DIRECT POSITIONING OF 50,000 OPTICAL FIBERS

Nathan Sayer

Open Source Instruments

National Science Foundation

Abstract

We propose a method for mounting optical fibers to provide spectroscopy of celestial objects. To do this, we solder piezo-electric actuators to a rigid base on a 5mm grid. By applying +/-250 V to the four electrodes of the actuator we can angle the fiber by 6.3 mrad in two directions (3.8-mm square motion). Using our system, the fiber can be positioned with a precision of 10 μm rms.

Background

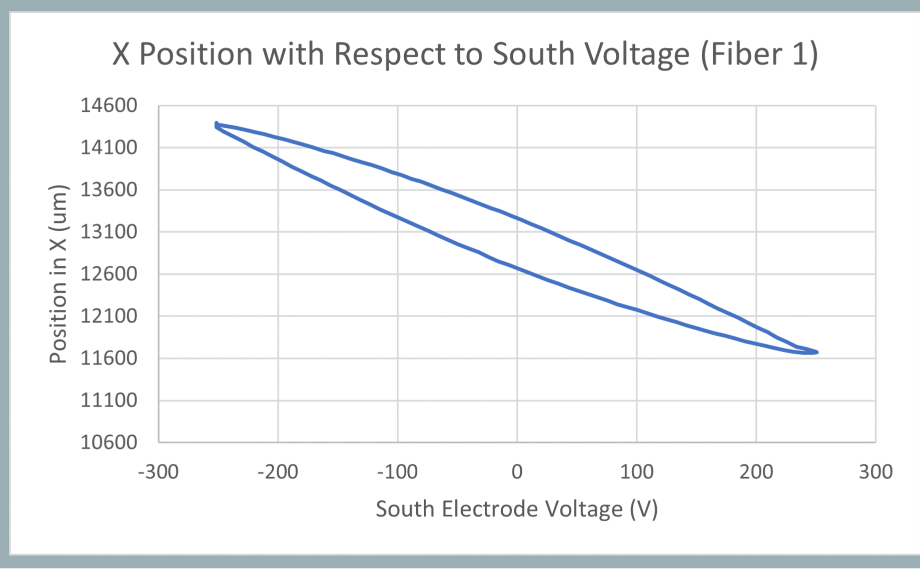
What makes our spectrograph unique is the density of fibers and method of travel. Our spectrograph positions all fibers simultaneously with one direct move using an electrically complex yet mechanically simple mechanism. This allows telescopes to gather light from more objects which are far away and close together.

Objectives

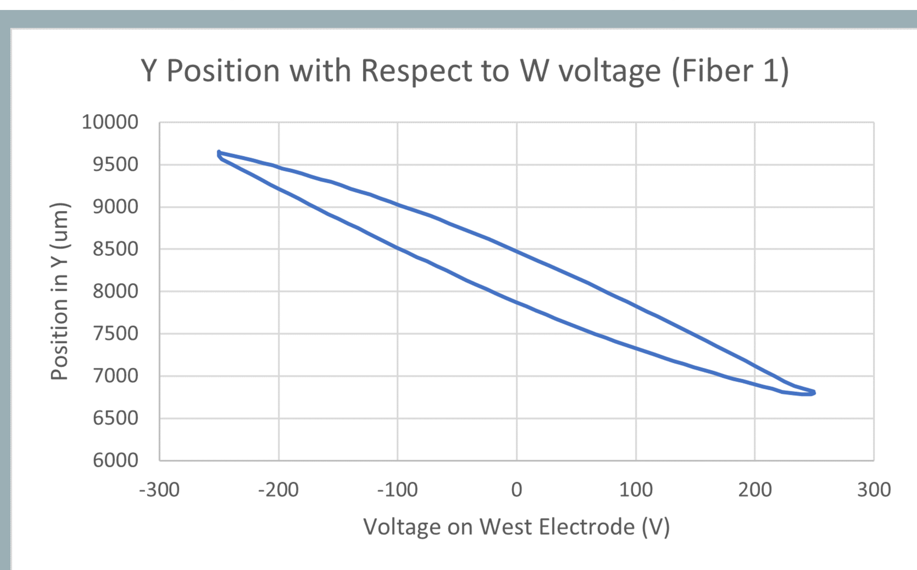
We plan to develop a system with 50,000 fibers on a 650 cm diameter focal plane. This will help with large-scale cosmological searches such as telescopes with a focus of studying dark energy.

Figure 6: Single fiber positioner surrounded by dark fabric

Hysteresis



Figures 1 (above) and 2 (below): We center the fiber in one direction (voltage on East/West electrodes or North/South electrodes) and move it in the other to observe the actuator's hysteresis. We observe 700um of hysteresis at the fiber tip.



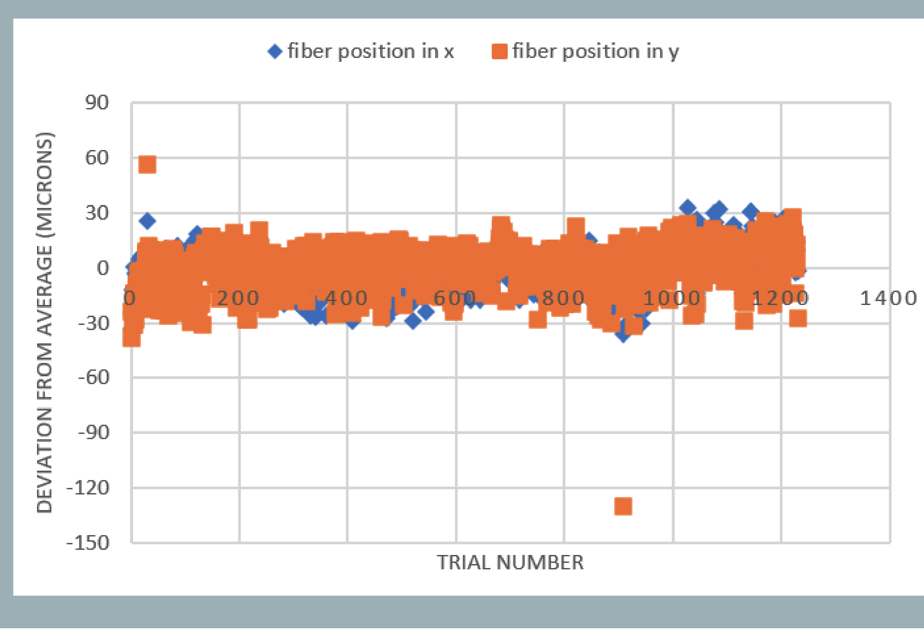


Figure 5: The deviation from the mean of each fiber position was graphed upon completing the spiral reset procedure. The standard deviations in x and y were 10 μm and 11 μm respectively.

Creep

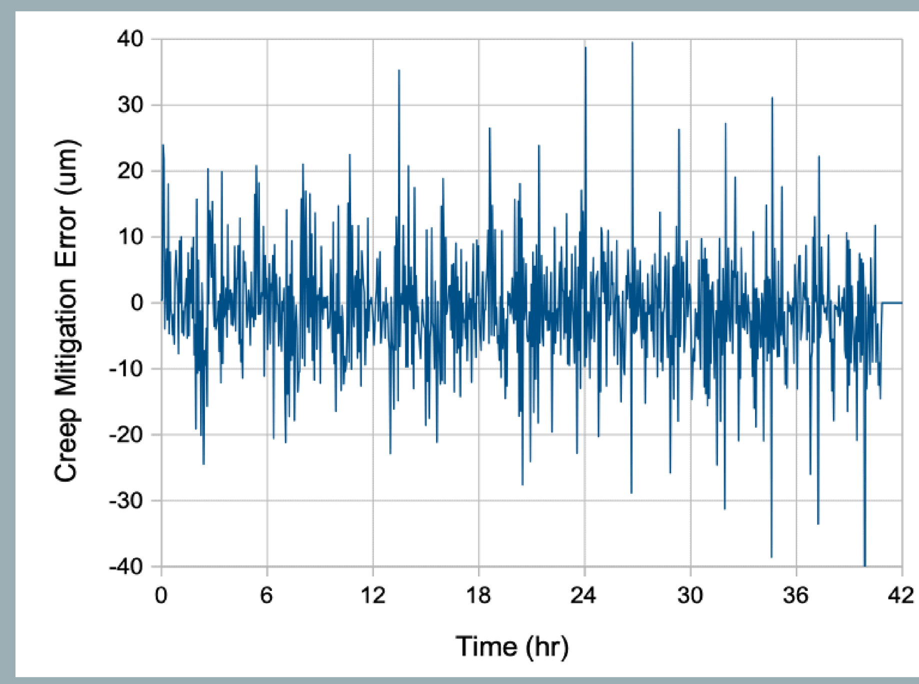


Figure 3: Creep measurements throughout 40 hours.

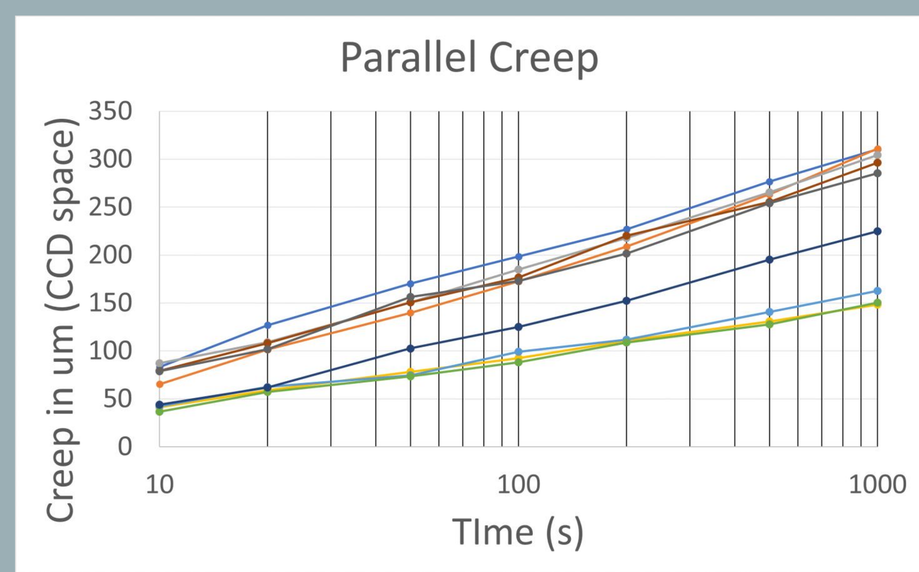


Figure 4: Parallel creep for a selection of movements.

Experimental Design

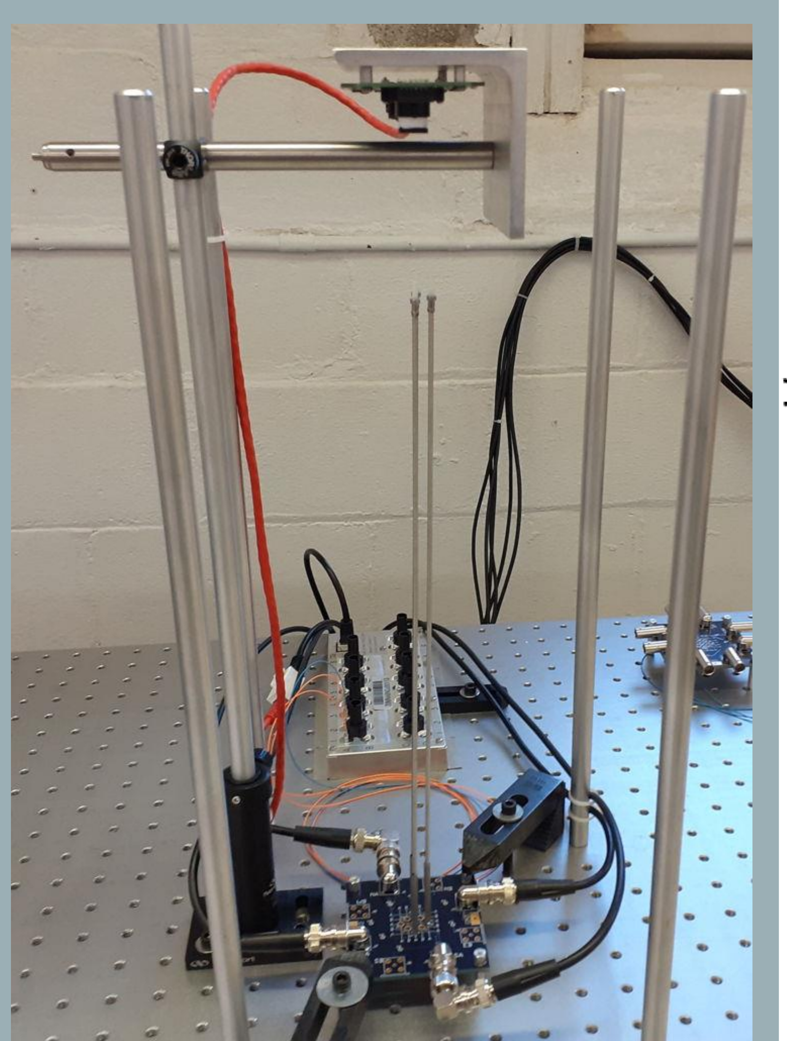


Figure 7: Three fiber positioner with injector

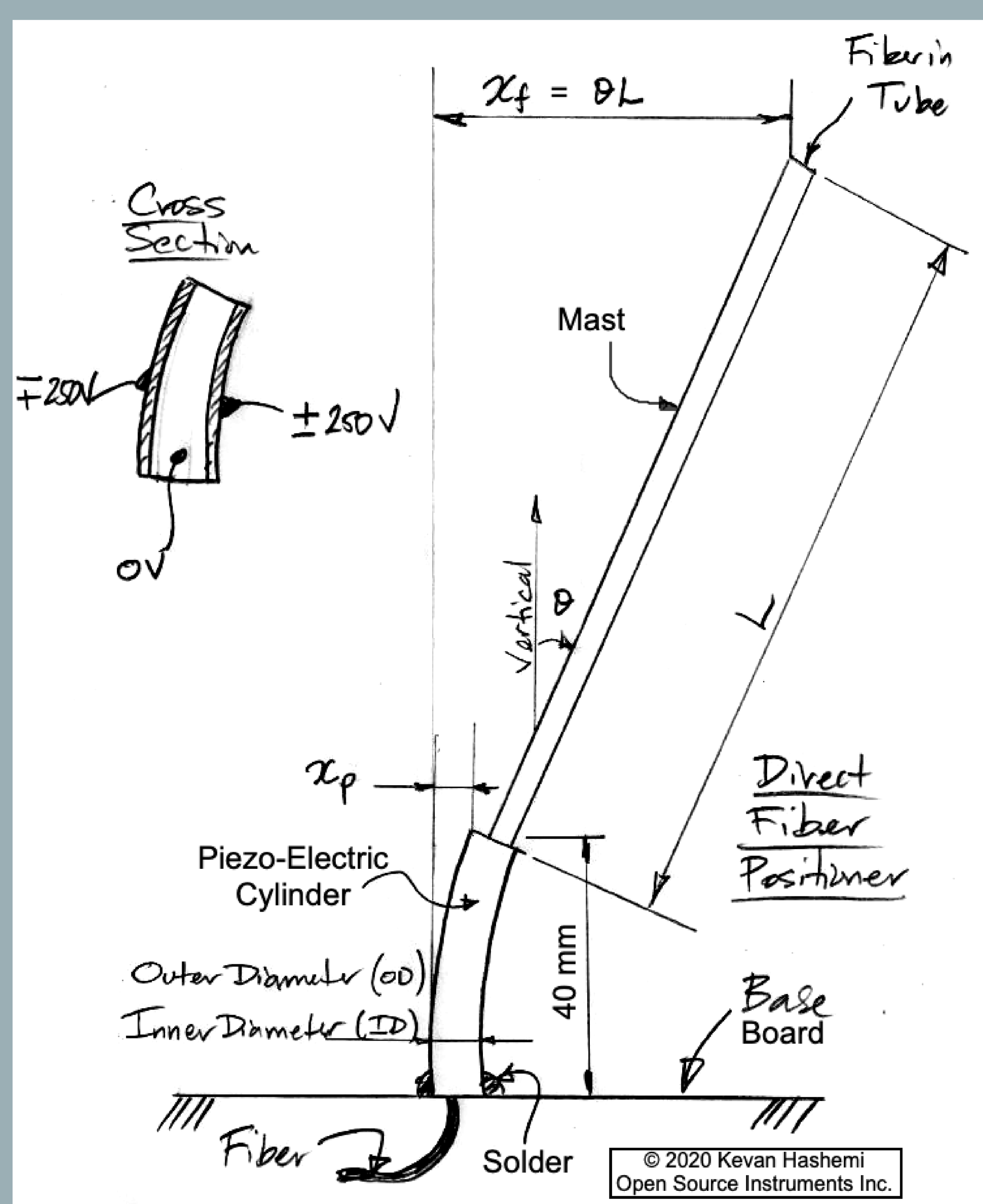


Figure 8: Sketch of experimental set up with an optical fiber that goes through a steel tube which is glued to a piezo. A circuit controls the voltage applied, the injectors shine light, and a camera above takes pictures of the fiber tip. The bending of the piezo-electric actuator is greatly exaggerated to demonstrate the positioner's movement. The fiber only bends by about 6.3 mrads in real space.

Conclusions

The piezo-electric actuators have a lot of potential for spectroscopy instrumentation. The two major hurdles to using them are creep and hysteresis. Through our creep experiments, we were able to reduce the error to <10 μm rms. Our reset procedures mitigate hysteresis by returning the fiber to its original position to within 10 μm. The piezo-electric actuators require a lot of circuitry to operate, so the major electrical challenge of this spectrograph is confining all the circuitry to one densely-packed area.

References

Website for Open Source Instruments: https://www.opensourceinstruments.com/DFPS/

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