Fringe Modulation For Atmospheric Optical Path Error Correction in Interferometry

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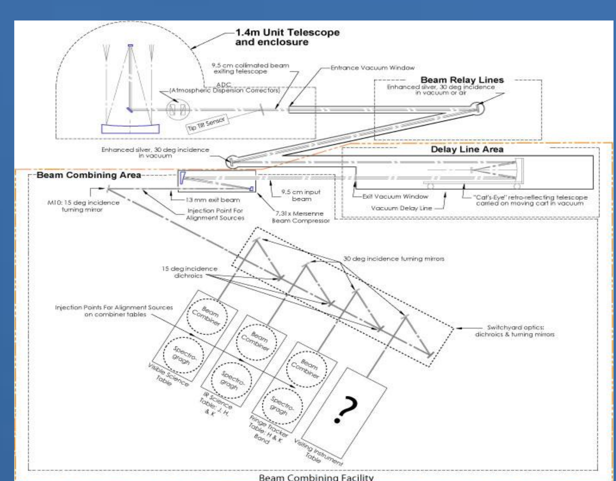
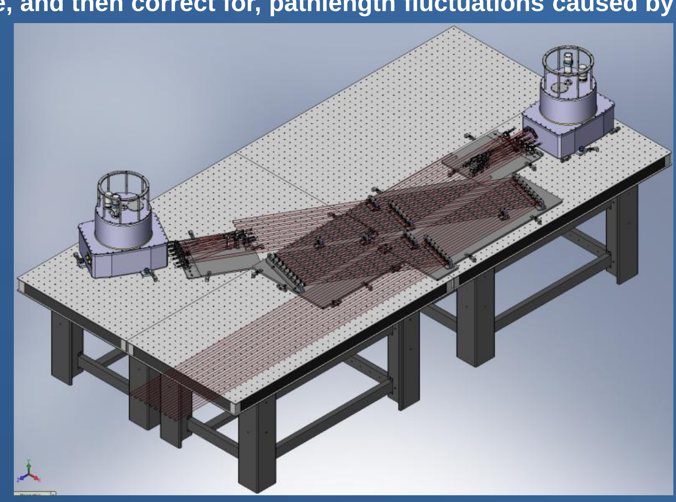
Introduction

<u>The MROI</u>: The image below is an actual aerial photo of the Ridge with an array CAD drawing overlaid. The interferometer is a ten telescope array. Each telescope will be 1.4m in diameter and its light is transported to the beam combining facility (upper left) via the beam relay system. The instrument will operate in different photometric bandpasses with wavelengths ranging from .6μm to 2.4μm. In the image it can be seen that the unit telescopes will be arranged in a "Y" shape. The arms of the interferometer are 200m in length, providing maximum baselines up to 350m. The main science goals are the study of star and planet formation, stellar accretion and mass loss, as well as active galactic nuclei.

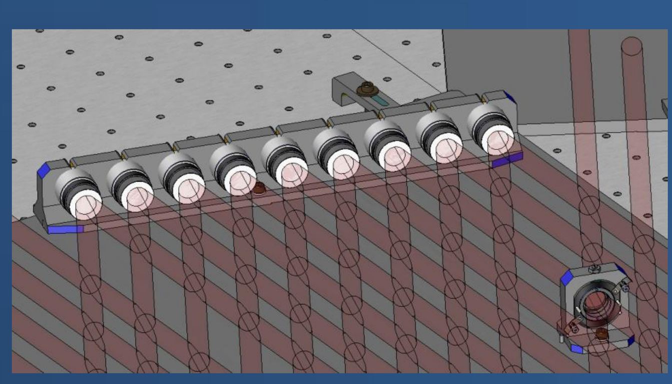
<u>The Optical Train</u>: The diagram below shows the path that the light from the object will take after it has passed through one of the unit telescopes. Upon exiting the telescope, light gets directed into the beam relay system. This is a vacuum pipe that will reflect the light twice to direct it into the delay line area. The delay lines function to match the optical paths between telescopes. Once the light passes through the delay line, it will leave vacuum and enter the beam combining area. It is then directed to different optical tables depending upon the bandpass of the radiation. The main focus of this poster is the modulator hardware that is situated on the fringe tracker table.

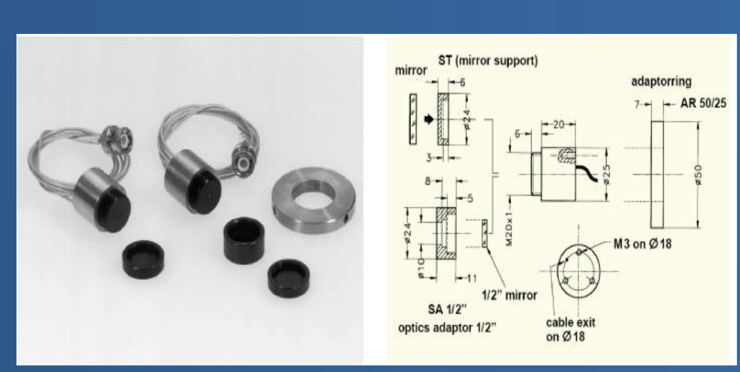


<u>The Fringe Tracker</u>: The diagram below shows the opto-mechanical layout for the fringe tracker table in the beam combining area. The role of the fringe tracker is to correct for pathlength fluctuations due to the changing atmospheric seeing conditions. The table itself is composed of four 1 x 2 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 (Dewars). At right center of the table sit the beam combiner optics. Aside from beamsplitters, the beam combiner optics contain modulators with mirrors. Without the modulators, it would not be possible to measure, and then correct for, pathlength fluctuations caused by the atmosphere.



<u>The Modulators</u>: The diagrams below show an image of the actual mirror shifters that will be used, and where they will be located on the fringe tracker table. The mirror shifters are the Piezomechanik model str-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, with a theoretical precision of .6557 nm/V, and a voltage error of 5mV.

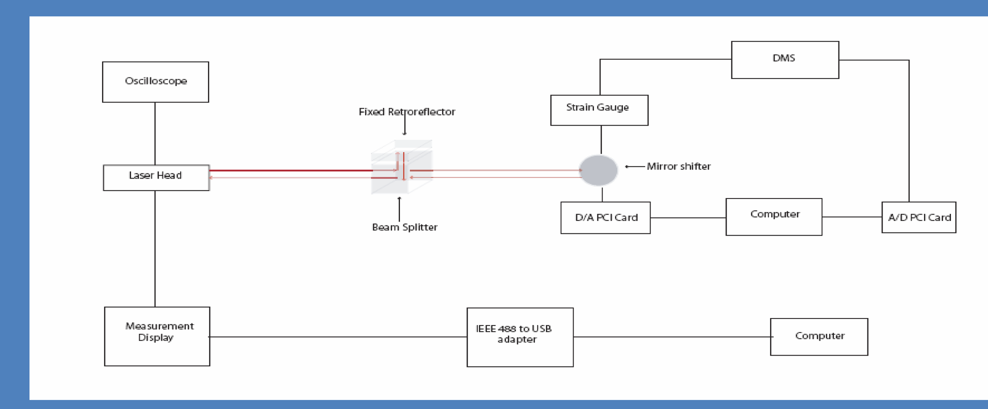




Abstract

The Magdalena Ridge Observatory Interferometer will be a ten telescope optical interferometric array on top of the Magdalena Ridge at 3,320 meters. A dedicated fringe tracking beam combiner and spectrograph is being developed to remove atmospheric induced pathlength fluctuations between unit telescopes. Mirrors on modulators will be used to create a known optical path difference between combination partners, allowing these path differences to be calculated, and then corrected for by the delay lines. The modulator that has been chosen is undergoing thorough testing to determine if the stepping motion of the modulator is reliable and up to specifications. We must also determine if it can create the types of wave forms that are required. Real time motion control software is currently under development, and initial results are reported here.

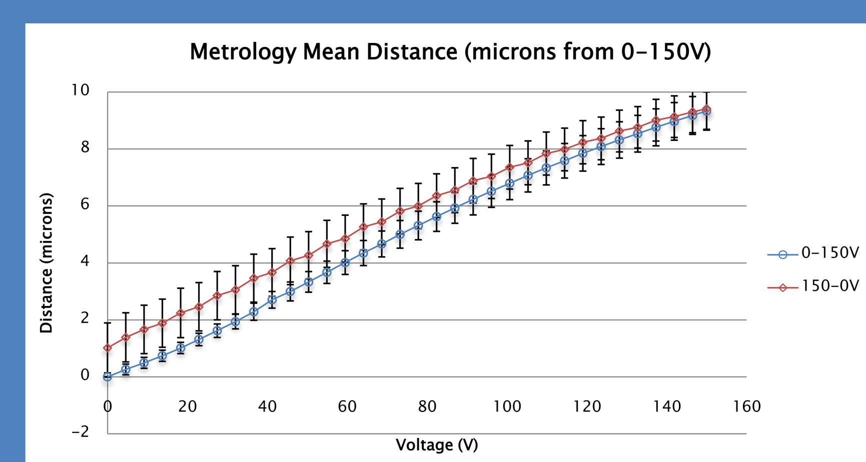
Experimental Setup



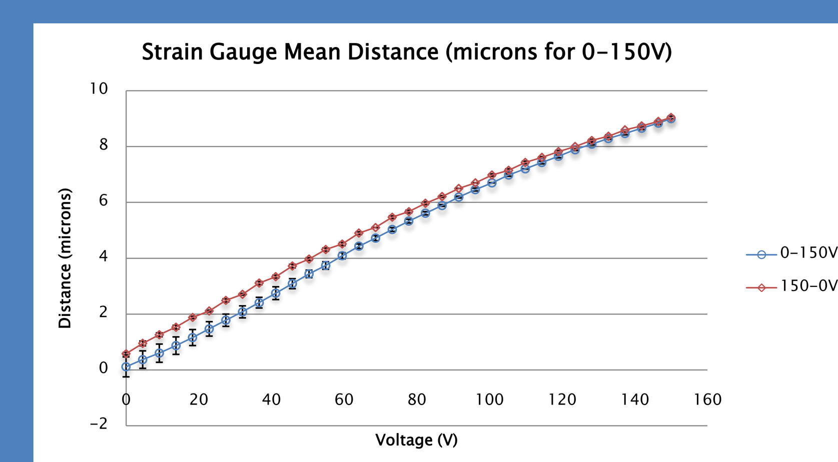
The above diagram illustrates the experimental set up. A laser beam from the metrology system laser head is injected into a Michelson interferometer. Part of the beam is reflected to a stationary CCR (Corner Cube Retro-reflector), and the other part is transmitted to a CCR on the mirror shifter. The intensity of the interference pattern is then measured at the return port of the laser head. The linear displacement, velocity, and angular displacement of the return beam is then calculated as the mirror shifter is driven. Position commands are entered into the computer via the user interface and sent to the mirror shifter from a D/A amplifier PCI card. The resulting linear displacement of the mirror shifter is measured by the strain gauge, and 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. This will allow control loop operation to correct for hysteresis.

Initial Results

<u>Test set 1 and results</u>: For this set of tests we used the experimental setup above. The modulator was stepped from 0 – 150V and back from 150 – 0V by increments of 4.578V which corresponds to .0025 μm. This was repeated ten times. For every step, a reading was taken off of the metrology measurement display, the strain gauge readout, and the A/D PCI card. In all cases a similar amount of hysteresis was observed from the recorded measurements. The strain gauge readout also showed that there was hysteresis, but the error was much smaller than what was read off of the metrology system and A/D PCI card. The reason being is because its readout does not display as many significant digits.

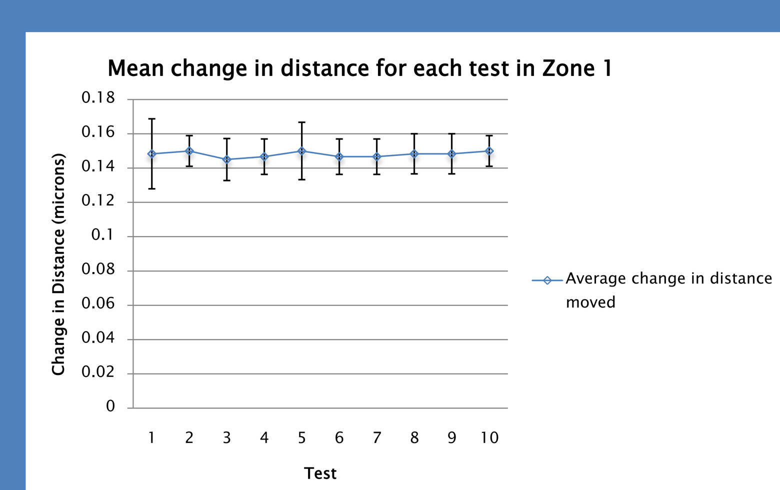


The above plot shows the results recorded from the metrology system. Each point represents the mean position of the modulator during the ten trial runs. The error bars shown were determined by the standard deviation calculated for each point of the ten trial runs.

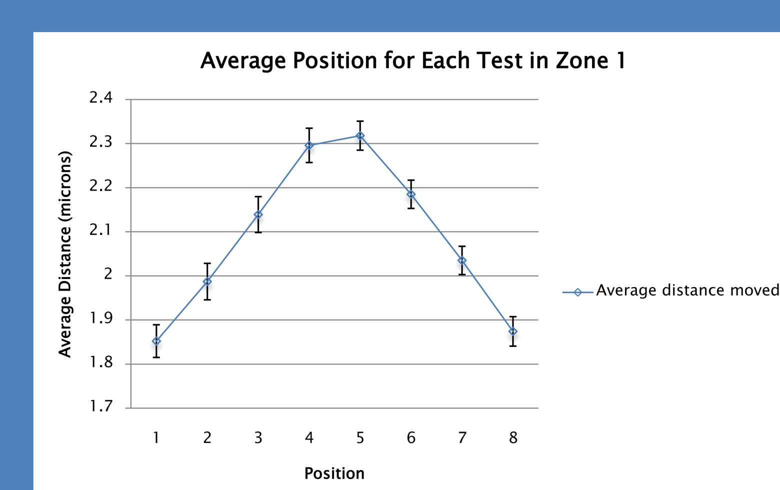


The plot above displays the readout from A/D PCI card and its error. Each point on the diagram is determined from the mean position of the modulator according to the strain gauge amplifier for the ten trial runs. The error bars were calculated by finding the standard deviation for each point of the ten trial runs. Comparing this plot to the plot for the metrology system it can be noted that the metrology readings were noisier. This could be due to the external influences that the strain gauge readout would not be subjected to. This would include optical path differences from air currents, table vibrations, and so on.

<u>Test set 2 and results</u>: The purpose of this test was to investigate the behavior of the modulator in different regions within its range of travel. It used a RTC (Real Time Control) program to send commands to the modulator, and then read the output from the strain gauge ADC PCI card. Four zones were picked between 0-150V. They were chosen by looking at the previous results to investigate where the best range of operation might be. The voltage zones ended up being 25-50V, 50-75V, 75-100V and 100-125V. Within each range, the modulator was stepped by .15μm four times in the forward direction, and four times back to the return position. This step size was chosen because this will be a typical step size when in operation. This was repeated ten times for each zone.



The above plot shows the average change of distance that the modulator moved over the course of the ten tests within the 25 to 50 voltage zone. The points were found by calculating the mean position for the ten trials. Then the change in the mean position from point to point was determined. The error bars were calculated by finding the standard deviation of each series of points from the ten trials.



The graph above shows the average positions for each test from the ten trials and their standard deviations.

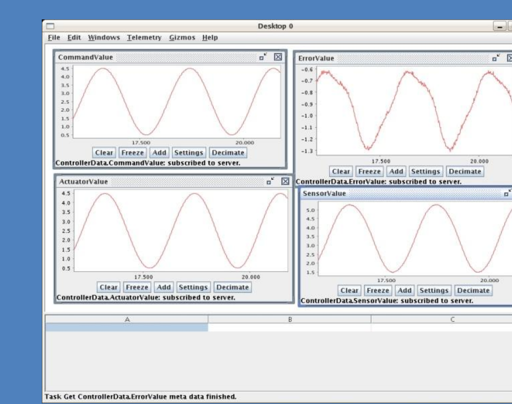
Future Plans

From the initial results, it is clear that the implementation of a closed loop control using the strain gauge to correct for the hysteresis could significantly improve the performance of the modulator. Feedback from the ADC strain gauge can be used to compute the error, and then a correction can be applied through the DAC amplifier card.

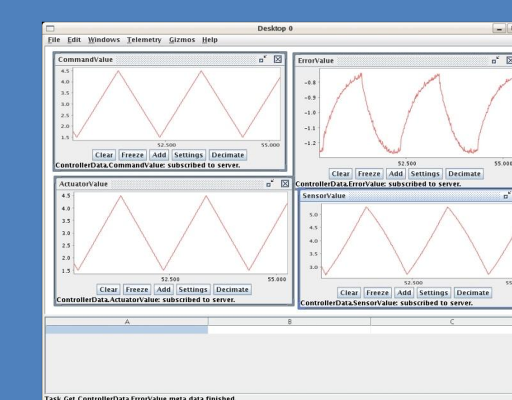
The three images below are screen shots of the newly implemented control software readout, while driving the modulator in open loop. The user selects one of three waveforms, its period, and amplitude. The "CommandValue" is the step value sent, the "SensorValue" is the readout from the strain gauge, and "ErrorValue" is the difference between the command and sensor values.

This software was just implemented, so closed loop operation has not yet been tested. This will involve tuning the PID motion control filter (minimizing the "ErrorValue"), and determining the appropriate scaling constants between the two PCI cards.

<u>Sine Wave:</u>



<u>Triangle wave:</u>



<u>Step Wave:</u>