FIBER POSITIONER SYSTEM: A METHOD TO GUIDE 30,000 OPTICAL FIBERS

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Abstract

We want to build a spectroscopic telescope, which is a tool that analyzes the light of the universe. The purpose of this study is to understand the feasibility of using piezoelectric tubes (piezos) as a method of positioning 30,000 optical fibers. The goal is to precisely move and position the fibers to a given location within 10um, and let them stay in that position for at least an hour. However, piezos have the properties of hysteresis and creep, which makes this significantly more challenging to do so. To combat these obstacles and gain better control of the piezos, it is necessary to learn the characteristics and quirks of the system. Therefore, this project focused mainly on understanding the behavior of the piezos under a changing voltage, as well as attempting hysteresis mitigation by experimenting with reset procedures, which, as the name implies, seeks to "reset" any memory that the system has of the previous state. Experiments showed that we can locate the fibers with a precision of 50um in one movement.

Background

Important information about the universe is written in the language of lights. To understand such a language, one might perform spectroscopy, which is a method of splitting light into its associated wavelengths. Through this technique, the composition of the universe, as well as the redshift of close and distant celestial objects can be analyzed, which will shed light onto many mysteries of the universe.

For instance, at the Large Synoptic Survey Telescope (LSST), there are plans to add a spectroscopic telescope with 30,000 optical fibers on a 3200 square centimeter plane. Such a telescope will be a major step in furthering research in physics and astronomy.

Objectives

The focus of my research is to experiment with piezos as a form of a fiber positioner system to take the initial steps of making the telescope at LSST a reality. We have two obstacles with the use of piezos that must be resolved:

1. Hysteresis: Tendency of the material to remember its past state.
2. Creep: Change in displacement over time under an unchanged voltage.

This research will focus mainly on understanding the system and attempting hysteresis mitigation.

Understanding the System

Experimental Design

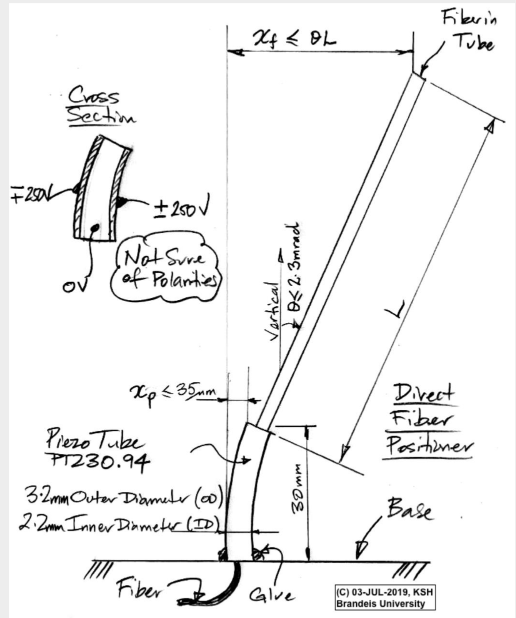

Figure 1: Experimental set up with an optical fiber that goes through a steel tube which is glued to a piezo. A circuit controls the voltage applied, the injectors shine light, and the camera above takes pictures of the fiber tip.

Position and Voltage

The x and y positions of the fibers as the applied voltage increased were measured and graphed.

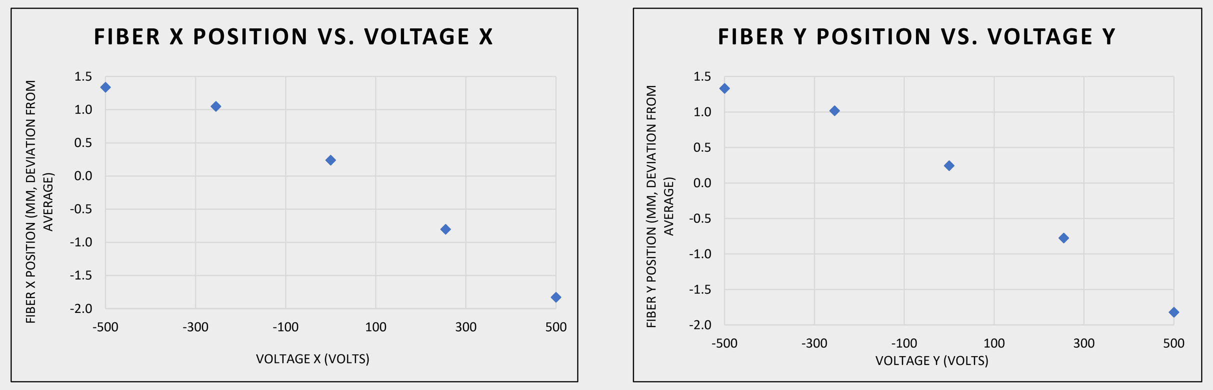

Figure 2: These graphs show the movement of the positions of the fiber tips as the voltage applied increased.

Dynamic Range of the System

The maximum and minimum voltage that can be applied are 500 volts and -500 volts, respectively. With these boundary conditions, we can determine the dynamic range of the system.

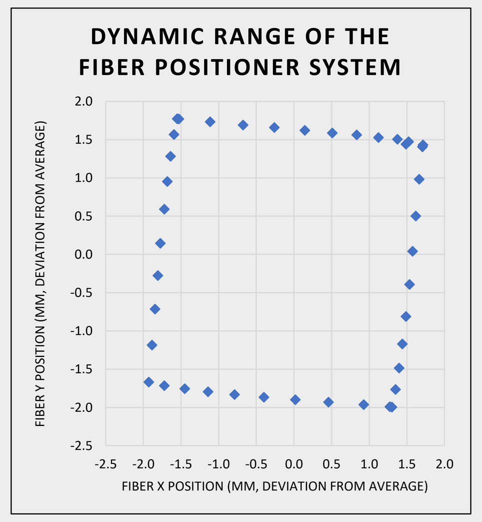

Figure 3: This graph shows the dynamic range of the fiber positioner system. Any movement of the fibers occurs within the boundaries of this 3.23mm by 3.44mm rectangle.

Eliminating Hysteresis

The first attempt in eliminating hysteresis involved the use of two reset procedures.

Diagonal Reset Procedure

1. Apply random voltage to piezos.
2. Apply diagonal algorithm.
3. Apply known voltage and measure fiber position.
4. Repeat 1-3 300 times.

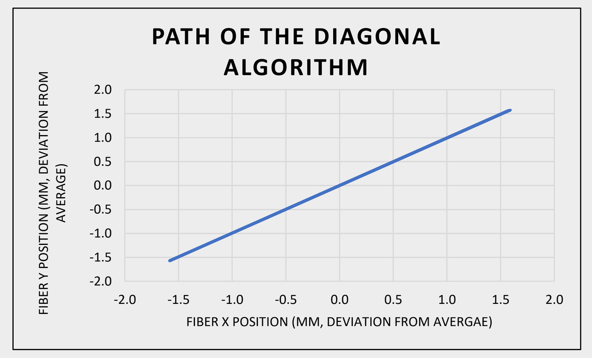

Figure 4: The diagonal algorithm applies max. then min. voltages to the piezos five times.

This experiment sought to understand whether the fiber positions measured in step 3 agreed to within 10 microns in real space. The results are as follows:

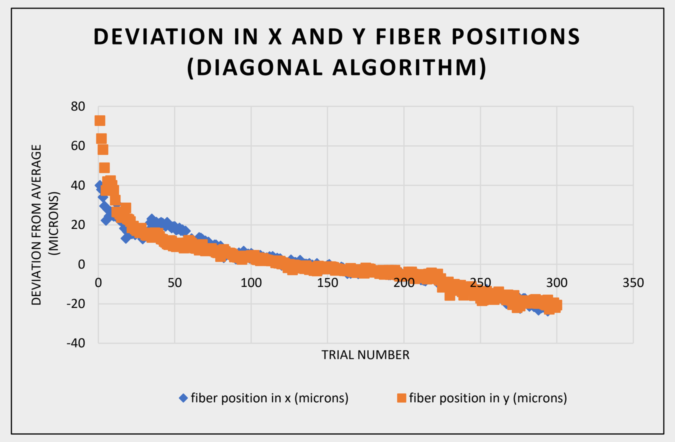

Figure 5: The deviation from the mean of each fiber position was graphed upon finishing the diagonal reset procedure. The vast majority of the positions are within 20 microns of the mean, though the first 20 or so spot positions are further away. Though this algorithm does not quite reach the 10 micron goal, it is a very promising result.

Spiral Reset Procedure

1. Apply random voltage to piezos.
2. Apply spiral algorithm.
3. Apply known voltage and measure fiber position.
4. Repeat 1-3 300 times.

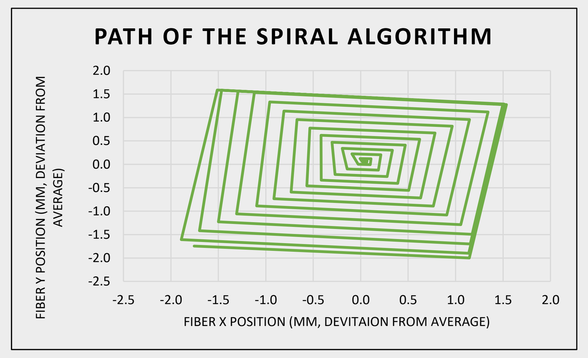

Figure 6: The spiral algorithm applies voltages that slowly spiral into the center.

Similarly to the previous experiment, we sought to understand whether the final fiber positions agreed to 10 microns in real space.

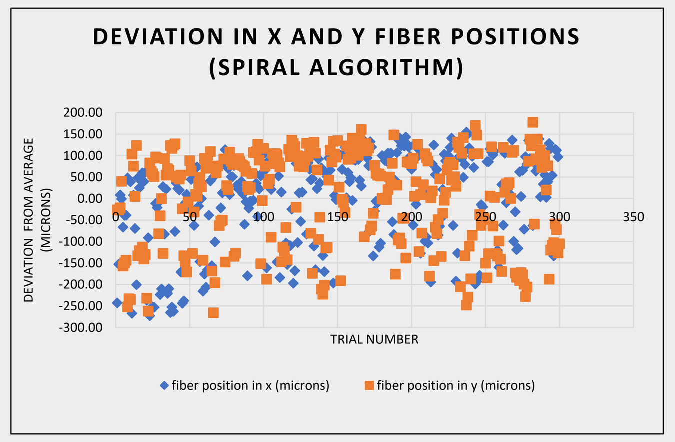

Figure 7: The deviation from the mean of each fiber position was graphed upon completing the spiral reset procedure. The vast majority of the positions are found to be within 200 microns of the mean, which is significantly greater than our 10 micron goal.

Comparison

To further understand the effects of the reset procedures, the same experiment was repeated, but this time skipping step 2.

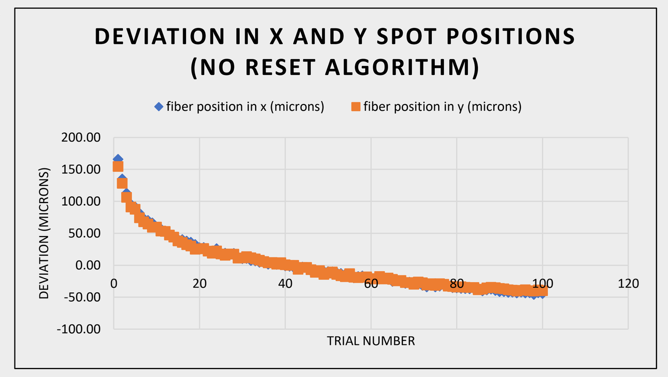

Figure 8: With no reset algorithm in step 2, the majority of the fiber positions are found to be within 50 microns of the mean. The results and shape of the curve is similar to the diagonal reset procedure.

Conclusions

The reset procedures explored in this project were unable to fully eliminate hysteresis. However, this study taught us that a single algorithm cannot completely erase a piezo's memory of the previous state, and perhaps it is best to explore a different method. The next step of this project would be to make precise corrections to the position of the fiber tip and ultimately construct a map between the DAC values applied to the location of the fiber. Positioning 30,000 optical fibers is no easy task, and the usage of piezos is one such way to make this telescope a reality.

References

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Acknowledgements

Thank you to the Provost Undergraduate Research Fund for funding my research, and my mentors and advisors for furthering my research experience through all the guidance and constant feedback.