Design and Fabrication of the Back-End for a Prototype Multi-Object Spectrograph

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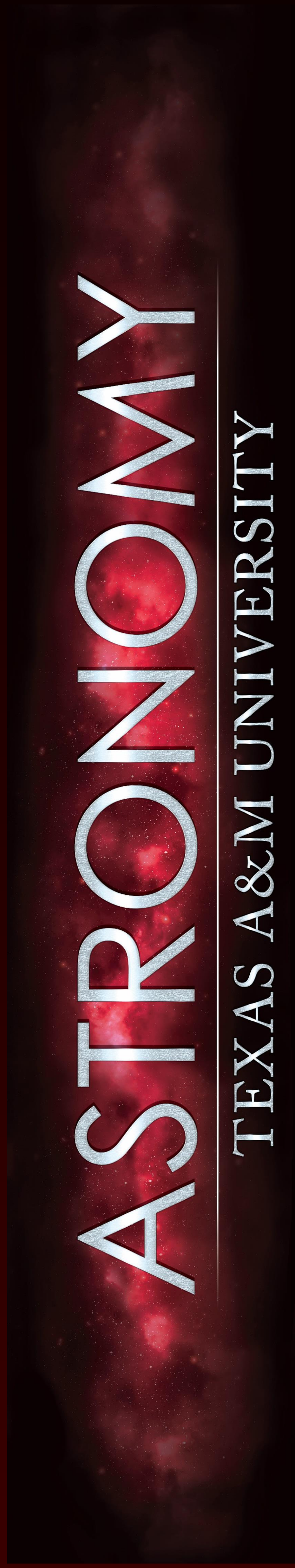

ABSTRACT

We present the results of the design, fabrication, and testing of a spectrograph to be fiber-fed by a prototype multi-object fiber positioner. This project is in collaboration with Open Source Instruments (OSI), who have designed and constructed the front-end light collection method that will observe 4 astronomical objects at a time. This prototype serves as a proof of concept for the Texas A&M Astronomical Instrumentation Laboratory's continued collaboration with OSI. In the future, OSI and Texas A&M plan to construct an instrument that can observe and take spectra of up to 80 objects at a time with the eventual goal of scaling to thousands of objects. The current spectroscopy setup utilizes ORIEL's MS125J spectrograph to spread light into its spectra, which is then collected by a KURO 2048B camera from Teledyne Princeton Instruments. The readout of the camera is then sent through a custom data pipeline to extract the unique spectra from each object. This data can then be used to determine the 4 objects' relative elemental abundances via observations of emission and absorption features that will give insight on the formation and behavior of these celestial bodies.

INTRODUCTION

For the development of many prototypes there are many constraints, especially in regards to the budget and time available. This is also the case with the construction of this system. All hardware components for this spectrometer were repurposed from various past projects in the instrumentation lab. The software for reading data from the camera was designed for use in another instrument, but has been modified from its original purpose to better suit this prototype. New calibration methods and data pipelines had to be developed due to the hardware limitations. These constraints dictated the design of this instrument and led to an incredibly unique system.

HARDWARE

There are three main hardware components for this system. The spectrograph to spread the light into its spectra, the camera to collect the light information from the spectrograph, and a fiber-optic USB relay device (Figure 1).

The spectrograph used is ORIEL's MS125J that is a compact system that has an adjustment screw to change the bounds of the spectra that the camera sees. The optics are intended to observe only one source at a time, so a cylindrical lens was added to reduce effects of the inherent astigmatism in the images. The camera is a KURO 2048B camera from Teledyne Princeton Instruments that can read at low noise with its 4 mega-pixel back-illuminated scientific CMOS. The fiber-optic USB relay device allows for control and data collection at a greater distance. These components are joined via two aluminum plates designed and fabricated in the lab that will also be used to attach this system to the OSI instrument (Figure 2).

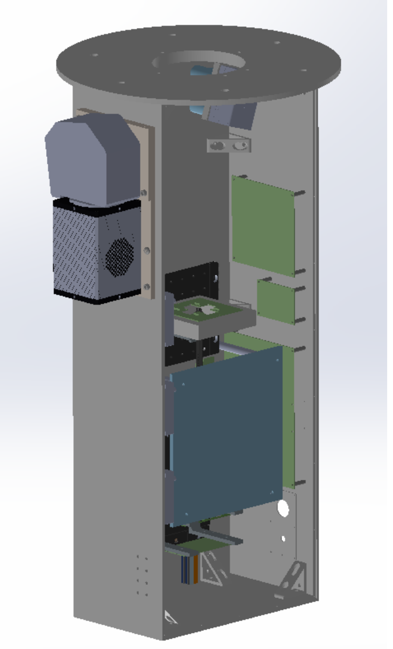

Figure 2. SOLIDWORKS assembly of the completed spectrograph attached to the OSI Direct Fiber Positioning System (DFPS) instrument.

SOFTWARE

The KURO 2048B camera utilized for data collection has been used in the instrumentation lab for many projects, so minimal work was required in modifying this aspect of the software. Additional capabilities such as viewing single exposures was added with basic data reduction methods; i.e., accounting for dark current.

To accurately obtain information about the spectra observed, a relation between the position of an emission line on the detector, the wavelength of the line, and the setting on the spectrograph's micrometer had to be found. This was done by observing the readings of a 650nm and a 780nm laser (Figure 3) at a range of settings for the micrometer. The pixel-wavelength relation was found by linear interpolation in the placement of the two peaks and a function for this transformation was found. Through fine adjustments of the micrometer the wavelength-micrometer relation was also found (Figure 4). This relation was extrapolated to test with a 450nm laser with great success.

A program for obtaining the desired setting on the micrometer adjustment screw was also constructed. This allows the user to input the wavelength that they wish to be in the center of the detector, and they are given the setting that best fits this wavelength.

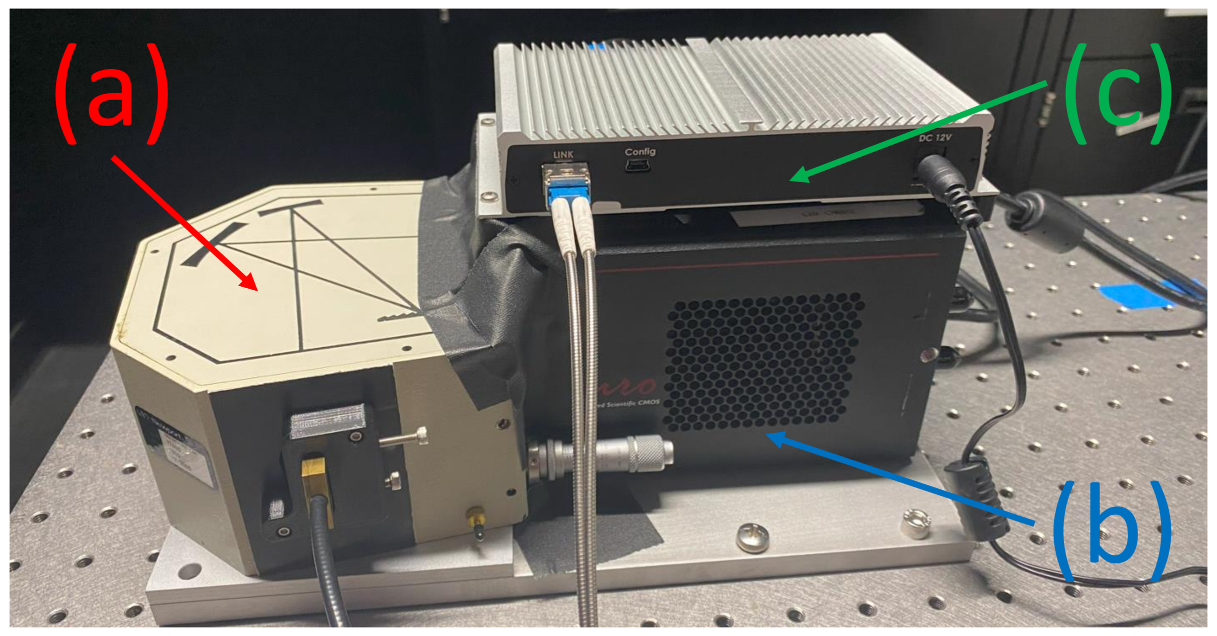

Figure 1. Spectrometer with the spectrograph (a), camera (b), and optical relay (c) ready for testing in the lab.

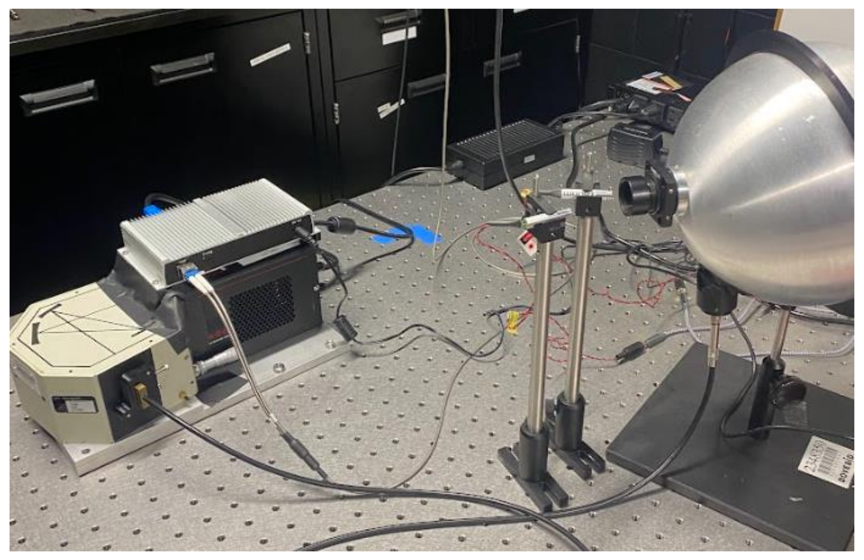

Figure 3. Experimental setup for obtaining the scale of the system through the use of two lasers of a known wavelength. Lasers were sent through an integrating sphere to reduce variability in the experiments

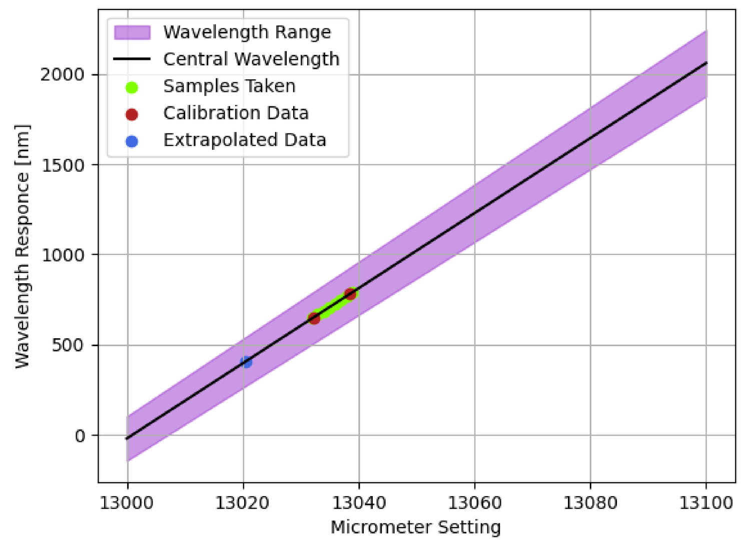

Figure 4. Result of the calibration, showing the relation between the micrometer setting and the wavelength response.

IMAGE CORRECTION

The ORIEL MS125J used to spread has an astigmatism in the optics as a tradeoff for its compact design, which is not an issue when viewing a single source. A cylindrical lens partially corrected this, but post-processing software corrections were needed to further improve image quality. Due to the unique properties of this system, a new correction algorithm had to be constructed for the best results. The details of this program are outside of the scope of this presentation. The correction results in an increase of spectral resolution by approximately 25%. A HgAr lamp was used for testing the correction software, and an example of this correction is shown in Figure 5.

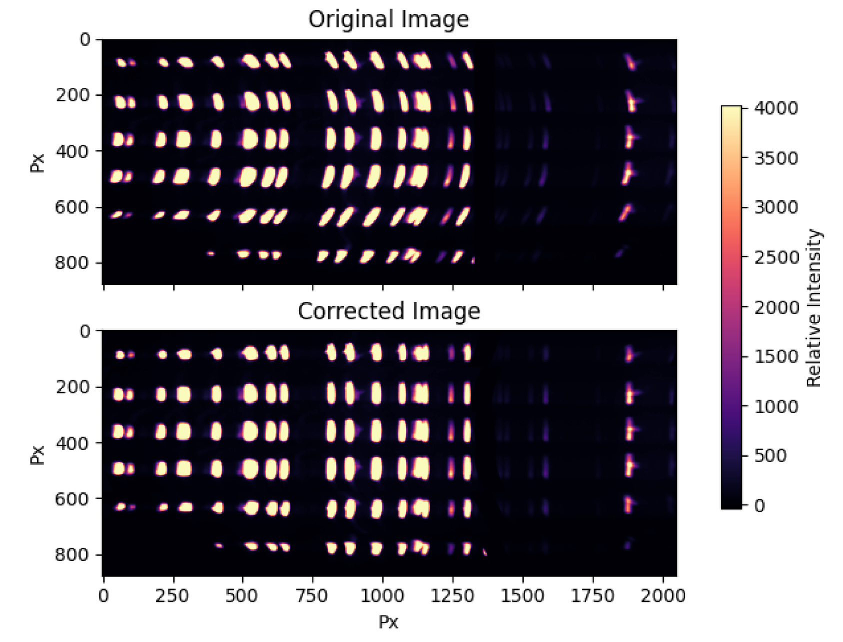

Figure 6. Detector reading of HgAr lamp centered at 740nm. Original on top displays the image before running through the software, bottom frame shows the corrected image.

CONCLUSION

After careful design and testing, the back-end for the prototype multi-object spectrograph is complete. It has been designed primarily with repurposed components working together in new ways and is ready for continued testing with the entire multi-object spectrograph prototype.

Follow our progress:
http://instrumentation.tamu.edu

Texas A&M University Department of Physics and Astronomy is an institutional member of:

Munnerlyn AIL astronomical instrumentation lab · GMT · HETDEX Hobby-Eberly Telescope Dark Energy Experiment · LSST Large Synoptic Survey Telescope · Dark Energy Survey

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