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PHASE-COHERENT ASTROMETRIC INTERFEROMETRY(U)
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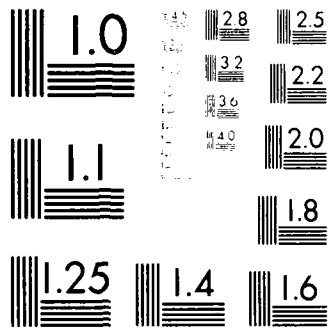
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ANNUAL REPORT

Phase-Coherent Astrometric Interferometry

Naval Research Laboratory

Contract N00014-86-C-2114

Covering the period

1 February 1986 - 31 January 1987

Submitted by

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Work by D. H. Staelin and his collaborators is summarized here.			
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Another effort involved expansion of the system for use with 3 siderostats: this included expansion of the system state description and interfacing the system with the various computers, communication channels, and related system elements. The fringe-tracking and star-tracking logic was also improved and expanded as part of this effort, and documentation for the siderostat system was greatly improved.

Additional tasks performed in the development of the laser siderostat system involved electrical design and construction, optical and mechanical design and construction, theoretical studies related to optimum estimation of siderostat pointing parameters, and related system software development. A complete vacuum system was also designed, assembled, and shipped to Mount Wilson Observatory; it services both delay line vacuum tanks.

Four papers were prepared for publication during this period. Abstracts for these manuscripts are attached; these manuscripts include:

- 1) "Application of Interferometry to Optical Astrometry," M. Shao, M. Colavita, D. H. Staelin, K. J. Johnston, R. S. Simon, J. A. Hughes, and J. L. Hershey.
- 2) "The Mark III Stellar Interferometer," M. Shao, M. M. Colavita, B. E. Hines, D. H. Staelin, D. J. Hutter, K. J. Johnston, D. Mozurkewich, R. S. Simon, J. L. Hershey, J. A. Hughes, and G. H. Kaplan, submitted to Astronomy and Astrophysics, May 1987.
- 3) "Atmospheric Phase Measurements with the Mark III Stellar Interferometer," M. M. Colavita, M. Shao, and D. H. Staelin, submitted to Applied Optics, June 1987.
- 4) "The Two-Color Method for Optical Astrometry: Theory and Preliminary Measurements with the Mark III Stellar Interferometer," M. M. Colavita, M. Shao, and D. H. Staelin, submitted to Applied Optics, June 1987.

APPLICATION OF INTERFEROMETRY TO OPTICAL ASTROMETRY

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ABSTRACT

An optical interferometer capable of tracking phase and measuring fringe visibility has demonstrated the ability to measure the precise positions of stars over large angles. This instrument has tracked phase over periods of many hours while switching sequentially among several stars. The 3.1 meter separation of the siderostats has been measured to an accuracy of 50 microns, indicating positional accuracies of three arc seconds. The formal error of the least-squares solution for the baselines is of the order of a micron. The major limitations to accuracy were thermal instabilities and unmonitored siderostat positions. With improvements this technique should be capable of astrometric accuracies exceeding one-hundredth of an arc second.

I. INTRODUCTION

Since Fizeau first pointed out the possibility of using interferometers in astronomy in 1862 (Muller), astronomers have sought to use interferometry to overcome the limits on optical resolution set by

The Mark III stellar interferometer

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Thesaurus codes

01.04.1 Astrometry

09.04.1 Interferometry

19.03.1 Seeing

19.30.1 Stars, Diameters of

09.03.1 Instruments

06.01.1 Fundamental Stars and Other Objects

Section: Instrumentation

Main Journal

Summary. The Mark III interferometer is an operational long baseline stellar interferometer on Mt. Wilson with four possible baseline configurations from 9 meters NE-SW to 20 meters N-S. The interferometer was designed to be a highly automated astronomical instrument to measure stellar positions and diameters to a magnitude limit of seven. Initial fringe observations were made in September 1986 with a 12-meter N-S baseline. In the following months, semi-automated astrometric and stellar diameter measurements were also made. This paper describes the hardware and software components of the instrument and its operational characteristics.

The interferometer has several novel features. One is the use of optimal estimation and control algorithms (e.g. Kalman filters) in the control loops. Another is the ability to operate both as a closed-loop phased interferometer and eventually as an open-loop or absolute coherent interferometer. High thermal stability and mechanical accuracy should permit the instrument to point blind at an astronomical object and maintain optical path equality to within the limits set by the atmosphere. In this absolute interferometric mode of operation, it should be possible to observe faint astronomical objects that are too dim for phase tracking. In theory, measurements of amplitude, group delay, and closure phase will be possible to 14 mag.

Key words: stellar interferometry, astrometry, stellar diameters, optical array, proper motion

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THE TWO-COLOR METHOD FOR OPTICAL ASTROMETRY:
THEORY AND PRELIMINARY MEASUREMENTS WITH THE
MARK III STELLAR INTERFEROMETER

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The Two-Color Method for Optical Astrometry:
Theory and Preliminary Measurements with the
Mark III Stellar Interferometer

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Abstract: The two-color method for interferometric astrometry provides a means of reducing the error in a stellar position measurement attributable to atmospheric turbulence. The primary limitation of the method is shown to be turbulent water vapor fluctuations, which limit the amount of improvement over a one-color measurement obtainable with a two-color estimate. Secondary atmospheric effects caused by diffraction from small refractive index inhomogeneities and differential refraction for the observation of stars away from zenith are shown to introduce errors that behave as white noise and which should usually not be significant. Other potential error sources due to photon noise, systematic instrumental effects, and imperfect data reduction are also considered. The improvement in accuracy possible with the two-color method is estimated as a factor of 5-10 over the corresponding one-color measurement. Some preliminary two-color measurements with the Mark III stellar interferometer at Mt. Wilson are presented which demonstrate approximately a factor of 5 reduction in the amplitude of the atmospheric fluctuations in a stellar position measurement.

Atmospheric Phase Measurements
with the Mark III Stellar Interferometer

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ATMOSPHERIC PHASE MEASUREMENTS
WITH THE MARK III STELLAR INTERFEROMETER

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Massachusetts Institute of Technology

Abstract: The Mark III interferometer is a phase-coherent stellar interferometer designed for astrometry. Operating through the turbulent atmosphere, the instrument is also a sensitive detector of atmospheric phase fluctuations. The effect of phase fluctuations on astrometric accuracy is reviewed, and phase measurements obtained with the instrument at Mt. Wilson using a 12-m baseline are presented. These measurements agree well with the predictions of a simple Kolmogorov spatial spectrum over the frequency range of 0.001 to 100 Hz. From these measurements, the outer scale of turbulence for propagation through the entire atmosphere is estimated to be greater than 2 km. The standard deviation for an absolute astrometric measurement estimated from these measurements is approximately $0.14T^{-1/6}$ arc sec for long integration times for conditions of 0.5-arc-sec seeing. For star-switched relative measurements, this error should decrease as the square root of the number of switching cycles.

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