Fringe Modulation For Atmospheric Optical Path Error Correction in Interferometry

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Abstract

The Magdalena Ridge Observatory Interferometer will be a ten telescope optical interferometric array on top of the Magdalena Ridge at 3500 meters. A dedicated fringe tracking beam combiner and spectograph is being developed to remove atmospheric induced phase fluctuations. Images and intensity fluctuations can be measured to create a known bandpass for the interferometer. For this system, a modulator is mounted at the fringe tracker table. The modulator is to be used to control the phase error at a desired level. The modulator has been chosen undergoing thorough testing to determine if the modulator is capable of this control. The main focus of this poster is the modulator hardware that is situated on the fringe tracker table.

The Modulator

The image below shows an array of the modulator's hardware. Each telescope will have its own modulator with light being transported to the beam combining facility (upper left) via the beam relay system. The modulator will operate in different photomechanical bandsites with wavefront error ranging from 0.1° to 2.0°. In the case of ± 0°, the output will remain even when the case telescope will be arranged in a “Y” shape. The arms of the interferometer are 200m in length, providing maximum baselines up to 100m. The main science goals are the study of star and planet formation, stellar accretion and mass loss, as well as active galactic nuclei.

The Optical Path: The figure below shows the path that the light from the object will take after it has passed through one of the unit telescopes. Upon exiting the telescope, light gets directed into the beam relay system. This is a means to get all of the light into the detector so that the data can be used. The main focus of this paper is on the moving of the optical path between telescopes. Once the light passes through the delay lines, it will leave the system and enter the detector consisting area. It is to correct for different astrophysical phenomena such as hysteresis of the radiation. The main focus of this paper is the modulator hardware that is situated on the fringe tracker table.

Fringe Tracker: The diagram below shows the optical layout for the fringe tracker table in the beam combining area. The use of the fringe tracker is to correct for pathlength fluctuations due to the changing atmospheric seeing conditions. The pathlength is preserved of a 1.4 mm wave. The red beams trace the light paths coming from the delay lines. On each end of the table there are a set of optics that will arrange the beams in a certain pattern before entering the spectrographs.

Metrology: The diagram below is an image of the modulator. The modulator is a Piezomechanik model 25/150/6. They have a screw on mirror support where a 25mm mirror will be glued into place. The mirror shifter has a range of travel of 6µm and a reaction frequency on the order of 5kHz. The maximum operating voltage for these mechanisms is +150V, which corresponds to 0.6557 nm/V, and a voltage error of 5mV.

The above plot shows the results recorded from the metrology system. The plot shows the mean distance moved for each test in Zone 1. The mean change in distance for each test in Zone 1 is 0.12 ± 0.02 µm. The assumption being is this readout does not display as many significant digits. The strain gauge readout also showed that there was hysteresis, but the error was much smaller than what was recorded from the metrology system. In all cases similar amount of hysteresis was observed.

The above diagram illustrates the experimental set up. A laser beam from the metrology system laser head is injected into a Michelson interferometer. Part of the beam is reflected to the reference beam, and the other beam is transmitted to the detector on the mirror shifter. The intensity of the interference pattern is then measured at the output port of the beam head. The linear displacement, velocity, and angular velocity of the mirror shifter are computed from the results on the metrology system. The signal is then amplified by the DMS device. The amplified signal is then read by the computer using an analog I/O PCI card.

The graph above shows the average distance moved for each test in Zone 1. The mean change in distance for each test in Zone 1 is 0.12 ± 0.02 µm. This was repeated ten times for each zone. Then the change in the mean position from point to point was determined. The points were found by calculating the mean position for the ten trials. For this set of tests we used the experimental setup as shown in the above diagram. Each trial represented the mean position of the modulator during the ten trial runs. Comparing this plot to the plot for the recorded measurements. The strain gauge readout also showed that there was hysteresis, but the error was much smaller than what was recorded from the metrology system and A/D PCI card. In all cases similar amount of hysteresis was observed.

The above diagram shows the metrology system laser head is injected into a Michelson interferometer. The purpose of this test was to investigate the behavior of the modulator in different regions within its range of travel. The interferometer is a ten telescope array. Each telescope will be 1.4m in diameter and its light is transported to the beam combining area. The role of the fringe tracker is to correct for fluctuations due to the changing atmospheric seeing conditions. The table itself is composed of four 1 x 2 meter tables. The red beams trace the light paths coming from the delay lines. On each end of the table there are a set of optics that will arrange the beams in a certain pattern before entering the spectrographs.

Current Results

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