Building an LED Light Source as a Calibration Tool and Testing Device for a Doppler Imager

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***Abstract* - In order to properly calibrate and test a previously constructed doppler imaging device, a LED driven light source was needed, which was built with lenses and a certain optical prescription. In order to take flat field data, calibrate the doppler imager, and to mimic the light coming from a telescope, the test bed was created using various optomechanical parts, and the prescription of the lenses calculated with a computer simulation program. The fully mounted LED light source, heatsink and driver was designed and assembly began in lab.**

***Index Terms* – Doppler Imager, Optomechanics, LED Light Source, Test Bed**

I. Introduction

A doppler imaging device created previously in lab at NASA-JPL was tested at the LICK Observatory in Mt. Hamilton, California. Images were taken from of Jupiter during opposition through an overnight observing run. Flat field data could not be taken that evening due to the image not being completely flat, so the data could not be properly analyzed until a flat field image could be taken with the doppler imager in the same configuration in which data was taken. Because of this and other reasons which will be explained, an LED light source was needed. Along with the flat field image, future calibration and configurations could be done in laboratory with the use of this light source as well, without having to take the device to an observatory. The instrument can undergo frequent and accurate calibrations with a properly built LED test bed, enabling faster development of the device. Of course, a few requirements had to be met of this LED light source. In order to properly take a flat field image with this light source, the light coming from the chip and into the doppler imager must be collimated to ensure a flat and even image. Also, in order to imitate the light coming from Jupiter at the LICK Observatory, the LED light source must converge at the same angle that the light at the observatory converges into the imager. Therefore, careful design of the optical system needed to be done in order to ensure the correct convergence angle, as well as maintain a clear image.

II. Build Plan

In building the test bed, a few constraints needed to be kept into consideration, with the first one being the path length of the light itself. The benchtop that the doppler imager was placed on limited our LED light source path to be about a meter in length. Anything longer and it would have been too long to do any accurate testing on the test bench. Also, as mentioned before, the light needed to converge at the same angle as the telescope used for observing, so a careful lens design was necessary. The telescope used for observing converged at an angle of 3.4 degrees, or a half angle of 1.7 degrees. Using a computer software program, many different iterations of different optical designs were simulated and examined. Using a combination of plano-convex 50 mm diameter lenses, plano-convex 75 mm lenses, and a few other elements such as diffusers and pinholes, the correct image was produced and satisfied the convergence angle required.

The LED needed to be in the infrared wavelength, specifically around 770nm. The chip that was used had the highest intensity in the 780nm wavelength, which provided enough of the infrared light our purposes. That specific wavelength is primarily the wavelength the doppler imager takes images in, and would provide the best test results. Light emitting diodes in nature get extremely hot during use, and require adequate cooling to ensure the longevity of the LED chip. Also, these diodes require drivers to properly supply them with the right current and voltage. That meant that without buying a pre-mounted solution, which exceeded the budget of this project, the LED chip would have to be mounted to a heatsink and wired to a separate driver in lab. After a third-party heatsink and LED driver were sourced, the next stage was to begin assembling the light source itself.

Using a optomechanical track, various post mounts and lens mounts could be attached to the track, as one iteration is shown in figure 1. One major issue was the 75 mm lens mount and its capabilities. Having a mount that has fine adjustment capabilities in the x and y directions perpendicular to the light path is crucial for a good optical design. There was no mount that could house such a large lens and still be translatable within the mount. One solution that was arrived at was to find an adjustable post mount, which would simply change the height of the lens, and align the rest of the optical design with these large, relatively fixed lenses.

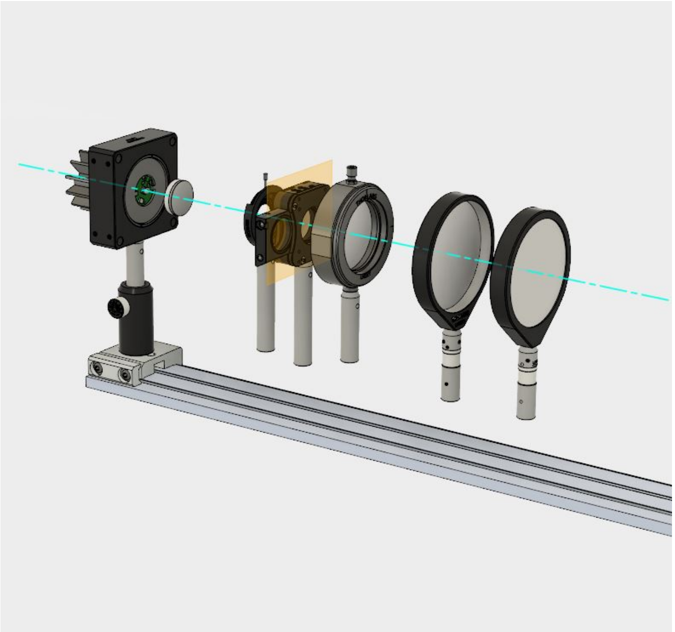

Fig. 1. Preliminary design of the optical track with all parts mounted.

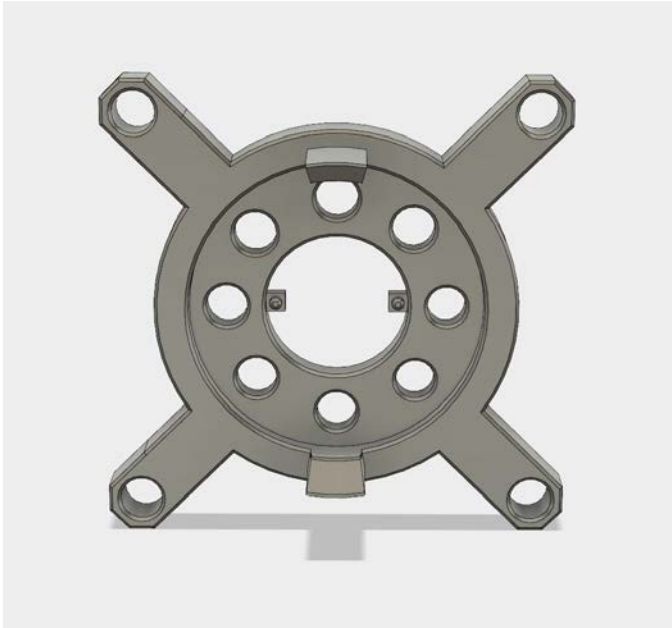

Fig. 2. One iteration of the clamp design, which would adjoin the heatsink to the LED chip.

III. Parts

As mentioned earlier, posts with lens mounts attached would be mounted to a straight track, and would hold all of the components relatively aligned with one another until further fine tuning and tweaking was necessary. Along with this, the LED light source itself, which would of course be the placed on one end of the track, needed to be assembled. This task itself consumed much of the time in lab, seeing as the driver and heatsink were both separate parts that needed to be adjoined and wired together. For this, 3-D printing was heavily involved and became a crucial part in this project.

Many of the pieces required to mount the LED chip onto the heatsink were designed and created in lab out of Acrylonitrile-Butadiene-Styrene, or ABS plastic. The operating temperature of the LED chip is anywhere from 0℃ to 40℃ according to the manufacturer, whereas the 3-D printer's extruder temperature necessary to partly melt the plastic was around 230℃. This meant that the plastic would not be affected by the heat produced from the LED chip and would be a viable option for creating a mounting solution.

In order for the LED to properly cool, maximizing contact between the LED and the heatsink was necessary. Because of this and the shape of the heatsink, a circular mount with a centered, smaller circular opening with two small tabs on either side to hold down the chip onto the front face of the heatsink was fabricated (figure 2).

With a small application of thermal paste, the LED chip would be securely fitted to the heatsink, allowing for sufficient dissipation of heat.

IV. 3-D Printing And Software

Many manufacturers or part makers for these optomechanical parts provide a design file, or CAD part free to use. Using these software files, it was extremely beneficial to assemble the test bed virtually, through the aid of other software, in order to better understand the realistic spacing and sizing of the components as they were coming together. Using an optical design software program, calculating the millimeters of spacing in between each lens proved difficult, as a system of 3 or 4 lenses becomes quite complex. Through the information given from a spot diagram and ray tracing paths, the correct prescription was arrived at, and fit to the specifications that the test bed required, such as the convergence angle, and length of track.

A small discussion of 3-D printing seems necessary seeing how crucial it was for a project such as this one. With the ability to 3-D print readily, cost effectively, and moderately easily in lab, many different parts could be made roughly to the specifications required for the project. The term roughly is used since there is always some margin of error during 3-D printing. Parts designed through CAD software would be exported to the 3-D printer, printed, and then measured to ensure it was of right sizing. With something as efficient as this, there was some trial and error involved. It proved challenging at times to ensure the plastic cooled at the same rate on all layers of the print. If the lower levels cooled too fast, by laws of thermal contraction, the bottom would warp upwards and unstick from the plate on which it was being printed on. To counteract this, a larger raft, or layer in between the part and the printing bed was printed. Initial sizing of this raft was 4 mm larger than the bottom layer perimeter. Increasing this raft to 8 mm on all sides seemed to minimize the warping of the print. On some occasions, the extruder nozzle would clog, requiring a thorough disassembly and cleaning. Because of this, the prints usually had to be somewhat monitored in order to ensure plastic was being extruded all times.

V. Next Steps

After finalizing the design, sourcing the individual parts for the LED light source itself and the lenses and their mounts, construction of the test bed can now begin. Some portions of the test bed have been successfully prototyped and assembled, such as the housing for the LED driver chip (figure 3) and the soldering of the wires to the driver, but the final assembly and track alignment still needs to take place.

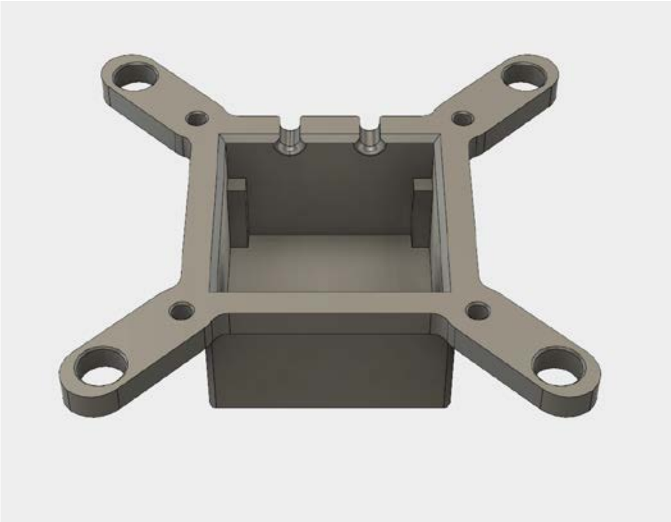

Fig. 3. Driver housing with holes on each arm for mounting purposes

Soldering the wires to the chip itself has brought some issues as well. According to the manufacturer, the chip turned out to have silver soldering pads, which were not fusing with our tin and lead solder. The power source, which in this case is a simple AC to DC converting wall plug, still needs to be soldered to the driver chip. Also, once each component is mounted on the track, careful alignment needs to take place to ensure the simulated light path is being replicated on the physical test bed. As mentioned earlier, the 75 mm lenses will not be able to articulate as freely as needed, so the overall design will have to revolve around these larger lenses.

Some further features have been considered as well for the final test bed design. Since the diode emits in the infrared wavelength, it will be difficult to see whether or not the LED is on and emitting light, which can be a hazard. For this, another smaller LED light bulb could possibly be put into the circuit to notify the tester that the chip is emitting light and should be cautious. Also, rather than simply plugging and unplugging the wall adapter, a switch needs to be wired and soldered into the circuit to allow efficient power management. Once these additional features are added and wired together, a large housing of the LED light source could be beneficial and would protect the parts from wear and tear. Once these are completed, a flat field image can be taken, and testing of the doppler imager can finally take place.

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