Portable Schwarzschild Spectrometer

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Background

- Spectrometers collect data from light.
- Different molecules and atoms have different spectra which can be distinguished with a spectrometer so they allow the chemical analysis of an object from a distance.
- Limitations of most spectrometers:
  1. Large in Size
  2. Expensive
  3. Gallium Arsenide and Silicon camera components cost a lot.

Operation

- See Figure 1.
- Light enters through the primary slit.
- Light continues goes through a mask and the remaining signal hits the primary mirror.
- From there it bounces off to the secondary mirror and bounces to a Littrow prism to be refracted, reflected and then refracted again.
- From exiting the Littrow prism, the light bounces off to the secondary mirror again.
- Light bounces to the primary a second time.
- From the primary remaining signal goes through the mask on a different end.
- This leads to a micromirror array which helps to encode the waves into data.
- From the micromirror array, the signals are bounced off a mirrored hypotenueal prism.
- The waves are focused through a lens to a dichroic mirror.
- The dichroic mirror reflects low wavelength spectra of visual light to a silicon diode and lets infrared spectra pass through it which leads to a gallium arsenide diode.
- The diodes are able to process and digitize data. The Silicon Diode's effective wavelength range is in the visual spectrum and the Gallium Arsenide Diode's effective wavelength range is in the infrared range.
- The data is read through the use of reverse Hadamard transforms which then gives the perceived spectrometer outputs.

Acknowledgements

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Objective

- Construction of a compact and inexpensive spectrometer that is portable and operates in visible and near IR ranges.
- Lightweight enough to be carried by a drone to collect data from a large environment.
- Cheap enough so that it is an affordable option to be used for daily tasks such as monitoring water content in plants to prevent overwatering.
- The entire apparatus should be compact (this design can fit in a hat).

Design

- The project construction started out in FRED optical engineering software,but we still had to determine the mechanical structure.
- From FRED, files were migrated to Solidworks to design infrastructure to support the optical system (fig. 2).
- After Solidworks, the parts are purchased from ThorLabs or machined. The parts that did not need strict specifications were sent to Makerbot (fig. 3) and 3D printed in black ABS at at at least 30 to 50 infill.
- Then the apparatus combining both printed and purchased parts is constructed.
- Littrow prism disperses light; a prism used instead of a diffraction grating to avoid multiple grating orders (visible/NIR).
- Supporting parts was black to absorb stray light.
- Silicon Diodes and Gallium Arsenide Diodes and micromirror array save space and cost compared to cameras used in standard spectrometers. Hadamard transform imaging on micromirrors encodes spatial and spectral information.

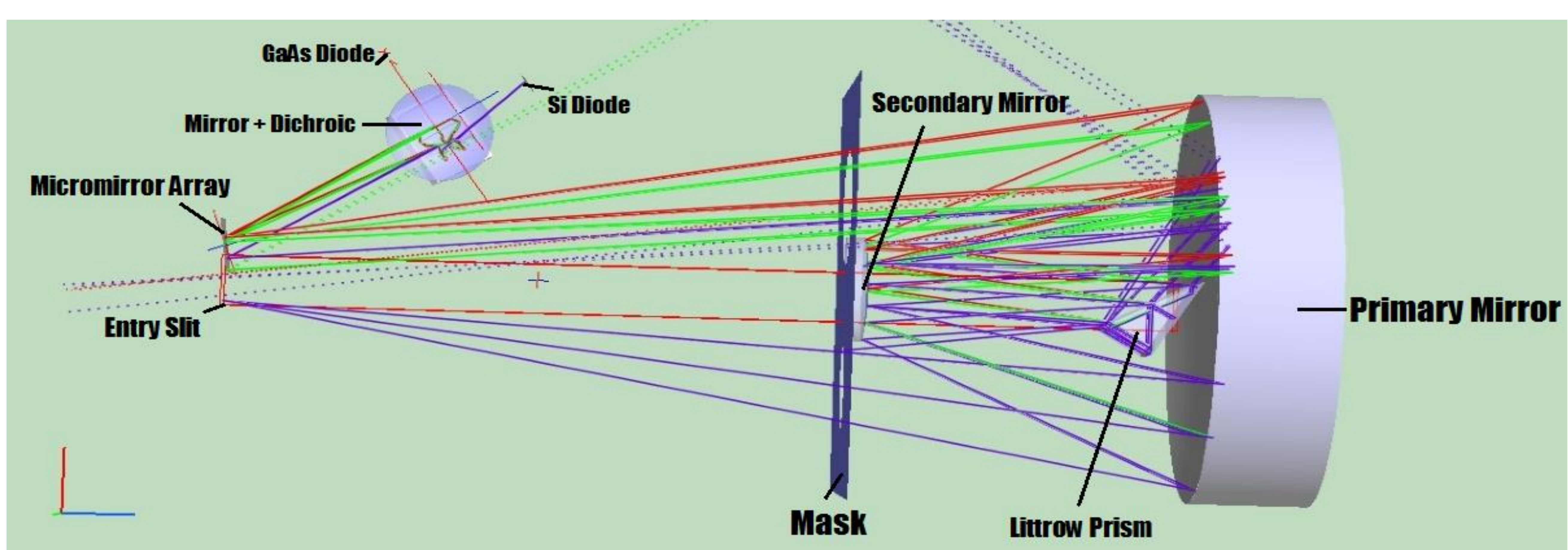

Figure 1. The FRED representation of the spectrometer, showing the optical elements inside the system as well as the way the light travels.

Future Development

- Currently have finished making printed parts.
- Will assemble at a future time.
- A spectrometer should be able to perform the following measurements:
  1. Identify the chemicals in an object
  2. Identify the concentration
  3. Recognize the position of the analyzed object when in flight

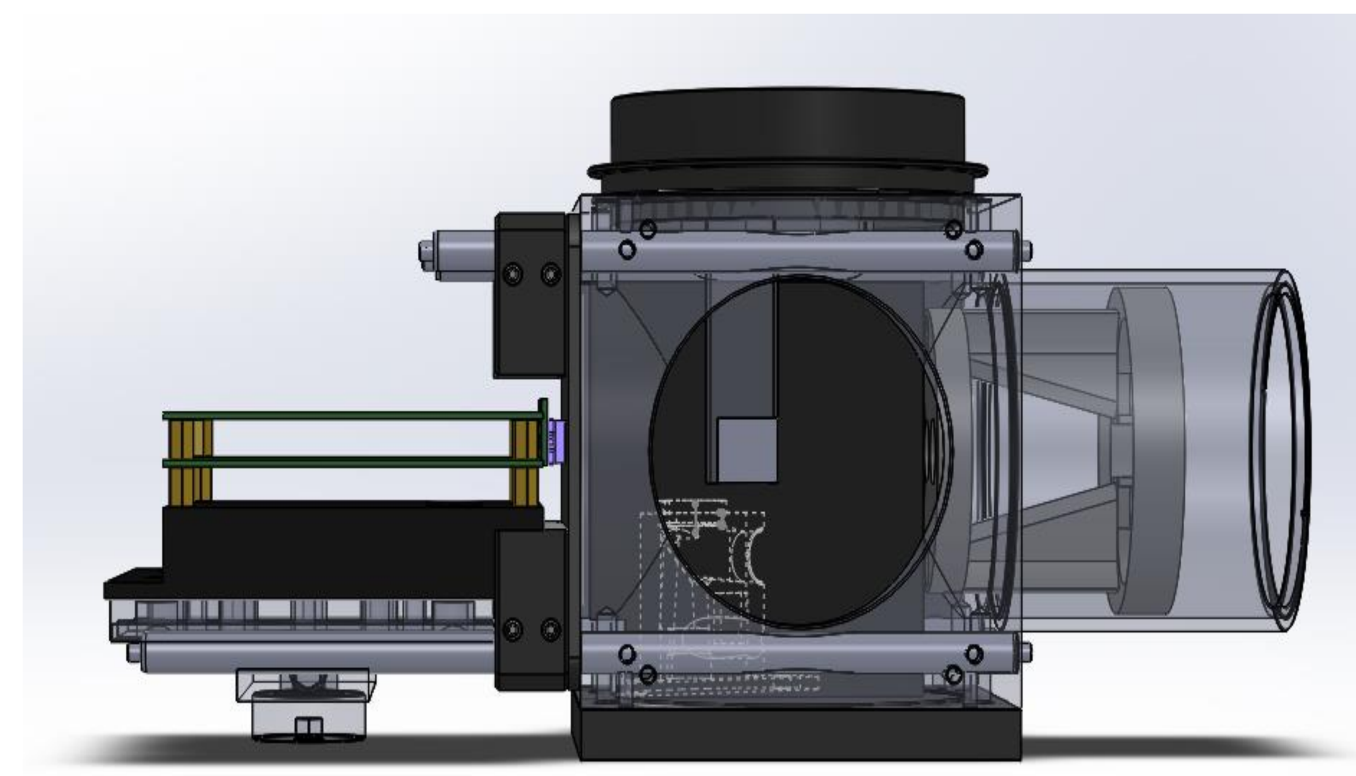

Figure 2. The Solidworks representation of the spectrometer, showing the infrastructure. Outlined in this figure is Figure 3.

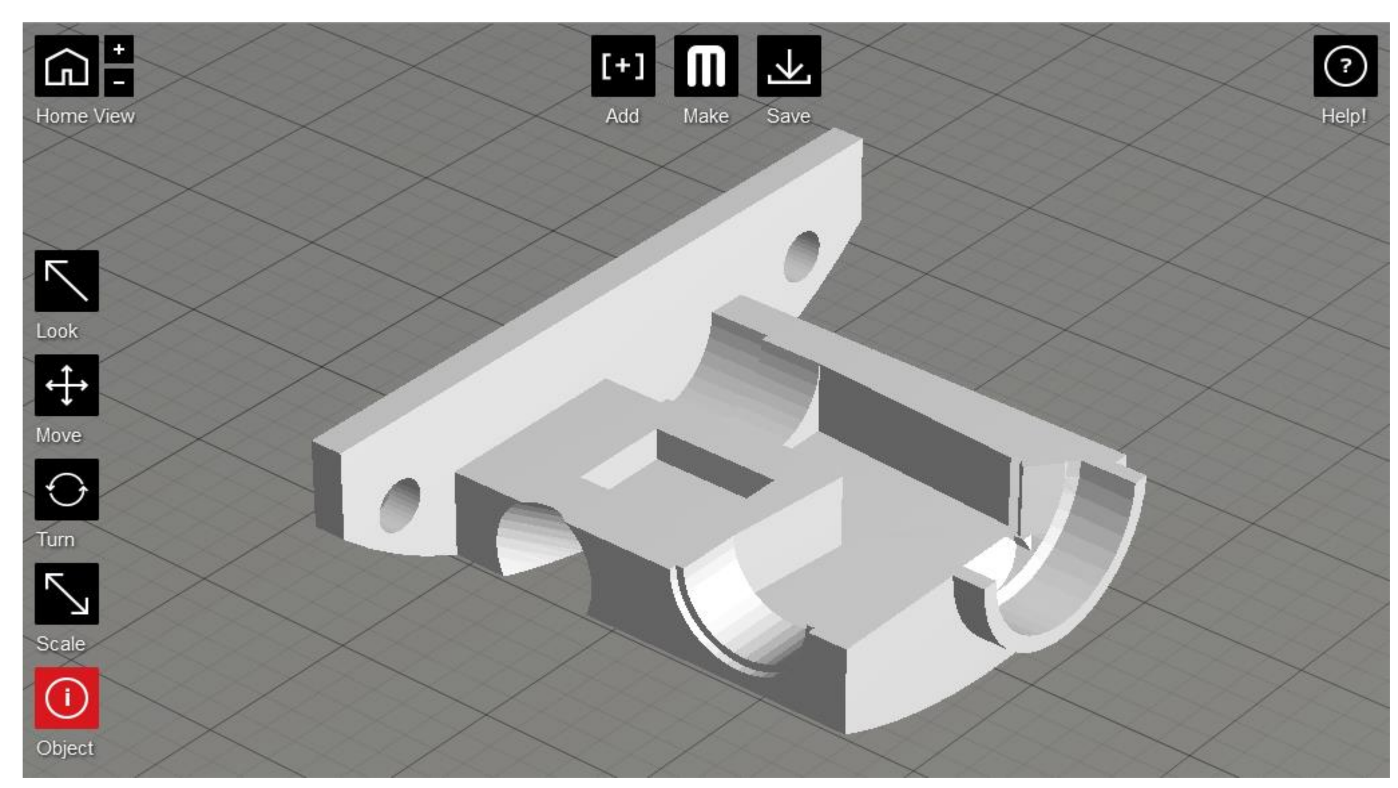

Figure 3. A part representation in Makerbot. The small squares are all 2 mm by 2 mm in size.