DEVELOPMENT OF A COMPACT HIGH-RESOLUTION SPECTROGRAPH WITH OPTIMISED MECHANICAL COUPLING FOR CASSEGRAIN TELESCOPES WITH ALT-AZIMUTH MOUNTS

M. Viveganandam [1, 2*], J. Adassuriya[2] and K.P.S.C. Jayaratne[2]
[1]Department of Mechanical Engineering, The Open University of Sri Lanka, Sri Lanka
[2]Astronomy and Space Science Unit, Department of Physics, University of Colombo, Sri Lanka

Spectroscopy is a vital tool in astronomical research, providing insights into the properties of celestial objects. The spectrographs separate the incoming light from the telescopes into constituent wavelengths and record the resulting spectra. A high-resolution spectrograph provides a spectrum with hidden details of the properties of molecules and atoms in stellar objects. However, integrating standard spectrographs with Alt-Azimuth telescopes mounts is mechanically impossible due to the lack of space between the telescope and the mount. This abstract presents the development of a compact high-resolution spectrograph tailored for such telescopes, addressing key mechanical engineering aspects. The proposed spectrograph model is designed for the 11-inch Cassegrain type Alt-Azimuth mount telescope at the Astronomy and Space Science Unit, Department of Physics, University of Colombo. This research utilises mechanical design principles and manufacturing processes to couple a spectrograph with Cassegrain telescopes. The newly introduced concave lens between the collimator and the slit provides an adjusting mechanism of the light cone which falls on the collimator and thereby maximising resolving power of the spectrograph. This ongoing research focuses on developing robust coupling mechanisms and fabrication techniques to seamlessly integrate a compact high-resolution spectrograph with Alt-Azimuth telescopes, aiming to address key mechanical engineering challenges and enable powerful spectroscopic analysis.

Keywords: Spectrograph, Mechanical Design, Alt-azimuth Mount, Resolving Power

[*]*Corresponding Author: vmadu@ou.ac.lk*

DEVELOPMENT OF A COMPACT HIGH-RESOLUTION SPECTROGRAPH WITH OPTIMISED MECHANICAL COUPLING FOR CASSEGRAIN TELESCOPES WITH ALT-AZIMUTH MOUNTS

M. Viveganandam [1, 2*], J. Adassuriya[2] and K.P.S.C. Jayaratne[2]

[1]Department of Mechanical Engineering, The Open University of Sri Lanka, Sri Lanka

[2]Astronomy and Space Science Unit, Department of Physics, University of Colombo, Sri Lanka

INTRODUCTION

In astronomy, spectrographs are fundamental analytical tools used to analyze the properties of light emitted from stellar objects. They work by dispersing incoming light into its component wavelengths or frequencies, allowing astronomers to record and examine the resulting spectrum (James John, 2007). High-resolution spectrographs play a crucial role in revealing hidden details within stellar spectra, providing insights into the intricate properties of molecules and atoms present in distant cosmic phenomena.

Conventional spectrograph configurations are ideally matched with telescopes equipped with equatorial mounts and focal arrangements like the Cassegrain focus (Astrosurf, 2023). Nevertheless, integrating standard spectrographs with telescopes employing Alt-Azimuth mounts poses a hurdle, necessitating a tailored design to guarantee peak functionality and efficiency due to the lack of space between the telescope and the mount as shown in the Figure 1 (Celestron LLC, 2022). Leveraging mechanical design principles and advanced manufacturing techniques, the research aims to surmount the inherent obstacles posed by coupling spectrographs with Alt-Azimuth telescopes. The seamless integration of standard spectrographs with telescopes boasting Alt-Azimuth mounts presents a formidable challenge, particularly concerning mechanical coupling and weight distribution.

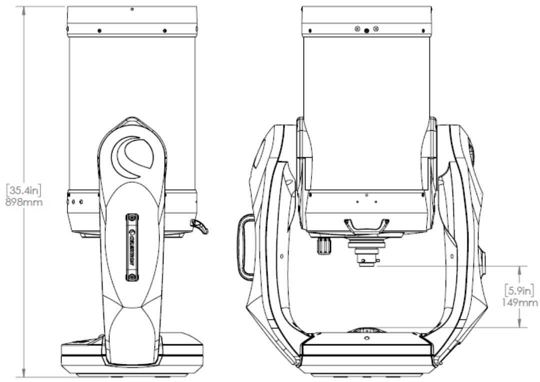

Figure 1: 2D view of CPC 1100 (Celestron, 2022)

To address this challenge and equip astronomers with a potent instrument for examining stellar phenomena using compact telescopes, including 11-inch Cassegrain Alt-Azimuth models, a novel compact high-resolution spectrograph is proposed for development. The principal aims of this study encompass the design and fabrication of a spectrograph and coupling mechanism and calculation of mounting weight to avoid detrimental effects on telescope functions optimized specifically for seamless integration with such telescopes, as well as the determination of optimal grating and diffraction angles, alongside exploration of stellar parameters pertinent to oscillation models.

The developmental trajectory of this compact spectrograph encompasses several pivotal stages. Initially, meticulous design and optimisation of the optical system using software like Solidworks is imperative to ensure precise alignment and compatibility with the 11-inch telescope. This phase is crucial for overcoming the distinctive challenges posed by Alt-Azimuth mounts and Cassegrain focal arrangements, thus facilitating seamless fusion of the spectrograph with the telescope.

The research also delves into the intricate mechanical considerations vital for preserving the integrity of the telescope's core components. When mounting the spectrograph on the eyepiece part of the telescope, careful attention must be paid to maintaining balance and avoiding any detrimental effects on the motors responsible for holding the telescope barrel and its auto-tracking system. Calculations are conducted to assess the necessity of counter masses on the other end or object piece of the telescope to offset any potential imbalance introduced by the spectrograph. By undertaking these meticulous calculations and ensuring the compatibility of the spectrograph with the telescope's mechanical framework, the research aims to protect the integrity of the telescope's critical components while enabling groundbreaking spectroscopic analysis of celestial phenomena. The selection of appropriate grating and diffraction angles assumes paramount importance in attaining high-resolution spectra. Rigorous experimentation and analysis are undertaken to identify the most suitable parameters, ensuring the acquisition of accurate and intricate spectral data.

The final phase involves rigorous testing of the compact spectrograph through observational campaigns targeting diverse stellar objects. These observations yield spectra, serving as a conduit for extracting invaluable insights into the properties and attributes of the observed celestial bodies.

In summation, the development of this compact high-resolution spectrograph represents a significant stride forward in astronomical instrumentation. Its compatibility with 11-inch Cassegrain Alt-Azimuth telescopes bestows astronomers a formidable tool for scrutinising the characteristics of stellar entities with heightened precision and fidelity.

OBJECTIVES

- Design and optimise the optical system.
- Determine a suitable collimator mirror, grating and diffraction angle.
- Construct the spectrograph and design the coupling mechanism
- Calculate mounting weight to avoid detrimental effects on telescope functions.
- Spectroscopic Observation of stellar objects using manufactured spectrograph.

METHODOLOGY

- Design and optimise the optical system for spectrograph using Solidworks, focusing on integration with the 11-inch telescope.
- Employ mechanical design principles to develop coupling mechanisms for integrating the spectrograph with Cassegrain Alt-Azimuth telescopes.
- Optimize fabrication techniques to ensure high precision and reliability, taking material selection and manufacturing processes into account.

- Calculations to determine the counterweight of the spectrograph to maintain telescope balance and functionality

RESULTS AND DISCUSSION

Despite facing obstacles stemming from the lack of exact internal component dimensions, we successfully formulated the light path layout through an innovative approach. Rather than relying on internal measurements, we determined the telescope's focal point by making a distance image on a screen and assessing the telescope's outer dimensions.

A diagonal with a plane mirror will be introduced as a coupling mechanism between the telescope and the spectrograph to achieve the desired light path. The adjustable mechanism is also included to make sure the slit is positioned at the focal point of the telescope. The diameter of the collimator mirror was determined, considering parameters such as beam diameter and optical tube diameter, given that the spectrograph is intended to be mounted atop the telescope.

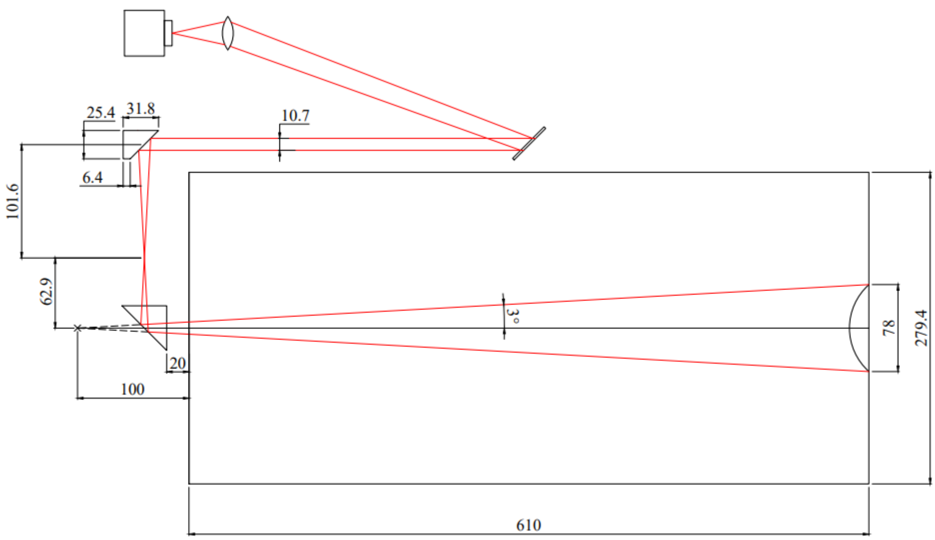

Figure 2: Lightpath layout

Using the focal point of 80mm from the telescope's outer edge as a starting point, the other dimensions required for the design were finalised. Specifically, the modified star diagonal with the plane mirror was positioned 20mm from the outer edge of the telescope. As depicted in Figure 2, the beam was bent 90° and focused vertically on a slit at a distance of 62.9 mm from the axis. The resolution of the spectrograph depends on the width of the light beam fallen on the grating.

Therefore the maximum width of the light beam depends on the diameter of the light cone fallen on the collimator mirror. As shown in Figure 2, the light cone from the collimator mirror was 10.2 mm which was very small to achieve high resolution. Therefore maximising the light cone fallen at the collimator is a key parameter to increase the resolving power of the spectrograph. To achieve this condition we newly introduced a concave lens in between slit and the collimator and it resulted a beam with 21.8mm from the collimator mirror. Also by adjusting the position of the concave lens it is possible to increase or decrease the light cone falling on the collimator. Hence this design is capable of coupling with a similar size cassegrain telescope adjusting the optimal condition of the resolution. The final design and the dimension of the proposed spectrograph is shown in Figure 3.

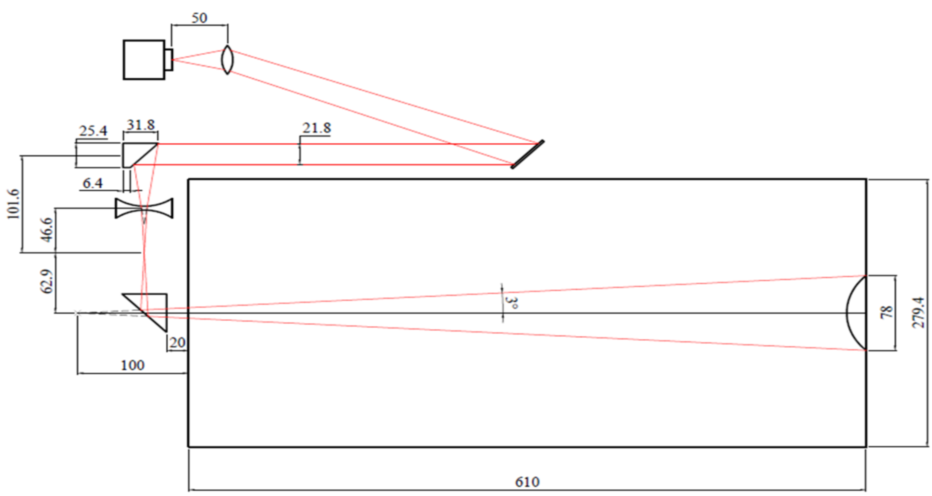

Figure 3: Light path layout with a new concave lens

Considering the beam diameter and the length at the outer surface of the optical tube, a collimator mirror with a focal length of 101.6 mm and a diameter of 25.4 mm was selected (Edmund Optics, 2024). This choice ensures the production of a parallel beam measuring 21.8 mm in size from the collimator mirror. Consequently, an ideal 25 x 50 mm grating will be appropriate to this design (Edmund Optics, 2024).

Based on the size and dimensions of the selected optical components, a comprehensive CAD design was created using Solidworks. Figure 3 illustrates a compact spectrograph with all necessary components integrated for seamless mounting onto the telescope. The 2D drawing of the spectrograph is depicted in Figure 4.

Figure 3: CAD of the Spectrograph

The research has made significant progress in developing the light path layout and CAD design for the spectrograph. Up to this point, the successful finalization of the slit placement, collimator mirror selection, and grating selection has been achieved. The concave lens was included in the design because the light beam at the collimator mirror was not large enough to proceed. The positioning of the diagonal mirror has played a crucial role in determining the vertical height of the spectrograph, as well as the selection of the collimator size and focal length.

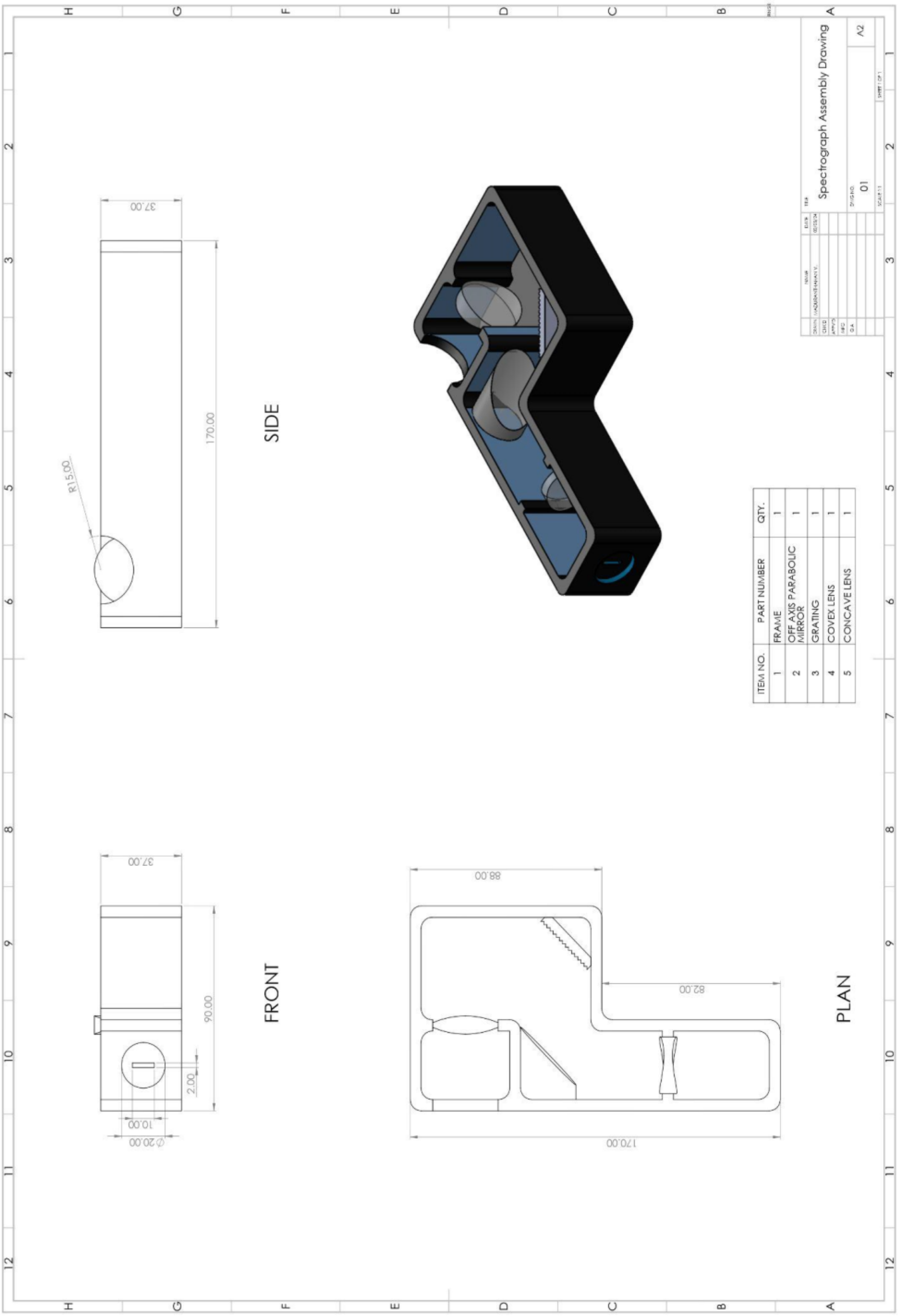

Figure 4: 2D Drawing of Spectrograph

CONCLUSION

Moving forward, the task of integrating standard spectrographs with telescopes featuring Alt-Azimuth mounts will be tackled, posing challenges in mechanical coupling and weight distribution. Mechanical design principles and manufacturing processes will be utilised in this research to couple a spectrograph with Cassegrain telescopes. Precision and reliability will be ensured through fabrication optimisation, while counter-mass requirements for telescope balance will be determined by calculations. The focus of this ongoing research will be on developing robust coupling mechanisms and refining fabrication techniques to seamlessly integrate a compact high-resolution spectrograph with Alt-Azimuth telescopes, aiming to address key mechanical engineering challenges and enable powerful spectroscopic analysis. Finally the design will be a physical model, which will further enhance the compact spectrograph's significance in advancing astronomical instrumentation and improving observational precision.

REFERENCES

1. James, J. (2007). Spectrograph Design Fundamentals. Cambridge University Press. https://doi.org/10.1017/CBO9780511534799
2. Celestron LLC. (2022). CPC 1100 GPS, Product dimensional drawing. https://celestron-site-support-files.s3.us-east-1.amazonaws.com/support_files/CPC%201100%20GPS.pdf
3. Instruction Manual, Celestron CPC series (2009), Celestron.
4. Astrosurf. (2024, March 4), Theoretical Parameters for the Design of a "Classical" Spectrograph (2023). http://www.astrosurf.com/buil/us/stage/calcul/design_us.htm
5. Edmund Optics. (2024, May 10), Available sizes and dimensions of optical mirrors, lenses and gratings. https://www.edmundoptics.com/