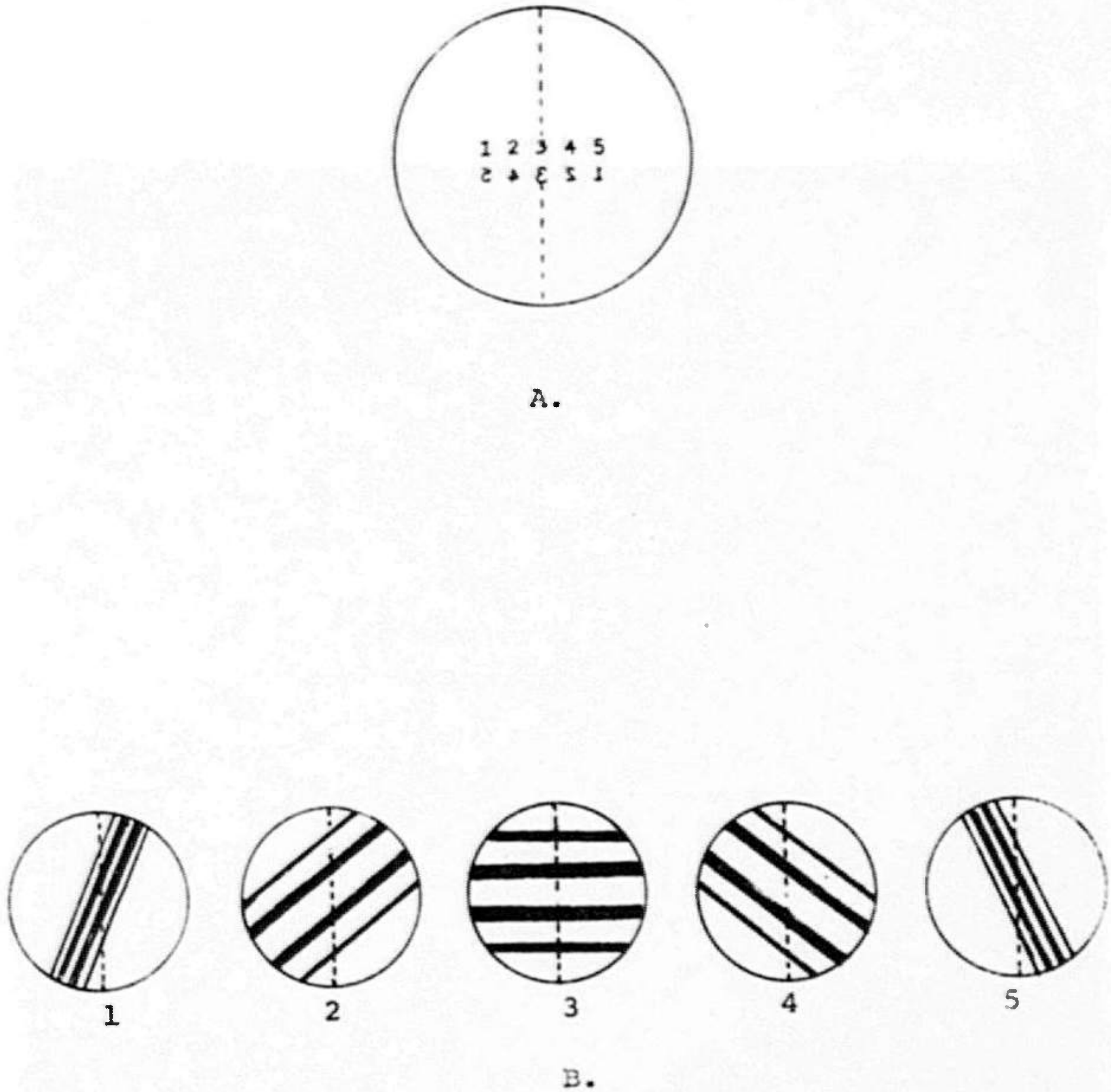


Figure 5 Fringes for sequential star positions.

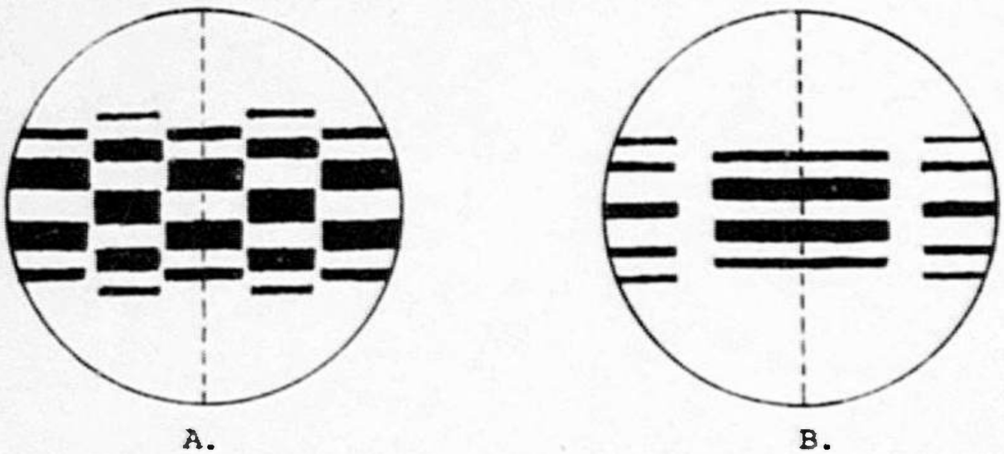


Figure 6 Fringe patterns in exit pupil.

SECTION II

FIELD MEASUREMENTS WITH A WAVEFRONT FOLDING INTERFEROMETER

2.0 Introduction

This section describes the prototype folding interferometer system developed for field use and the results of experiments performed with the instrument. Basically, the instrument consists of a 14 cm collector telescope, a wavefront folding interferometer of the 3-D configuration described in the preceding section, and an 8 mm camera to record the fringe pattern. In order to make the instrument reasonably portable and to facilitate its mounting on existing trackers, both its size and weight were restricted. The instrument is approximately 31 inches in length and weighs less than 40 pounds. The experimental program, carried out on the Pacific Missile Range, involved measuring the apparent angular projection of a re-entry body.

2.1 Description of the Instrumentation

A simplified optical diagram of the instrument is shown in figure 1. The 14 cm diameter objective lens was chosen as the collector by consideration of the typical diameters to be measured and of the expected source intensities. The re-entry bodies to be tracked were to range from 1 to 5 seconds of arc in apparent diameter. The minimum measurable diameter using a 14 cm collector is approximately 1.1 seconds of arc. The minimum diameter that can be measured with the folding interferometer is the diffraction limit of the collector used. It is given by the expression $\delta_d = \frac{1.22\lambda}{D}$, where δ_d is measured in radians, λ is the average wavelength of the point source being observed, and D is the diameter of the collector. Use of the 14 cm collector was to result in fringes which would extend over a large part of the collector for a typical source.

Moreover, since the re-entry bodies to be observed were to be at least of first magnitude on the stellar brightness scale, the lens was adequate as an energy collector.

Placed behind the focal point of the collector at a distance equal to its own focal length is a small transfer lens which essentially re-collimates the incoming light. (Since fringes may be formed only from sources which subtend extremely small angles, one may think of the light arriving at the collector as being collimated). The clear aperture of the interferometer determines the focal length of the transfer lens since the lens must work at the same focal ratio as the collector. While it is not necessary that the transfer lens exactly re-collimate the light to be passed through the interferometer, significant distortions of the fringe pattern will occur if the beam passing through the interferometer is converging at a rate faster than f 15. The explanation for this effect is quite simple; it is caused by astigmatism due to the finite thickness of the beamsplitter substrates. It is interesting to note that since the collector and transfer lenses are used essentially on axis, any optical aberrations of these components - even axially symmetric aberrations such as longitudinal spherical - are of little concern.

There are two outputs emerging from the second beamsplitter of the interferometer. One of these is used by the viewfinder system which consists of a small low power telescope. The telescope may be focused at infinity so that the field-of-view is imaged sharply; or it may be slightly defocused so that one sees the collector lens illuminated by the source being observed. In this way one may observe the fringes formed by the interferometer. By varying the focus of the viewfinder one may control the apparent size of the collector, a great aid in compensating for different source intensities.

The other output from the interferometer passes through the lens of the 8mm movie camera used to record the fringe patterns. One could, by the choice of an appropriate transfer lens, eliminate the need for the camera lens; but this lens does serve a useful function, since it may be used to control the size of the image on the film. It must be remembered that the image on the film is that of the illuminated collector and not the sharply imaged source. For this reason, it is meaningless to describe this particular optical system in terms of a focal ratio. The image size, and thus the flux density of energy on the film may be changed optically at two locations in the system. Aside from adjustment of the framing rate of the camera, the photographic speed of the system is, of course, increased. While film graininess establishes the limit beyond which the film resolution is inadequate, it may be shown that the quantum efficiency is greater when using a fast (and thus coarse grained) film than when a slow, fine grain film is used.

2.2 Method of Data Interpretation

Interpretation of data from the folding interferometer is very straight-forward. The fringes appear to pivot about the axis of folding of the interferometer, being normal to the axis of folding when the source is on the optical axis of the collector. Shown in figure 2 is the appearance of the fringes for a point source which can be resolved, located slightly off-axis. The extent of the fringes across the image is inversely proportional to the apparent angular diameter of the source. The angle of tilt of the fringes about the axis of folding is a measure of the absolute error in the pointing of the instrument. Since there is no way of resolving the pointing error into components, it is impossible to fix the exact position of the source within the field of view; one can determine only that it was in a certain angular displacement from the optical axis. The appropriate formulas for calculating the apparent angular diameter of the source and the pointing error are given also in Figure 2. The four quantities which must be measured on the film are seen to be the diameter of the image, the extent of the fringes, the separation of the fringes, and the tilt of the fringes measured from the axis of folding of the interferometer. For a source which does not change radically in diameter, only the tilt and extent of the fringes need be measured on every frame since the other quantities will remain constant within the error of the measurement. In the experiments to be described, these measurements on the film were made using a traversing microscope and appropriate reticles.

The chief problem in using a folding interferometer to measure the angular diameter of a re-entry body is the required tracking accuracy. This is the result of two factors: the narrow useful field of view of the interferometer (about 1.5 minutes of arc for typical diameters encountered); and the tilting of the fringes as the pointing error of the instrument changes as a function of time. The former means simply that if the source is not within that narrow field, no fringes will be formed. The latter is a more subtle limitation since it implies that not only will the chances of successfully using the instrument depend on the maximum value of the pointing error, but also on the rate of change of error. That is, while it may be quite possible to keep the source within a small pointing error, it may still be impossible to record the fringes if the source is moving around in the field of view rapidly enough. In the extreme case, the fringes can tilt through 180 degrees during a given photographic exposure. The only possible procedure to compensate for this behavior of the fringe pattern is obvious: the camera should be run at as great a framing rate as the intensity of the source will allow.

2.3 The Experimental Program

During the experimental program carried out on the Pacific Missile Range, the interferometer was installed on a Perkin-Elmer Roti optical tracking mount. This tracker is located on Roi-Namur, Marshall Islands, and is operated by Lincoln Laboratory as a part of Project PRESS. The Roti is part of an integrated system for tracking re-entry vehicles and satellites. During a re-entry the PRESS radar system identifies the object to be tracked and produces a data file on the observed trajectory which is used by a 7090 computer to plot the re-entry trajectory for the Roti. For use in the late stages of re-entry when the object being tracked is below 100K feet, at which time it may deviate from the programmed trajectory, a manual override is provided for two operators whose function is to turn on all photographic systems and keep the re-entry body within the field of view. The manual override system, in fact, makes it difficult to evaluate the performance of an instrument as sensitive to tracking errors as a folding interferometer, since the present system would begin to record the re-entry only when the object being tracked came below a certain altitude (usually 90K feet) when the brightness would increase by orders of magnitude as denser layers of the atmosphere were encountered. On some re-entries, particularly those when the re-entering body is within 35 miles of the Roti, the manual override is almost invariably used. For more distant re-enteries, however, the override is seldom necessary. This is equivalent to saying that the Roti system performs satisfactorily for the latter case, often inadequately in the former. The explanation for this behavior of the mount is, of course, related to the apparent angular velocity of the re-entry body. Moreover, since the Roti follows the re-entry body by means of a step function in altitude and azimuth, there is considerable jitter in the tracking of fast moving targets (close re-enteries) which causes extremely fast tilting of the fringe pattern. At worst, the jitter is a randomly directed motion of approximately 1 minute of arc over a 1/30 second time interval. For many of the re-entry bodies it was planned to observe, one may determine that the fringes would tilt through more than 160 degrees during this 1/30 second period, making successful photography of the pattern virtually impossible.

The first re-entry observed with the folding interferometer was one in which splash down was approximately 30 miles from the Roti. When the film from the interferometer was developed, it was evident that the trackIng had been grossly inadequate. Shown in figure 3 is a plot of the tracking error on this particular re-entry as measured from the interferometer film. The interferometer shears two views of the collector lens, one travelling through an alternate path having an additional reflection. Looking into the system one sees double images which move at 45° to each other as the pointing of the system is changed. When a point source such as a star is brought on the optical axis of the collector, its images will coincide and both will be in the center of the field of view. Fringes will extend across the illuminated collector normal to the axis of folding. If the pointing of the instrument is slightly changed, the fringes will begin to tilt about the axis of folding, approaching as a limit the direction of this axis at which time they become narrow and eventually disappear. Visually the fringes can no longer be resolved when the centers of the images of the collector illuminated by the source are displaced from each other by some small fraction of their individual diameter. In figure 3, the vertical axis is the measured center to center distance (ΔCC) of the image pairs of the collector expressed in terms of an image diameter. Shown near the bottom of the graph is the approximate line of fringe visibility. Fringes might have been visible on any image pair whose displacement was below that limit. Each data point in Fugure 3 represents one frame on the interferometer film, and it may be seen that fringes were possible on five frames. Unfortunately, the pointing error was changing so rapidly that the fringes were tilting through large angles during each exposure and were not recorded on the film. It is obvious that the probability of obtaining diametric information with tracking this poor is very small.

Significantly better tracking by the Roti system is possible, however, when the re-entry takes place at a distance greater than 60 miles. Both the total apparent angular path and the apparent angular velocity for a re-entry under this condition are less. Also, there is very little jitter of the mounting since the track consists primarily of motion of only one axis, namely slowly decreasing elevation. In terms of tracking capability, this type of re-entry represents the ideal case for making diametric measurements with the folding interferometer. The disadvantage of distant re-entries is that for the present instrument, only the brighter re-entry bodies can be recorded.

Tracking data from a re-entry in which splash down was between 60 and 70 miles from the Roti is shown in Figure 4. The film from which this data was taken contained 46 consecutive frames with well defined fringes. The fringe tilt as a function of time given in Figure 4 may be used to calculate the absolute pointing of tracking error. The maximum absolute pointing error corresponding to those times when the fringes had tilted 75° was 21.8 seconds of arc. The tracking error of the Roti for this re-entry is in sharp contrast to that shown in Figure 3, where it was not possible to calculate the absolute values. It is safe to assume that there is at least an order of magnitude difference in the relative accuracy of the tracking for these two experiments.

The diametric data from the successful film is plotted in Figure 5. There seems to be a cyclic variation in the apparent diameter with a period of approximately 0.5 second. The effect is caused by tumbling of the re-entry vehicle. While the Roti was programmed to follow a decoy vehicle during this re-entry, the object recorded by the interferometer is more likely the primary nose cone. Later re-entries have demonstrated, in fact, that most secondary type vehicles are much too dim to be recorded by the present instrument.

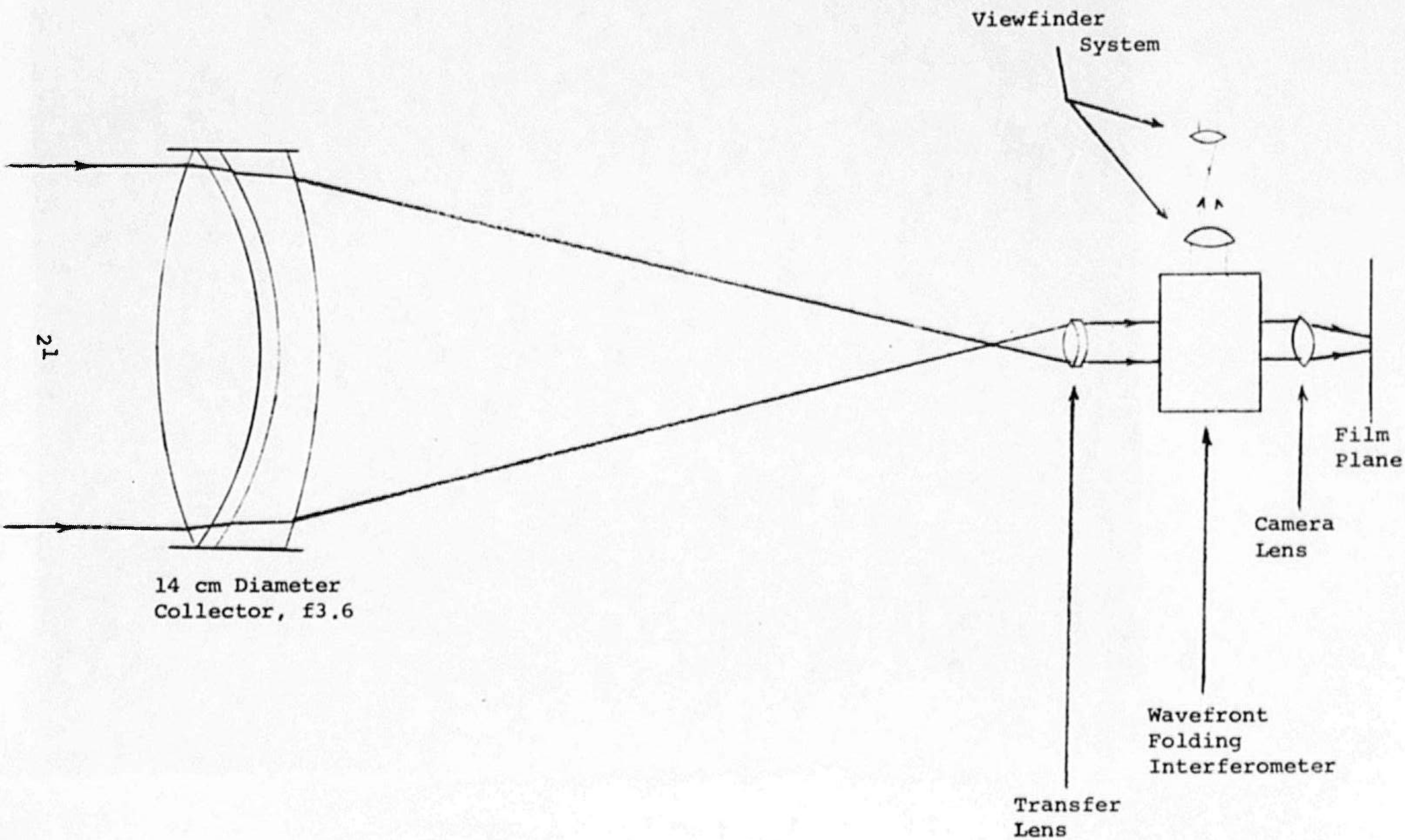
2.4 Photographic Exposure

The problem of correct photographic exposure is not an unsurmountable problem even with the present instrument. Films recently received from Kwajalein of operations carried out during November, 1965 show that there is adequate energy during the brighter portions of re-entry to produce acceptable images with framing rates as high as 32 frames per second. The film from PRESS TEST 1077, for example, contains an intermittent series of images, some of which are considerably over-exposed indicating it is probably possible to use even shorter exposure times. Unfortunately, the adjustment of the instrument has not been checked in the last year and one-half; and, it is apparent from these recently received films that there is a large error in the bore-sighting of the instrument. Here again, the high sensitivity of the interferometer to pointing errors which is an advantage in measuring the exactness of the tracking means that the bore-sighting, just as the tracking during a re-entry, must be exact. It is quite easy to adjust the bore-sighting within five (5) seconds of arc, but this adjustment must, of course, be repeated if the instrument is moved in any way. It is obvious that the instrument at Kwajalein has changed in position since the bore-sighting was last adjusted as the error as estimated from the recently received films is quite large, perhaps as great as five (5) minutes of arc.

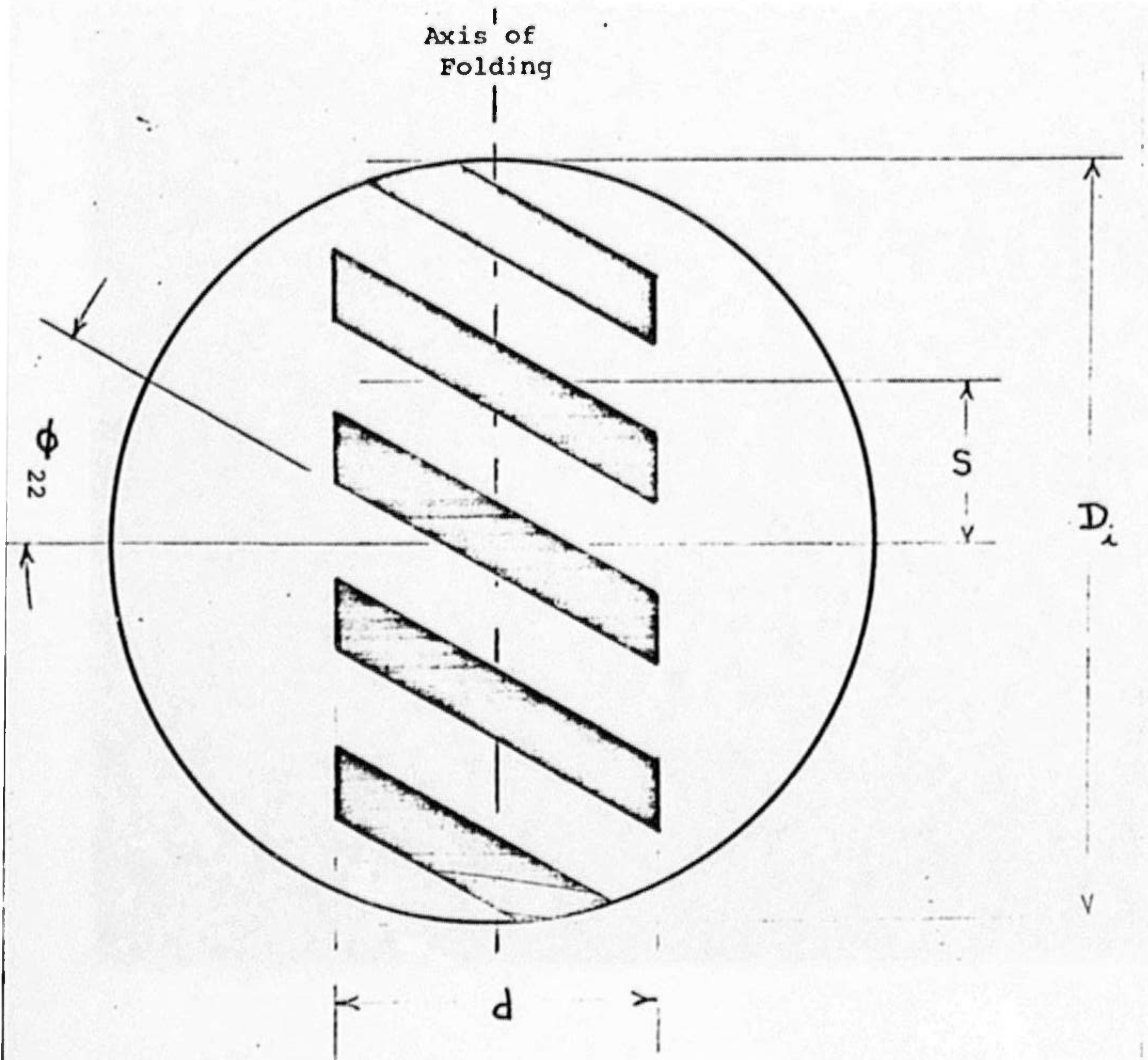
2.5 Conclusions

The results from these two experiments demonstrate the difficulties encountered in trying to use the interferometer with poor tracking as well as the measuring capabilities of the interferometer when the tracking is adequate. There are a number of steps possible to increase the chances of obtaining data when the tracking is less than ideal. If the photographic speed of the system were vastly increased, for example, the fringes could be photographed at rates in excess of 100 frames per second; and intermittent data would be obtained when the object being tracked passed through the field of view. Of course, with adequate tracking - tracking not beyond the capabilities of certain existing systems - the use of the folding interferometer to measure the apparent diameter of a time varying source such as a re-entry body is a promising technique certainly worthy of further investigation.

SIMPLIFIED OPTICAL DIAGRAM OF THE PROTOTYPE FIELD INSTRUMENT



APPEARANCE OF A TYPICAL FRINGE PATTERN OF A FOLDING INTERFEROMETER



Diameter:

$$\delta = \frac{d}{D_i} \quad \frac{1.22\,\lambda}{D}$$

Pointing Error:

$$\text{Abs. error (radians)} = \frac{D_i}{S} \quad \frac{1.22\,\lambda}{D} \quad \text{Tan}\,\phi$$

δ = angular diameter of source in radians

D = diameter of collector

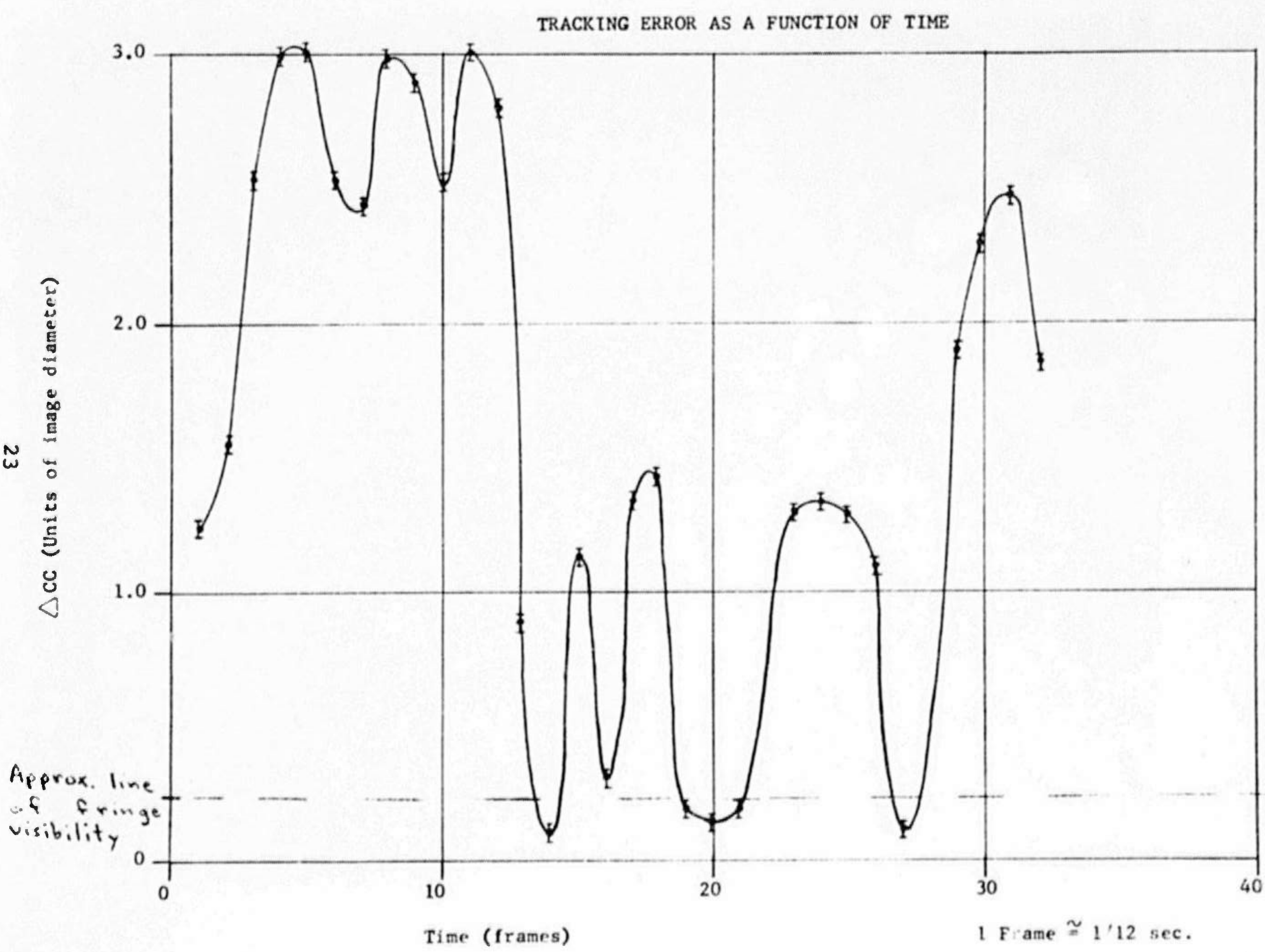
D_i = diameter of image on film

d = extent of fringes

S = spacing of fringes along axis of folding

λ = average wavelength of the source

ϕ = tilt of the fringes measured from the normal to the axis of folding


TRACKING ERROR AS A FUNCTION OF TIME
$\triangle$CC (Units of image diameter)
3.0
2.0
1.0
0
Approx. line of fringe visibility
0
10
20
30
40
Time (frames)
1 Frame ≅ 1/12 sec.

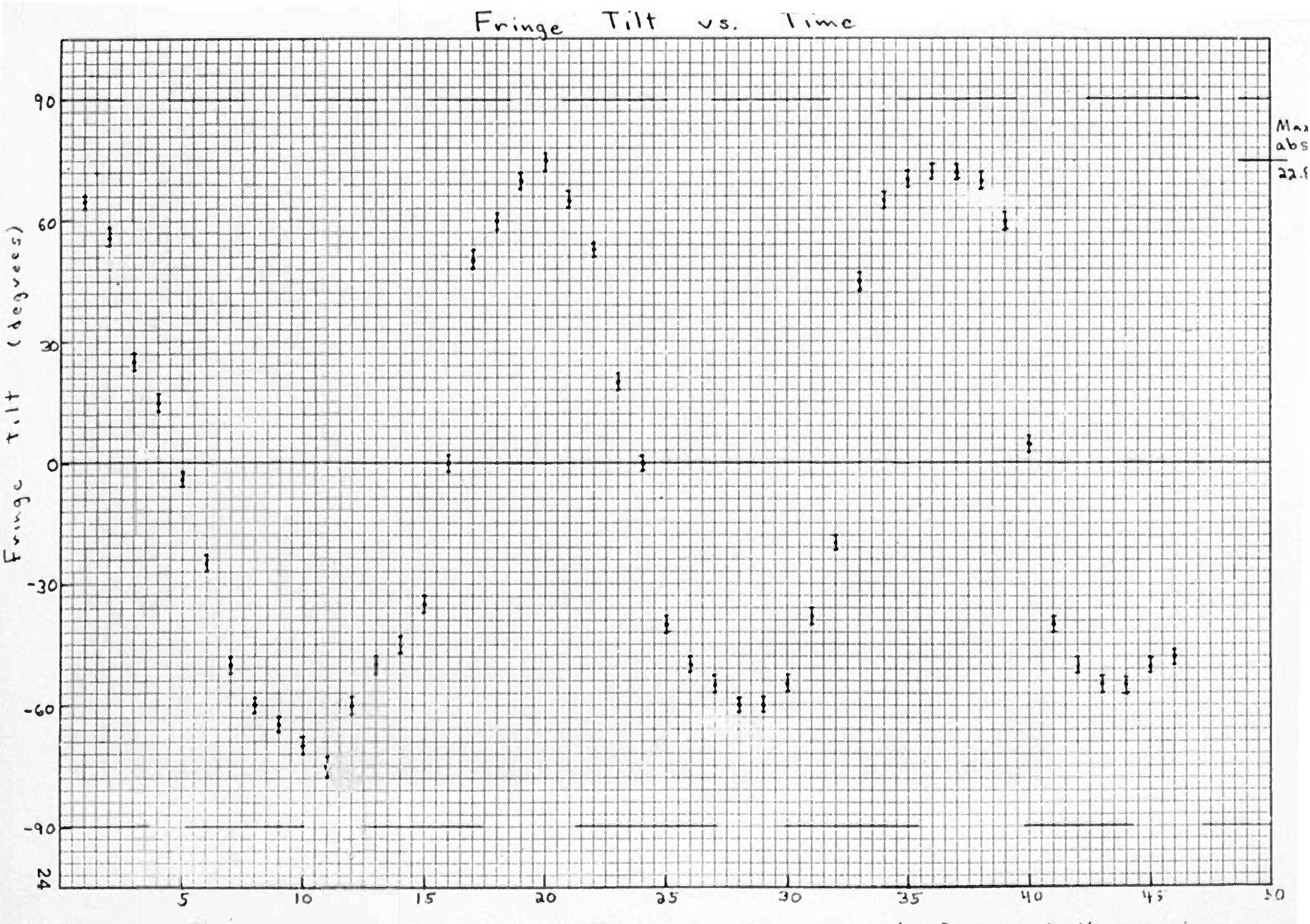

Fringe Tilt vs. Time
Fringe Tilt (degrees)
90
60
30
0
-30
-60
-90
24
5
10
15
20
25
30
35
40
45
50
Time in Frames (1 frame ≅ 1/24 second)

Figure 4

Angular Diameter vs. Time

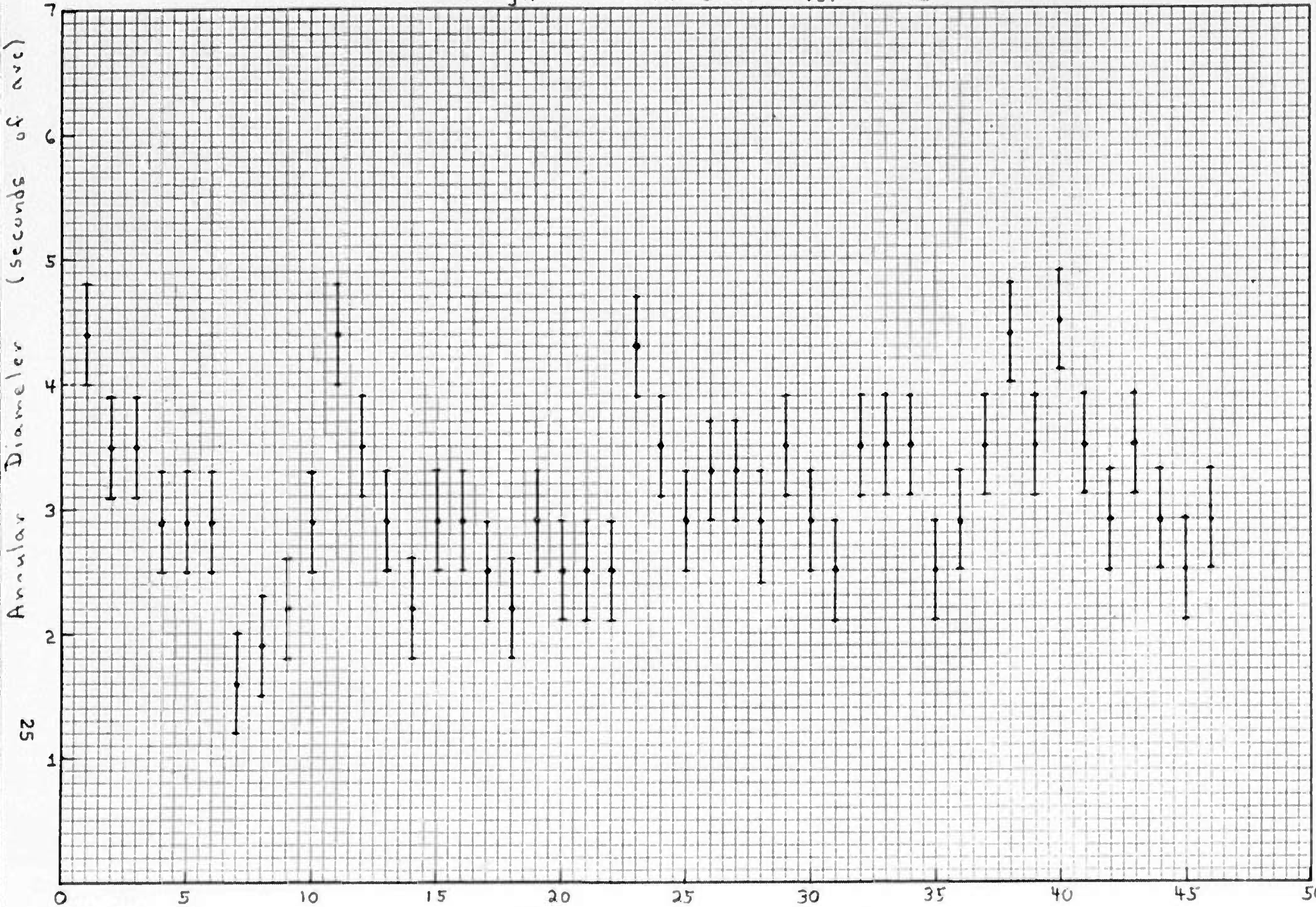


Figure 5

The work reported under this contract was primarily the contribution of Robert L. Whalen and Lawrence Mertz.

OTHER PUBLICATIONS UNDER SUBJECT CONTRACT

1. Quarterly Report #1 - Folding Interferometer, by L. Mertz, December 31, 1963
2. Quarterly Report #2 - Folding Interferometer, by L. Mertz, April 4, 1964
3. Quarterly Report #3 - Folding Interferometer, by L. Mertz, May 28, 1964
4. Quarterly Report #4 - Folding Interferometer, by R.L. Whalen, October 2, 1964

BLOCK ENGINEERING, INC.
19 Blackstone Street
Cambridge, Massachusetts

9 June 1966

Defense Documentation Center (DDC)
Cameron Station
Alexandria, Virginia 22314

Subject: Contract No. AF19(628)-3314, Final Report
Dated 1/25/66

Gentlemen:

ERRATA

There is a typographical error on the cover and on the DD Form 1473 of the subject report. The project code should read 3730 in lieu of 3720.

Very truly yours,

BLOCK ENGINEERING, INC.

John J. Theall
Contract Administrator

JJT/ces

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

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3. REPORT TITLE

"Wavefront Folding Interferometer"

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13. ABSTRACT

Results of a design study of a wavefront folding interferometer were applied to the fabrication of a prototype interferometer which was experimentally employed to make angular diameter measurements of missile re-entries. The interferometer, based on a modification to Lloyd's mirror, displays the space frequency Fourier transform, including both amplitude and phase, of an incoherently illuminated object. Because the wavefront folding interferometer provides a direct positional reference, this instrument was used in the field to provide a measure of both apparent angular diameter and tracking error. The field instrument consists of a 14 cm collector telescope, a wavefront folding interferometer, and an 8 mm camera to record the fringe pattern. During the experimental program carried out on the Pacific Missile Range, the interferometer was installed on a Roti optical tracking mount. Because of the extreme pointing sensitivity of the instrument and the relatively crude tracking provided, difficulties were encountered which would be absent with more accurate tracking. Use of the folding interferometer to measure the apparent diameter of a time varying source such as a re-entry body is deemed a promising technique worthy of further investigation.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
1. Wavefront Folding Interferometer						
2. Re-entry Measurements						
a) Apparent Angular Diameter						
b) Tracking Error						

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