Long Slit Spectrograph using Asymmetric Offner Relay

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ABSTRACT

Spectrographs are a key instrument in astronomical observation. They spread out incoming light into its component wavelengths. Analyzing the spectra produced by spectrographs can tell us the elemental composition and radial velocity of what we are looking at, which can provide context clues to help us figure out how old an object is, how far away it is, and if a planet may contain life. In the instrument described here, a long slit spectrometer is designed and assembled, utilizing an asymmetric Offner relay. Due to the asymmetry of the Offner relay, an accessible pupil is formed, where a grating is placed to disperse the light. It is designed to utilize 3D printing in its construction, and commercially available parts, and is designed for mounting on a C14 Celestron telescope.

INTRODUCTION

Inside instruments, light must be moved around to reach the detector, while trying to deform it as little as possible. One of the ways to do this is with an optical system know as an Offner relay. The Offner relay makes use of the characteristics of spherical mirrors to transport the light with minimal aberrations. Generally, an Offner relay consists of two spherical mirrors, one convex and one concave, with the radius of curvature of the concave one being twice that of the convex. A typical Offner relay is depicted in Figure 1A. However, Offner relays can also be asymmetric (Figure 1B), a fact which was recently noted[1].

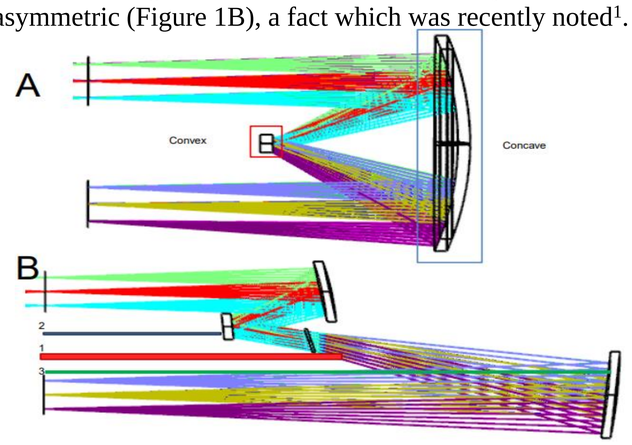

Figure 1. A: A symmetric Offner relay, where the radius of curvature (RoC) of the concave mirror is twice that of the convex mirror
B: An asymmetric Offner relay. The RoC of the third mirror is determined by the RoC of the first two mirrors in the relay, by the equation $r_3 = r_1 r_2/(r_1 - r_2)$[1] .

The benefit of an asymmetric Offner relay is that an accessible pupil is formed, while maintaining all other properties of a normal Offner relay. An accessible pupil is a place where all the light in a system passes through only once. This is useful as it allows us to place something like a filter or grating in the pupil.

DESIGN

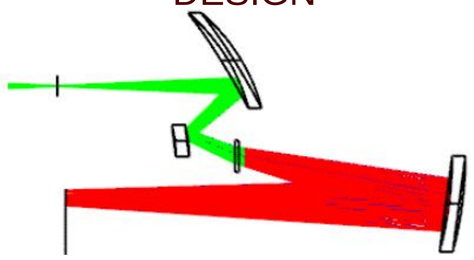

Figure 2. The optical setup of the spectrograph as seen in Zemax OpticStudio, an optical design software. Light is gathered by a Celestron C14 telescope and comes through a slit, hitting the first mirror, the second mirror, passing through a grating and dispersing, then hitting the final mirror and arriving at the detector.

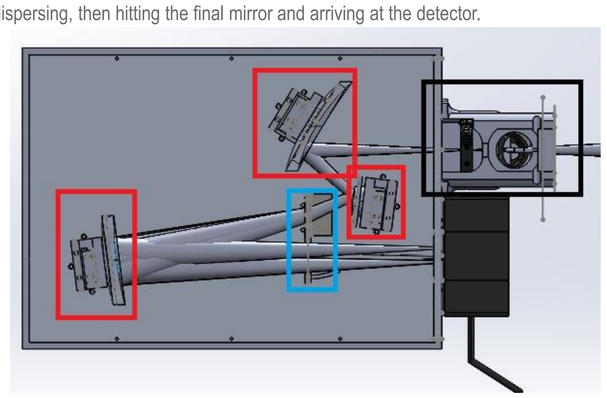

Figure 3. The instrument design in Solidworks, a CAD program. In red are the three mirrors and mounts. In blue is the grating mount. In black is the telescope interface/guide camera housing. Inside that housing is an adjustable slit, a 50/50 beam splitter at a 45 degree angle, a mount for a camera and a guiding camera, and an attached threaded part for attaching to the telescope.

The optics sit on a baseplate which is designed to precisely locate each piece and is to be machined out of aluminum. It will be enclosed by an easily assembled case, designed to be similar to a computer case, which will be 3d printed and screwed together.

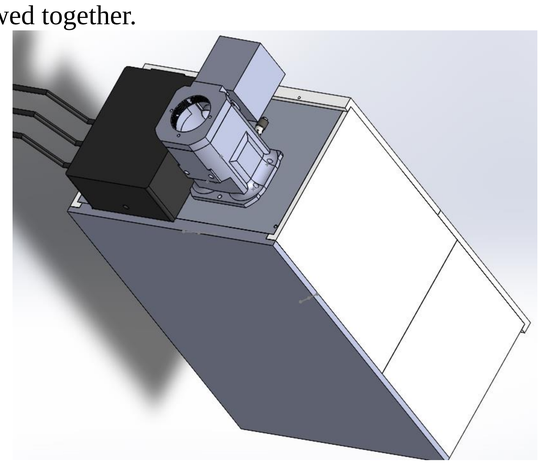

Figure 4. Outside view of the case, interface, and detector. The interface has already been manufactured, and the case will be 3d printed out of PETG (polyethylene terephthalate glycol) as a final step for assembly.

CURRENT WORK

Most of the parts that are necessary have been ordered and have arrived. The first of three major sections has been finished, that being the guide camera housing seen in Fig. 6. The housing contains a slit, a beamsplitter, a camera, and a threaded interface for a C14 telescope. The interface was machined from aluminum, and the main housing was 3D printed with PETG. The other major sections are the case, including base plate, front plate, and 3d printed enclosure, and the optics: the mirrors, mirror mounts, and grating mount.

Figure 5. Point source microscope setup.

Currently, I am working on adhering the mirrors to the mounts. I will do this with RTV (room temperature vulcanizing) silicone adhesive. In order to make sure that the mirrors are at the same height on each mount, I am using a point source microscope (PSM). A PSM is an instrument which allows opto-mechanical assemblies to be aligned precisely, by referencing both mechanical and optical reference points.

Figure 6. The parts which have already been manufactured. The guide camera housing and telescope interface, the mirror mounts, and the grating mount. The mirrors have not been placed yet on the mounts, and the grating has not been placed yet in its mount.

CONCLUSION

The design of a spectrograph utilizing an asymmetric Offner relay is nearing completion. Once finished, it will be tested and used at the TAMU teaching observatory on the C14 Celestron telescope

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

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[1]Rakich, Andrew ; Rogers, John R. "A generalized Offner relay with an accessible pupil" December 2020

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