Semester: Spring 2024

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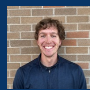
NAU NORTHERN ARIZONA UNIVERSITY
Mechanical Engineering

Drone Mountable Enclosure and Optics for Eco-Sensing Optical Spectrometer

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Abstract

A hyperspectral VIS-NIR (Visible to near infrared wavelengths) solar CCD spectrometer to be used to analyze forest health. Composed of a series of optics to focus and isolate individual wavelengths for detection enclosed in a polycarbonate 3D printed enclosure. The final design incorporates a field of view of 45 degrees and allows for focused light in the wavelength range of 400-1000nm. Weighing just under 3 lbs and being smaller than 10x10x5in, this allows the final product to be mounted on a UAV for aerial data collection. This device is capable of operating in standard weather and temperatures including heavy rain/snow as well has an operating temperature range of 0-50 °C. The enclosure protects the internal components (both optical and electrical) from liquids and dust. Design software's used include Zemax, Onshape, and MATLAB.

Requirements

- Optical effectiveness
  - Wavelength range of 400-1000nm
  - Secured for flight
- Enclosure requirements:
  - Lightweight (<3.6lbs)
  - Fits within drone payload area
  - Drone mountable
  - Durable
  - Ease of access (can access in field to acquire data and in lab to align optics)
  - Stable internal conditions
    - Dust and water resistant
    - Temp range of 0-50 °C

Methods

- Started with simulation design via Zemax to comply with design criteria
- Then completed an OnShape CAD model to house optics and leave space for future EE components which will record the data
- Made sure housing met standards of the ingress of elements for the operating environment
- 3D printed portions to test for accurate fits

Printed full enclosure:
- Integrated EE components
- Performed testing on the enclosure
- Used laser to align optics and spectrum tubes to calibrate the recording of data.
- Specific order of operations required for assembly:
  - O-ring: RTV layer then place o-ring in groove
  - Heat-set: use soldering iron to heat the inserts to melt into designed holes in print material
  - Optics: grating mount, vertical mounts with lenses, grating lens, slit, and entrance slit.

Results

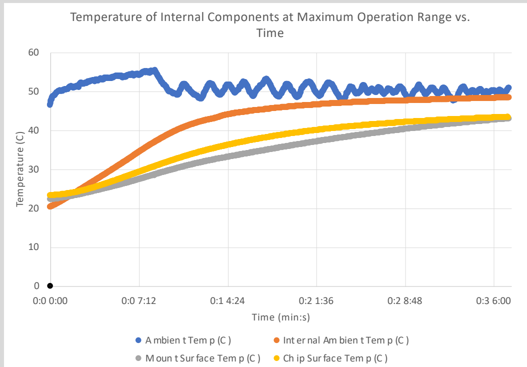

Figure 1: Heat Test Results

Figure 2: Final CAD Design of Enclosure

Figure 3: Finalized Lens Setup (Isometric)

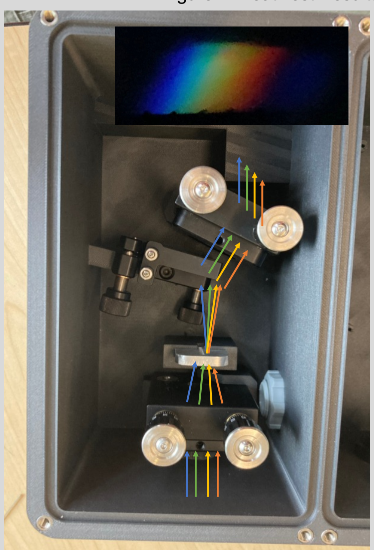

Figure 4: Finalized Lens Setup (Top View with ray trace and "results")

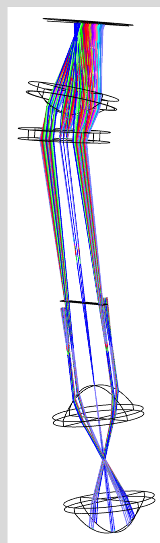

Figure 5: Zemax Light Distribution

Figure 6: Final Enclosure

Figure 1: Within ambient air of 50 °C, after 40 minutes, the internal temperatures of the air, mount, and chip were all below the ambient external temperature of 50 °C.
Figure 2: CAD final design with all purchasable items included.
Figure 3: Optic mount layout shown in isometric view with a half-height print for easy viewing.
Figure 4: Optic mount layout viewed from above with ray tracing estimates and a rough results image take via phone camera while the device was pointed towards a ponderosa pine. Image is roughly in location of detector.
Figure 5: Zemax software showing full lens layout and ray tracing, grating is present which allows for a rainbow at the detector (at the top of the figure).
Figure 6: A second to final model showing full print as well as all parts inputted in, iterated after due to testing being done on this enclosure as well as late changes from the EE team.
Figure 7: transmitted light that will be read by the detector in an ideal light scenario

Conclusion

- Successfully produced a reasonably affordable design to increase access to spectroscopy to help further forest health research, less than $800.
- Design meets given requirements:
  - VIS-NIR wavelength range of 400-1000nm
  - Built with market available items and 3D printing
  - Operation of 0-50 °C
  - Weight and size within 3lbs and 10x10x5in respectively
  - Ingress rating beyond expected environmental conditions of rain and temperature changes.
- In the future:
  - Improving design to incorporate a wider FOV and extending the wavelength range.
  - Spectrum Tube calibration test to align data intake.
  - Research using non-adjustment mounts to reduce weight.

Transmitted Light Data

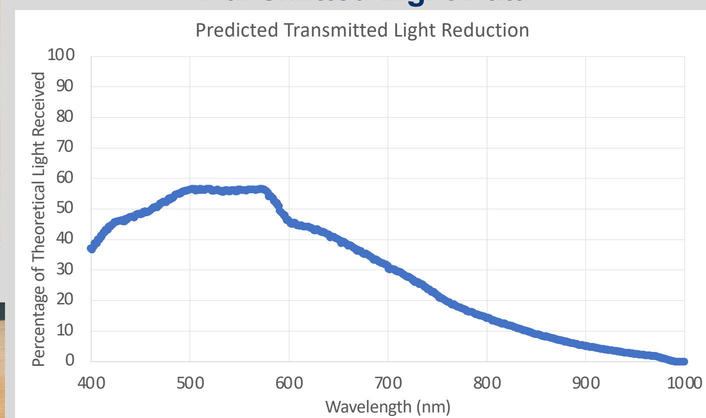

Figure 7: Light Transmission Percentage Data

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