Skipper CCD Spectrograph

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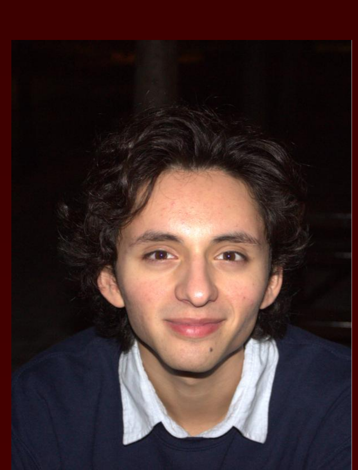


ABSTRACT

We present the results of the design, fabrication, and testing of a spectrograph that utilizes a Skipper CCD detector. This project is in collaboration with Fermilab and University of Illinois Urbana-Champaign, who have provided the scope of the project and the detector that will count photons from a fiber-fed spectrograph on an optical bench. The Skipper Spectrograph was initially designed for detecting a 560 nm wavelength. The spectrograph design was built on an optical bench to check measurements and detections. A prominent green spectrum was observed to be hitting the detector, which confirmed the setup. The light source was then changed to a Mercury Argon Lamp to detect the closest wavelength to 560 nm accurately. Photos were taken and observed. After the data was analyzed, the setup was updated to be calibrated for an 810 nm wavelength along with minor upgrades to account for elevation alignment. The same process in the 560 nm calibration was followed, and focusing is currently being done in attempt to improve the quality of the detector.

INTRODUCTION

Our lab is designing and building the spectrograph required to disperse the light onto the Skipper CCD. Originally, the spectrograph was calibrated to a wavelength of 560 nm, wavelength range of 20 nm, and a resolution of 10000. However, the spectrograph has been adjusted to a wavelength of 810 nm +/- 20 nm calibration. The goal is for the final application to detect nanometer shifts in the spectrum.

INITIAL DESIGN

The components of the spectrograph include the detector, an SBIG STF-8300M. This detector has a width of 13.52 mm, which is considered in the spectrograph design calculations. The collimation and camera lens from Thorlabs are the same, with focal lengths of 200 mm. The grating has a density of 1200 grooves/mm.

At first, the spectrograph design was configured for a wavelength of 560 nm. These design calculations were done using Python in Jupyter Notebook while referencing spectrograph design principles such as the grating equation as seen in Figure 1. The calculations were then confirmed through a Zemax schematic.

$$m\lambda = d(sin\alpha + sin\beta)$$

Figure 1. The grating equation used for the spectrograph design. m is the magnification or order (1), λ is the target wavelength (560 nm), d is the pitch (0.0012 nm/groove), α is the incident angle (15.9°), and β is the diffraction angle (73.1°).

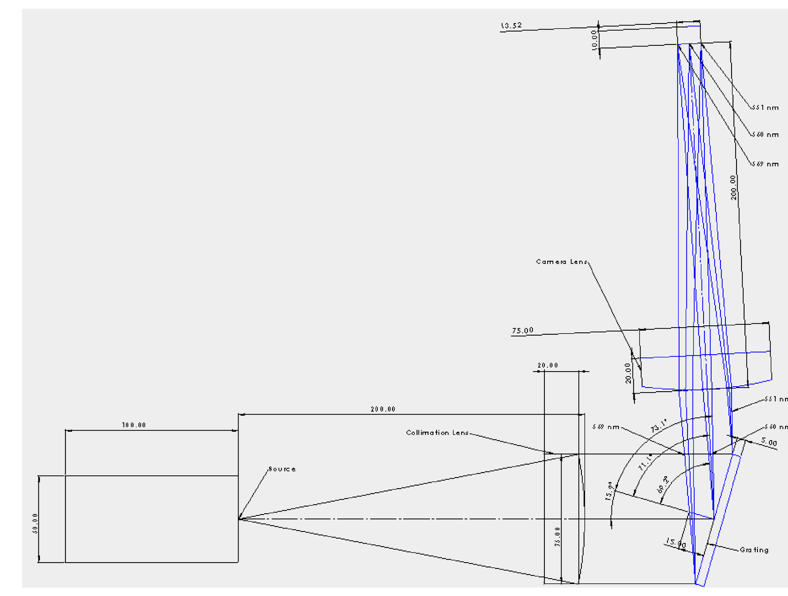


Figure 2. The Zemax schematic drawn in SolidWorks. In this schematic, the incident angle is 15.9° and the diffraction angle is 73.1°.

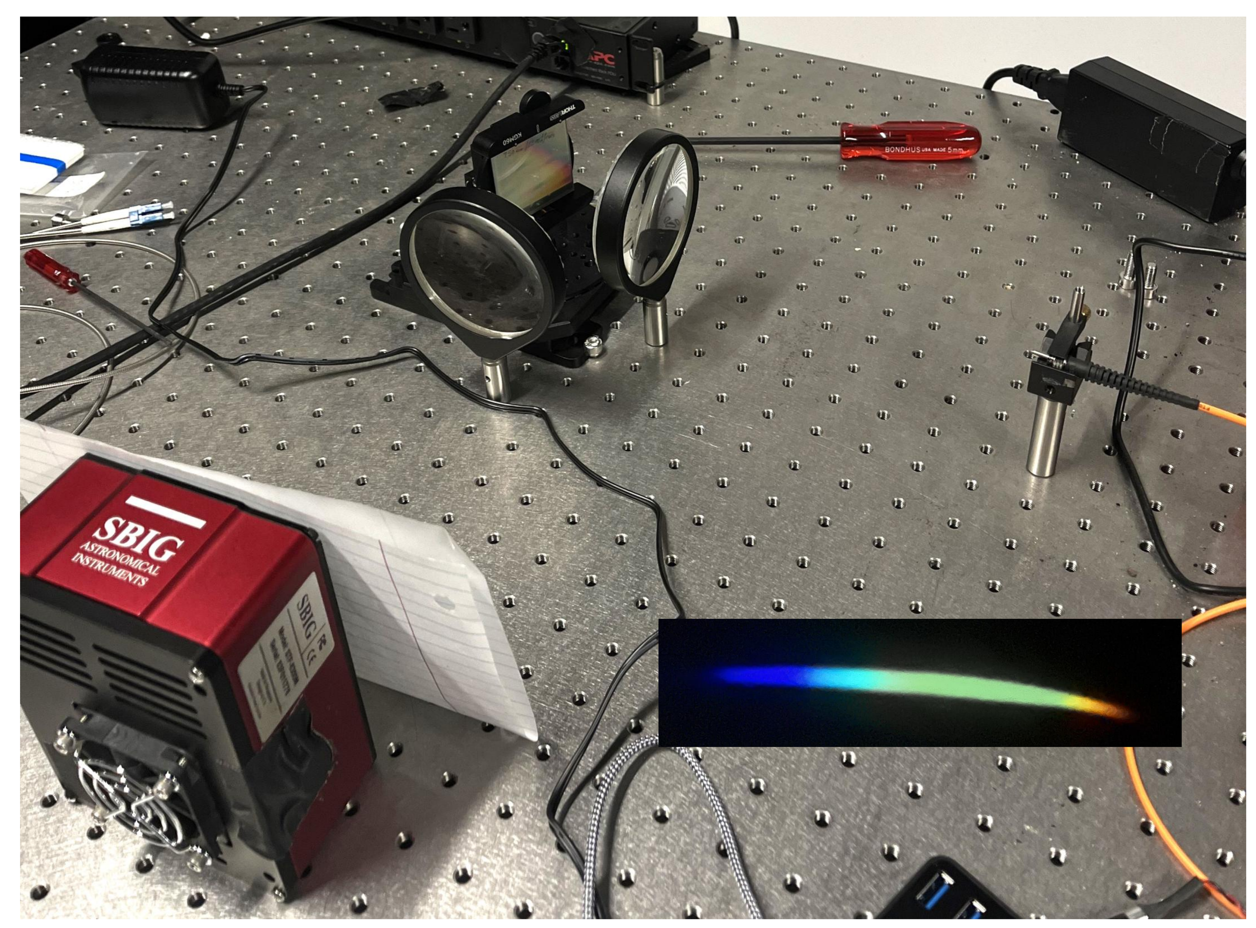
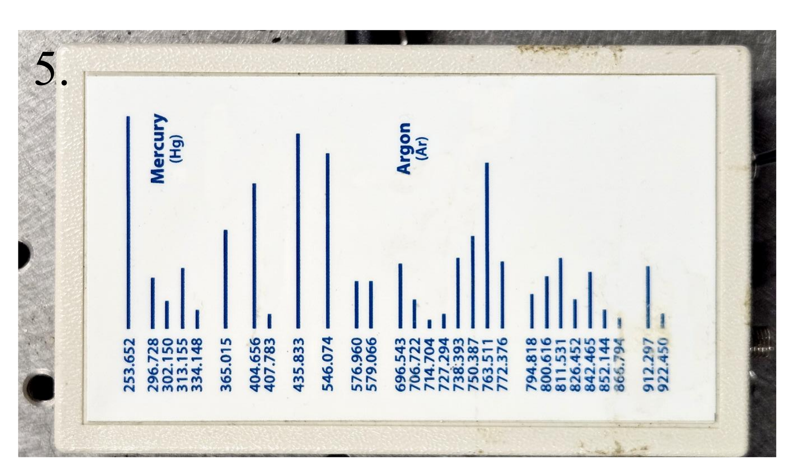
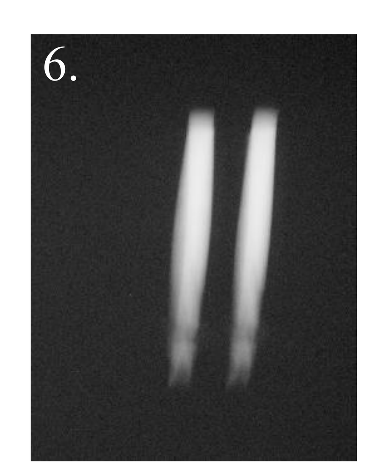


Figure 3. Initial design of the spectrograph. The light source can be seen on the top right. The lenses and grating are in the middle-top, and the detector is seen on the bottom left. A paper is placed over it to observe the spectrum that hits the detector by eye. The resulting spectrum that was hitting the detector can be seen on the bottom right. The spectrum is mostly green, which confirms the central wavelength being 560 nm.

As seen in Figures 2 and 3, the schematic was able to be transferred from SolidWorks to an optical bench. This rough sketch of a design was used to confirm the calculations were accurate, and the spectrum that the detector was seeing can also be seen in Figure 3. The light source was then changed to a Mercury Argon Lamp seen in Figure 5. The detector reading of the lamp is shown in Figure 6.





Figures 5 and 6. Mercury Argon Lamp scale and results from the detector. The 576.960 and 579.066 nm lines from left to right.

CURRENT DESIGN

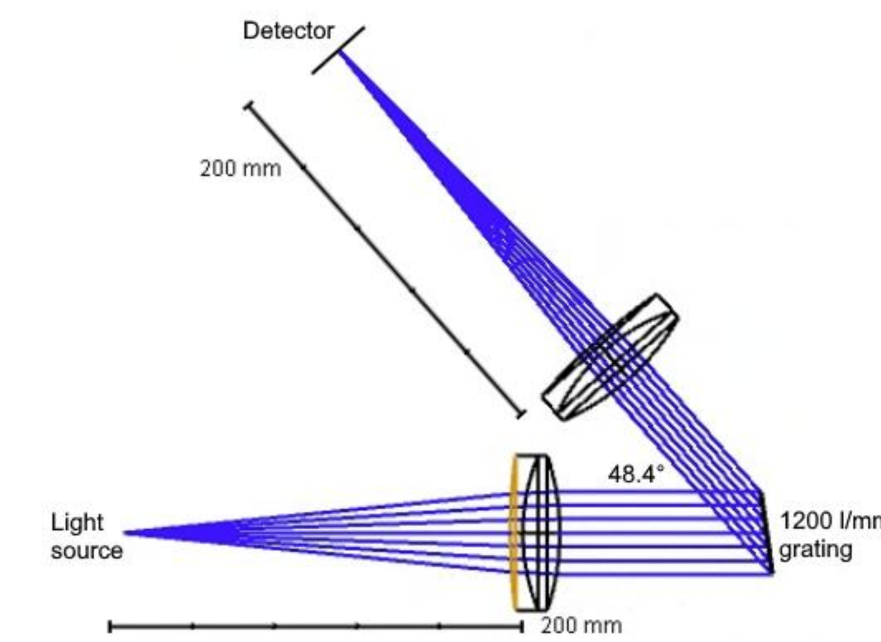


Figure 7. Zemax updated schematic for 810 nm.

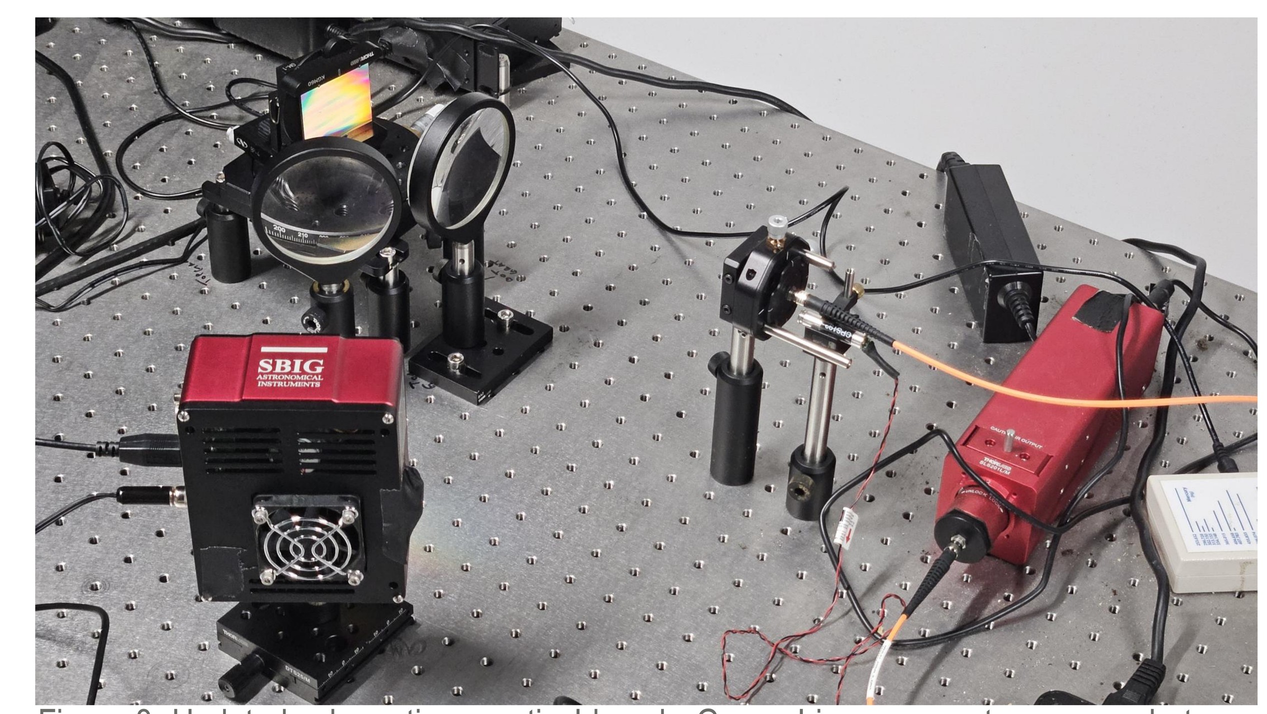


Figure 8. Updated schematic on optical bench. General improvements were made to account for elevation alignment.

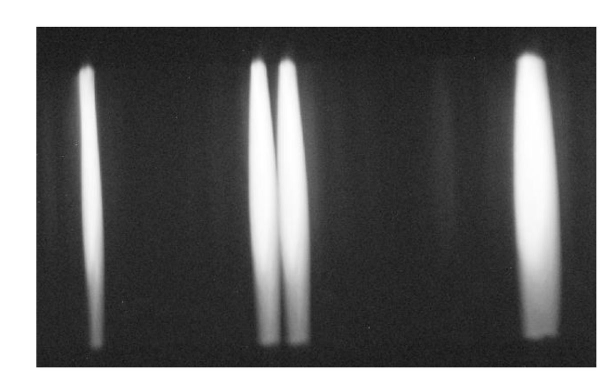


Figure 9. Mercury Argon Lamp results from the detector. The 772.4, 794.8, 800.6, and 811.5 nm lines are shown from left to right.

For the 810 nm calibrated design, the major change was the incident angle to be -8°. The mounts were also placed on adjustable stands to aid in elevation alignment. The detector was focused to a focal length of about 180 mm. Although the detector images are clear, the detected wavelengths are not supposed to be long. Currently, the design is being adjusted so that the detected wavelengths are smaller and circular.

CONCLUSION

The design of the spectrograph continues to be focused as it's calibrated for the 810 nm wavelength. For future integration, it will likely be developed into a cage system and sent to Fermilab for further use.

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