The Mark III stellar interferometer


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Summary. The Mark III interferometer is an operational long baseline stellar interferometer on Mount Wilson with four possible baseline configurations from 9 m NE-SW to 20 m 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-m 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

I. Introduction

The Mark III interferometer is the third of a series of stellar interferometers at Mount Wilson Observatory. The first instrument demonstrated white-light fringe tracking in 1979 (Shao and Staelin, 1980). The second instrument observed fringes in 1982 and was used as a technology test bed for astrometric measurements until 1984 (Shao et al., 1987). Several devices critical to the operation of a stellar interferometer were developed for the Mark II interferometer. One such device was a high speed, ultra high accuracy, laser controlled optical delay line. An operational procedure for rapid switching between stars was also developed.

Traditionally, the most difficult task of a stellar interferometer has been finding and tracking the central fringe. In rapid switching, this procedure is totally automated. Thus, operation of the Mark II helped identify the technical problems of making astrometric measurements with a long baseline interferometer.

Like the previous instrument, the Mark III interferometer was also designed to be a test bed for new techniques and technologies relevant to optical interferometry and synthetic optical aperture synthesis. However, the principal purpose of the Mark III interferometer was to initiate a test program of fundamental astrometric measurements to demonstrate a significant improvement in accuracy. Another goal was to initiate a program of accurate stellar diameter measurements. Most important of all, the instrument was designed to be astronomically productive.

Long baseline stellar interferometers have traditionally been considered one of the most technologically challenging astronomical instruments. In the Mark III interferometer, the goal has been to build an instrument that is reliable, easy to operate, and capable of extremely accurate astronomical measurements. In order to achieve these goals, a number of active subsystems were incorporated into the design of the instrument. In implementing these subsystems, the design philosophy involved keeping the mechanical and optical systems as simple as possible and shifting the bulk of the complexity into software.

Although the Mark III was originally designed as a closed loop phased interferometer, operational experience has shown that it has sufficient accuracy and stability to operate as an absolute interferometer. An absolute interferometer is one whose mechanical accuracy and stability in open loop operation, without fringe tracking, is sufficiently high that optical path errors are dominated by atmospheric turbulence. This level of accuracy and stability, usually associated with the primary mirror of a large astronomical telescope, is the level of accuracy exhibited by the Mark III interferometer with the 12-m baseline. Operation with the 20-m baseline is expected to exhibit the same level of accuracy and stability.

The ability to operate as an absolute interferometer makes possible three new modes of interferometric observations for long baseline interferometers. They are photon starved amplitude measurements, photon starved group delay astrometry, and photon starved closure phase measurements. Photon starved amplitude measurements have long been a part of speckle interferometry with single apertures. The importance of photon