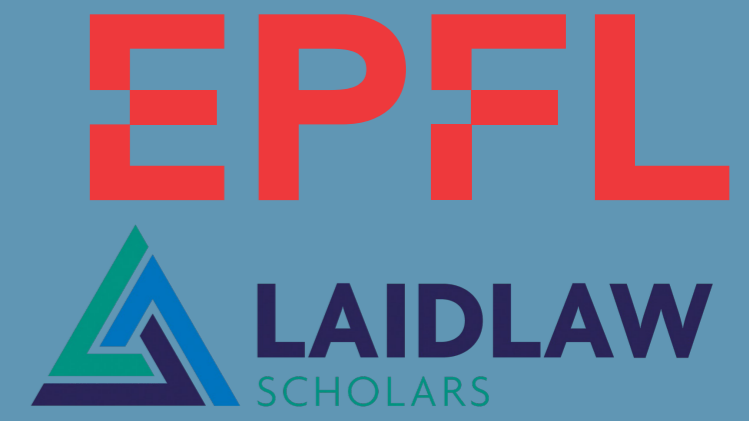


HOW TO DESIGN A LIGHT ENGINE FOR A 3D PRINTER

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Background

Tomographic Volumetric 3D printing uses a laser-based procedure to cure resin through a process called photopolymerization.

Lasers are reflected off of the surface of a Digital Micromirror Device (DMD), creating patterns that are directed onto a vial of resin, which is then solidified into the desired object.

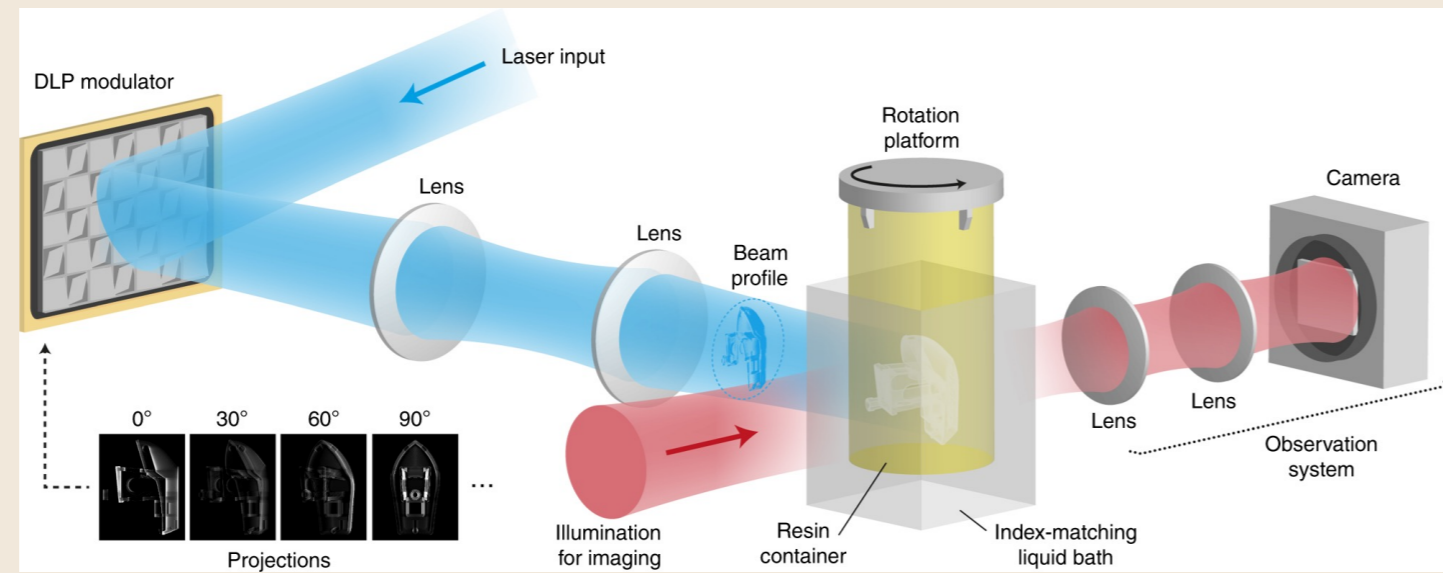


Figure 1: Layout of a Tomographic Volumetric 3D printer

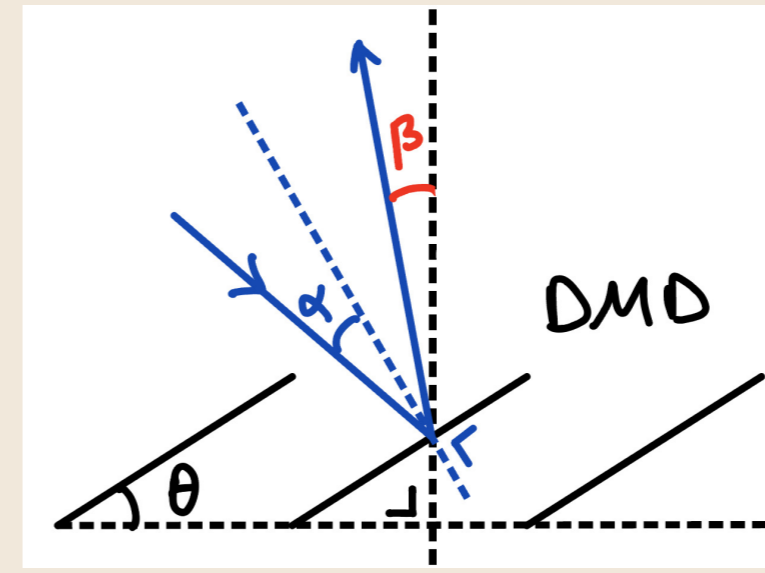


Figure 2: Diagram of the DMD's surface

A **DMD** consists of an array of tiny, individually controllable mirrors, typically arranged in a grid pattern. Each mirror can be tilted independently to direct light either toward or away from a specific point. This manipulation of light allows for precise control over the reflection and propagation of light beams.

However, this control over light beams introduces geometrical constraints. The DMD acts like a diffraction grating, meaning that diffraction orders of differing intensity may appear. This concerns the reflected beam, of angle β .

The intensity of the light beam is either mostly concentrated into a single point, the zeroth order, or equally split into multiple copies of the same point, implying higher diffraction orders.

The **goal of this project** is to develop a method of optimizing the incident angle α , for energy efficiency and reflected beam orientation. This technique must function with different wavelengths of light, allowing for the accommodation of multiple wavelengths in the printer.

These are the important angles. α is the incident angle, β is the reflected angle and θ is the pitch angle of the DMD.

Research question: How can the efficiency and versatility of Tomographic Volumetric 3D printing be optimized by systematically aligning a Digital Micromirror Device (DMD) to accommodate multiple laser wavelengths while minimizing energy loss through diffraction?

Methods

3D modeling

Using the 3D model of the previous support, we developed and designed a new system. The holder is based off of two rotation stages, counteracting each other's movement. The bottom stage is connected to the laser arm, which focuses a beam of light onto the DMD's surface, and the second stage, on which the DMD is set, is placed on top of the first one. This allows the laser arm to rotate freely, without transmitting any movement to the DMD.

Prototyping

Thanks to the laboratory's SLA printer, we were able to print a prototype. This allowed us to verify the structural stability and feasibility of the design.

Simulation

To find values of α , that generate minimal energy loss, we adapted pre-existing code from Sébastien Popoff, who writes articles about setting up DMDs and their uses. The values we chose to test were 32 and 52 degrees.

Building the setup

Using equipment from Thorlabs, an optical equipment manufacturer, we built a laser arm that focuses a 50 mW laser onto the DMD's surface.

Empirical Tests

To be able to test the desired angles, we needed a method to calculate the position of the laser arm according to the DMD. To do so, we wrote a code that takes as inputs, the incident angle α and the distance between the end of the laser arm and the DMD (to ensure the reflected beam is not cropped). The script then gives us the necessary information to calibrate our setup correctly.

The awaited results are good energy efficiency and correct reflected beam orientation.

Results

Both tests ($\alpha = 32$ degrees and $\alpha = 52$ degrees) resulted in inadequate outcomes. While showcasing high energy efficiency in the zeroth order of diffraction, the desired orientation of the reflected beam was not achieved.

Wanting to verify that obtaining the correct reflected beam orientation was possible, we calculated an angle $\alpha = 23.5$ degrees, such that β is parallel to the surface of the table and in the proper axis. However, this resulted in significant energy loss due to multiple diffraction orders

After multiple other empirical tests of trial and error, we decided that modifications to the setup were necessary. The main refinement was allowing the support to rotate backwards, around a horizontal axis perpendicular to the DMD's screen's normal. Tilting the whole support backwards allows the reflected beam to shine in the correct orientation. However, modifications also had to be made to the code to compensate for this change.

Having decided to test the first angle ($\alpha = 32$ degrees) with the modified setup, the results were much more satisfying. Both the reflected beam's orientation and the energy efficiency were sufficient.

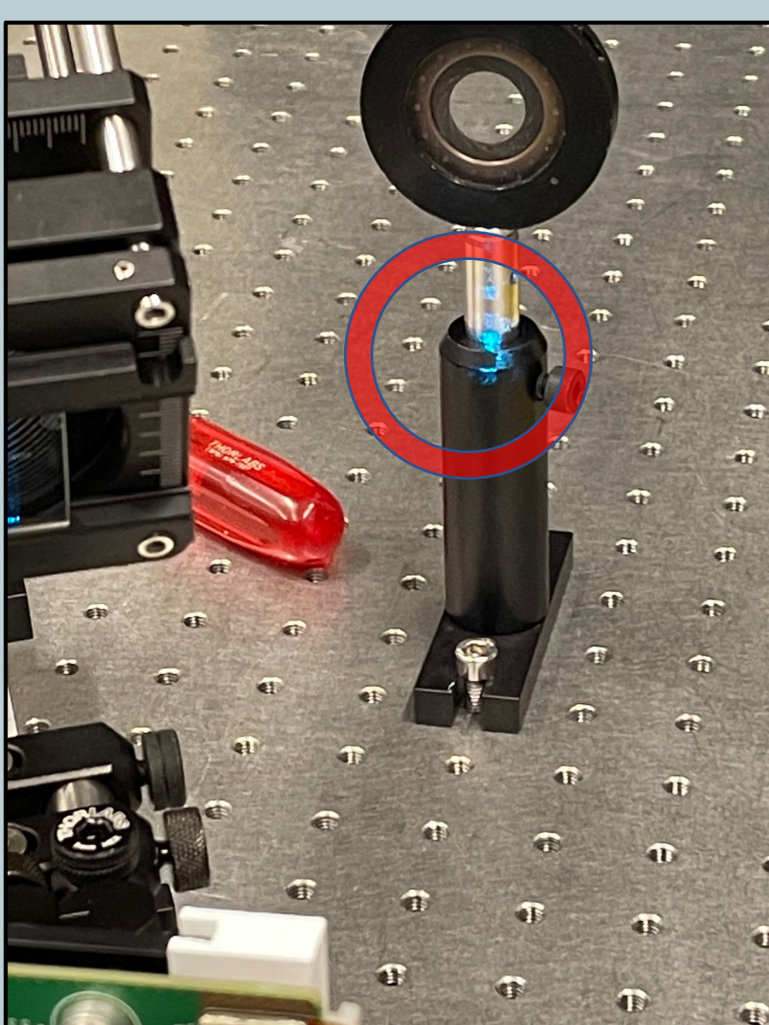


Figure 3: Test 1 ($\alpha = 32$ degrees)

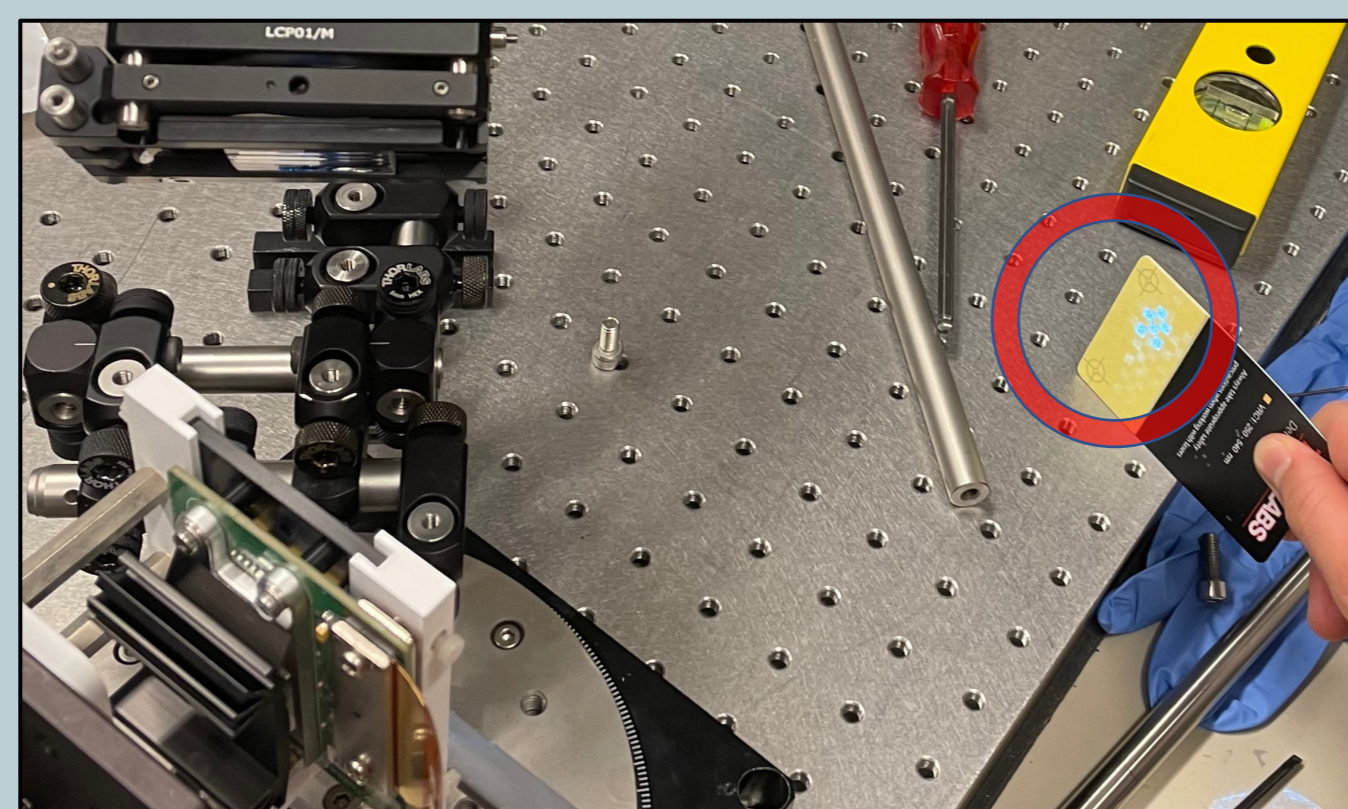


Figure 4: Test 2 ($\alpha = 52$ degrees)



Figure 5: Test 3 ($\alpha = 23.5$ degrees)

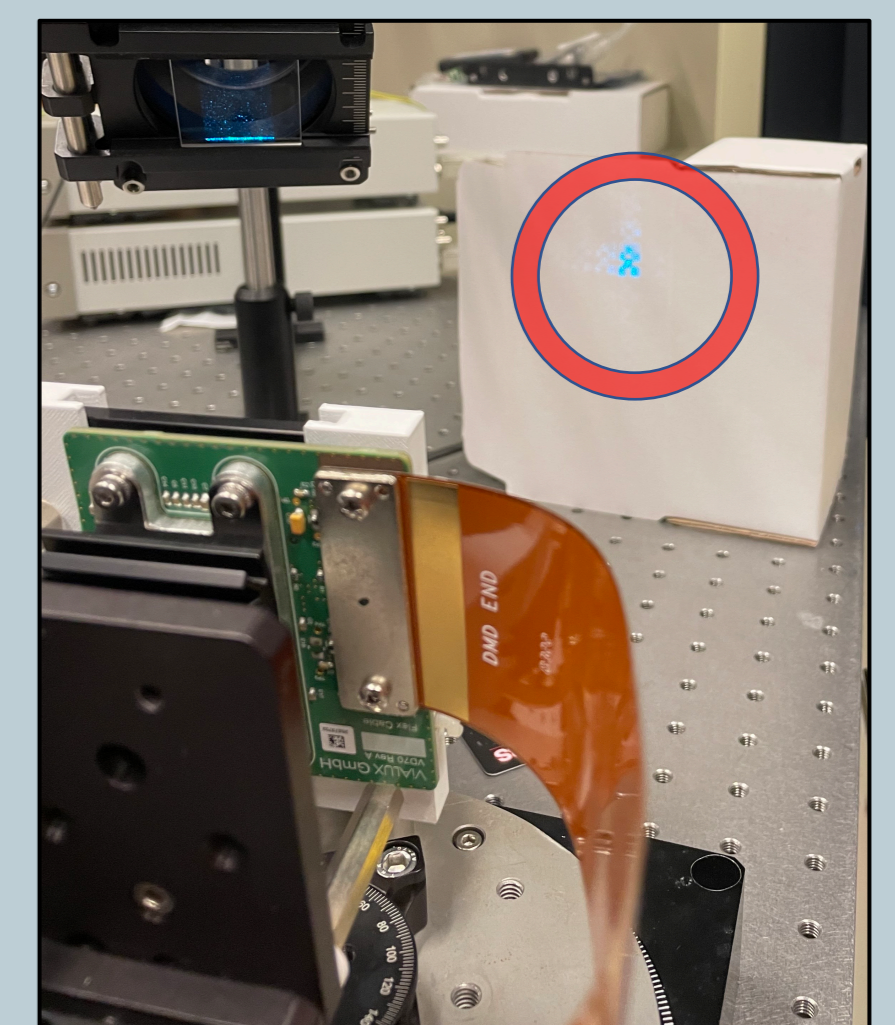


Figure 6: Test 4 ($\alpha = 32$ degrees, with modified setup)

Discussion and Conclusion

After conducting the first two tests, we took a step back to reflect on the reasons the results were not satisfying. The third test was to ensure that our understanding of the hardware was good. Finally, after making significant changes to the setup, we managed to achieve great results.

The next steps in this process are to implement the setup into the 3D printer. Future modifications could be to motorize the rotation of the laser arm in the vertical plane. This would allow the users to easily switch wavelengths, without having to manually adjust the setup.

The outcomes of this project are the following:

- A working prototype of the support, with an angle α that has been proven to work
- A script that calculates all the angles that could work
- A code that outputs the necessary information to build/adjust the setup

This work will help implement the use of multiple wavelengths in Tomographic Volumetric 3D printers, by facilitating the calibration process, which is time-consuming and meticulous.