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***TIDA-00293 DLP 3D Printer Test Data***

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*DLP Catalog***ABSTRACT**

The DLP 3D Printer is a complete hardware solution for the stereolithography (SLA) method of 3D printing. The SLA method involves curing photo-reactive resin with light of a sufficient energy to drive the reaction from liquid to solid. The test data was collected with an emphasis on resin curing times, resin cure thickness, resolution from the printer and LED characteristics.

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## Related Documentation From Texas Instruments

DLPC350 Data Sheet: *DLP Digital Controller for Portable Advanced Light Control (DLPS029)*.

DLP4500 Data Sheet: *DLP 0.45 WXGA Visible DMD (DLPS028)*.

DLPC350 User's Guide: *DLPC350 Programmer's Guide (DLPU010)*.

## If You Need Assistance

Refer to the DLP and MEMS TI E2E Community support forums

## Test Data

### 1 LED Output Characteristics

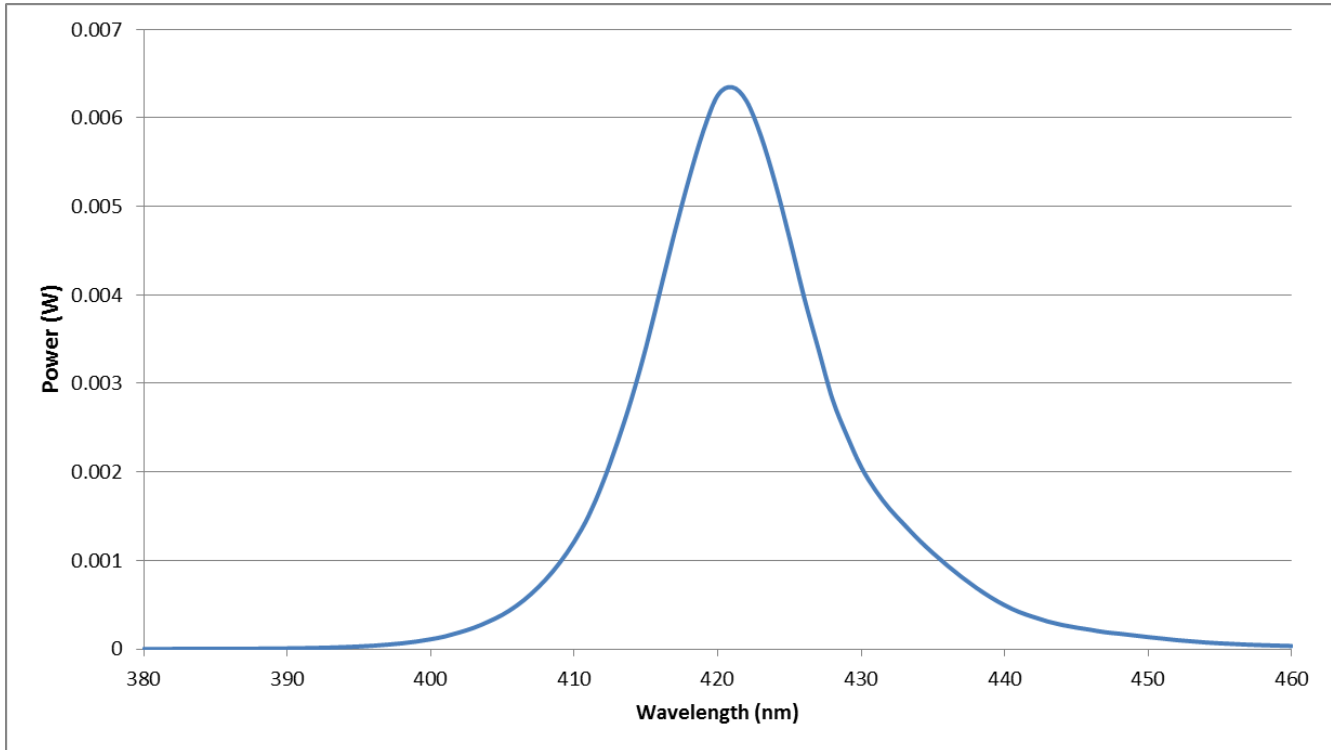
This chapter provides test data from the 420 nm LED by Philips Lumileds. The chemical reaction that takes place when the liquid resin monomer cross links into a solid polymer is driven by energetic light in the SLA method. The light used has to be of sufficient energy to drive the reaction. The light intensity needs to be high enough to have a large amount of photons available to link the monomer quickly. The visible light photoresin used in the development of the DLP 3D Printer cures at any wavelength below 440 nm. The LED used was tested for wavelength output and power output.

#### 1.1 Test Procedure

1. Drive the LED with its maximum rated current, without optics, into an integrating sphere connected to a OL756 Spectroradiometer.
  - a. Measure intensity vs wavelength
    - i. Multiply each power reading by the area of the aperture to get watts per nanometer
    - ii. Integrate from 0 to 440 nm to find total useful optical power to drive the resin reaction
  - b. Characterize peak wavelength and wavelength distribution of emitter
2. Install the LED in the DLP LightCrafter 4500 light engine and perform the same measurements in step 1
  - a. Measure intensity vs wavelength
    - i. Multiply each power reading by the area of the aperture to get watts per nanometer
    - ii. Integrate from 0 to 440 nm to find total useful optical power to drive the resin reaction

- iii. Divide resultant optical power in step 2.a.i by optical power in step 1.a.i to find the light engine's efficiency for the LED

## 1.2 Results



**Figure 1. Wavelength distribution of Philips 420 nm LED**

**Table 1. Output of LED without optics**

$\lambda(\text{nm})$	$\text{W}/\text{cm}^2/\text{nm}$	$\text{W}/\text{nm}$			
380	7.85257E-08	3.55E-07			
381	9.20462E-08	4.16E-07			
382	1.42201E-07	6.43E-07			
383	1.9969E-07	9.03E-07			
384	2.6717E-07	1.21E-06			
385	3.5319E-07	1.6E-06			
386	4.5749E-07	2.07E-06			
387	6.10025E-07	2.76E-06			
388	8.55957E-07	3.87E-06			
389	1.12843E-06	5.11E-06			
390	1.4919E-06	6.75E-06			
391	2.00987E-06	9.09E-06			
392	2.66243E-06	1.2E-05			
393	3.62287E-06	1.64E-05			
394	4.74088E-06	2.14E-05			
395	6.31127E-06	2.86E-05			
396	8.35932E-06	3.78E-05			
397	1.09358E-05	4.95E-05			
398	1.4252E-05	6.45E-05			
399	1.86478E-05	8.44E-05			
400	2.44013E-05	0.00011			
401	3.14462E-05	0.000142			
402	4.13842E-05	0.000187			
403	5.29601E-05	0.00024			
404	6.80096E-05	0.000308			
405	8.56328E-05	0.000387			
406	0.000108588	0.000491			
407	0.000137716	0.000623			
408	0.000172945	0.000782			
409	0.000215851	0.000977			
410	0.000268043	0.001213			
411	0.000332328	0.001503			
412	0.00041617	0.001883			
413	0.000515023	0.00233			
414	0.000625781	0.002831			
415	0.000752917	0.003406			
416	0.000896431	0.004055			
417	0.001039839	0.004704			
418	0.001173867	0.005311			
419	0.00129373	0.005853			
420	0.001382359	0.006254			
421	0.001402864	0.006347			
422	0.001368495	0.006191			
423	0.001282093	0.0058			
424	0.001164459	0.005268			
425	0.00102707	0.004646			
426	0.000880494	0.003983			
427	0.000751031	0.003398			
428	0.000623407	0.00282			
429	0.000533126	0.002412			
430	0.000454512	0.002056			
431	0.000395998	0.001791			
432	0.000349126	0.001579			
433	0.000310455	0.001404			
434	0.000272994	0.001235			
435	0.000239459	0.001083			
436	0.000208534	0.000943			
437	0.000179809	0.000813			
438	0.000153449	0.000694			
439	0.000129662	0.000587			
440	0.000109168	0.000494			
			<b>Total Opt Pwr (W):</b>	<b>0.09748699</b>	
			=SUM(380nm:440nm)		

**Table 2. Output of LED through DLP LightCrafter 4500 light engine**

$\lambda$ (nm)	W/cm <sup>2</sup> /nm	W/nm			
380	8.2312E-10	3.72E-09			
381	2.3422E-09	1.06E-08			
382	0	0			
383	8.48173E-10	3.84E-09			
384	1.28186E-09	5.8E-09			
385	0	0			
386	0	0			
387	1.81482E-09	8.21E-09			
388	1.92176E-09	8.69E-09			
389	9.03037E-10	4.09E-09			
390	1.2978E-09	5.87E-09			
391	2.99648E-09	1.36E-08			
392	1.1692E-08	5.29E-08			
393	2.16693E-08	9.8E-08			
394	3.1093E-08	1.41E-07			
395	6.80159E-08	3.08E-07			
396	1.03925E-07	4.7E-07			
397	2.09089E-07	9.46E-07			
398	3.77174E-07	1.71E-06			
399	6.179E-07	2.8E-06			
400	1.01291E-06	4.58E-06			
401	1.60348E-06	7.25E-06			
402	2.50673E-06	1.13E-05			
403	3.81014E-06	1.72E-05			
404	5.57589E-06	2.52E-05			
405	8.17122E-06	3.7E-05			
406	1.16665E-05	5.28E-05			
407	1.63026E-05	7.38E-05			
408	2.25125E-05	0.000102			
409	3.04443E-05	0.000138			
410	4.13533E-05	0.000187			
411	5.49166E-05	0.000248			
412	7.32828E-05	0.000332			
413	9.68613E-05	0.000438			
414	0.000122775	0.000555			
415	0.000155031	0.000701			
416	0.000191021	0.000864			
417	0.000226084	0.001023			
418	0.000264461	0.001196			
419	0.000298098	0.001349			
420	0.000325015	0.00147			
421	0.000335497	0.001518			
422	0.000338426	0.001531			
423	0.000323224	0.001462			
424	0.000301652	0.001365			
425	0.000271522	0.001228			
426	0.00023448	0.001061			
427	0.000202916	0.000918			
428	0.000169586	0.000767			
429	0.000146297	0.000662			
430	0.000125342	0.000567			
431	0.000110406	0.000499			
432	9.74133E-05	0.000441			
433	8.64189E-05	0.000391			
434	7.64944E-05	0.000346			
435	6.80277E-05	0.000308			
436	5.89811E-05	0.000267			
437	5.11285E-05	0.000231			
438	4.40515E-05	0.000199			
439	3.73423E-05	0.000169			
440	3.17009E-05	0.000143			
			Total Opt Pwr (W):	0.0692204	

From the resulting power outputs, the DLP LightCrafter 4500 light engine is calculated to be 23.5% optically efficient from emitter to projection lens.

## 2 Printed Object Resolution

This chapter provides test data from the DLP 3D Printer to show usable resolution. High resolution prints lead to smoother surfaces and the ability to print more complex shapes. The resolution of the printer can be closely approximated from the equation to find the pixel size on the image plane:

$$PixelSize = \frac{(EnvelopeWidth)}{(DMDRowCount * \sqrt{2})}$$

The DLP 3D Printer's resolution is set to a theoretical resolution of 59 microns by:

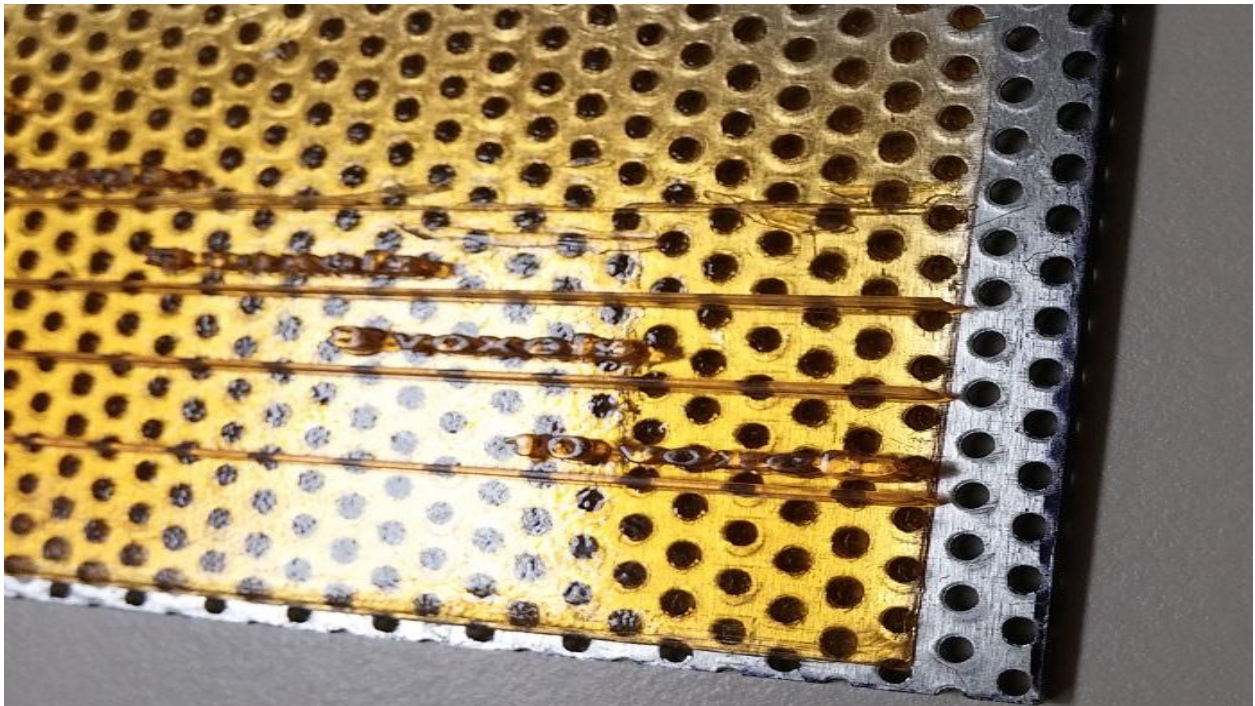
$$PixelSize = \frac{(760 \times 10^3 \mu m)}{(912 * \sqrt{2})} = 58.9 \mu m$$

### 2.1 Test Procedure

1. Load the DLP 3D Printer with an image of lines ranging from 1 pixel wide to 10 pixels wide
  - a. Build multiple layers of the test image to determine the minimum thickness line that will survive
2. Load the DLP 3D Printer with an image containing 2 lines: 10 of the minimum thickness found in step 1.a, and a line 1 pixel wider
  - a. Build multiple layers of the test image
3. Measure the difference between minimum thickness line in step 2 and 1 pixel wider line.
  - a. Take the difference of the two measurements to determine minimum printable resolution

### 2.2 Results

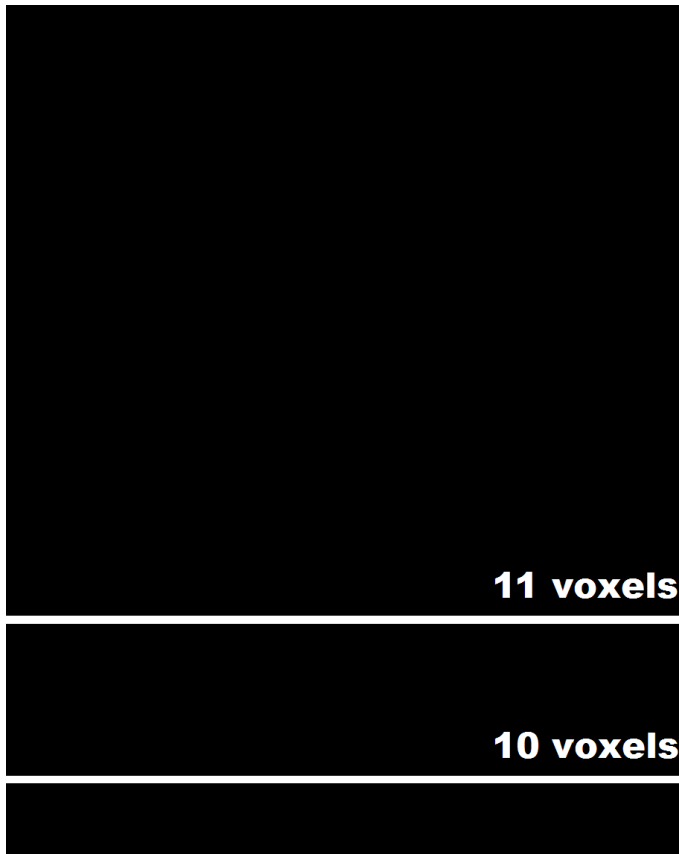
The first resolution test print was created and the minimum, reliable line was 10 pixels wide.



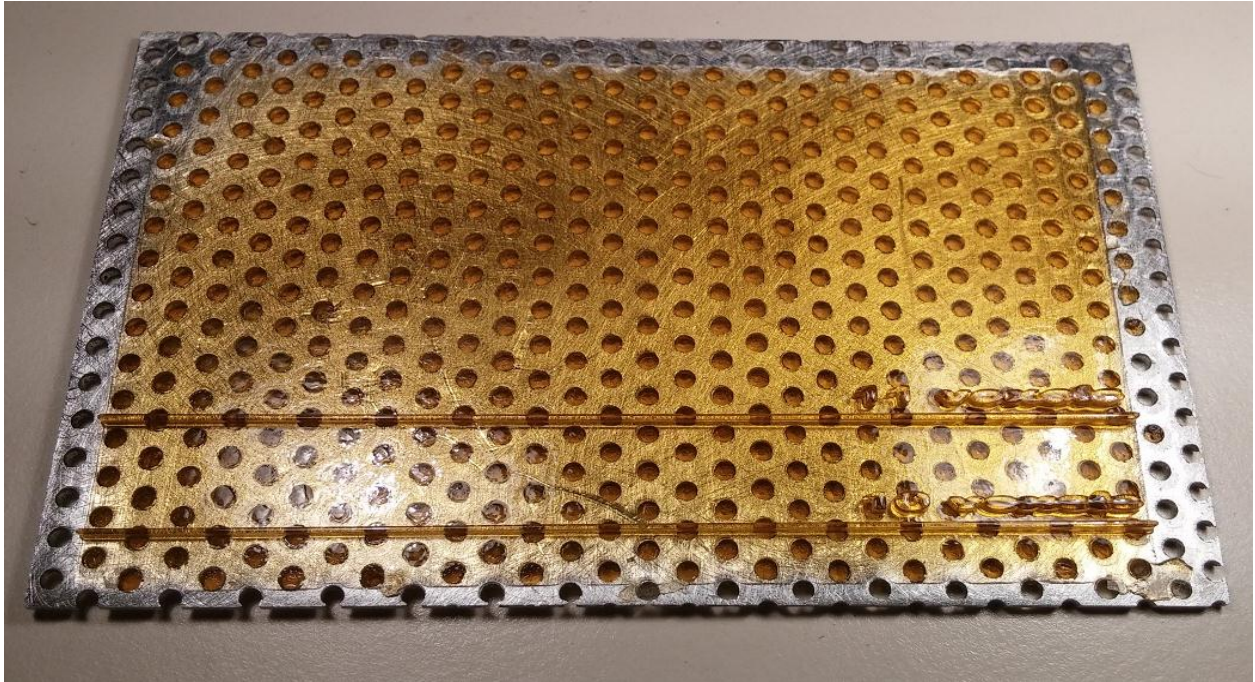
**Figure 2. Determining minimum printable line width**

The test image in figure 3 was created.





**Figure 3. Minimum printable resolution test image**



**Figure 4. Minimum printable feature test object**

The two lines were measured with the following results:

10 pixel stripe size: 0.59 mm = 590  $\mu$ m

11 pixel stripe size 0.66 mm = 650  $\mu$ m

Difference = Minimum printable resolution = 590  $\mu$ m - 650  $\mu$ m = 60  $\mu$ m

### 3 Resin Cure Time Per Layer Thickness

Resin cure time is a function of layer thickness and optical power per unit area. The higher the light intensity hitting the surface, the faster the material will cross-link and harden. The test was performed with the photo-resin obtained here: <http://www.buy3dink.com/p/59/uv-resin>

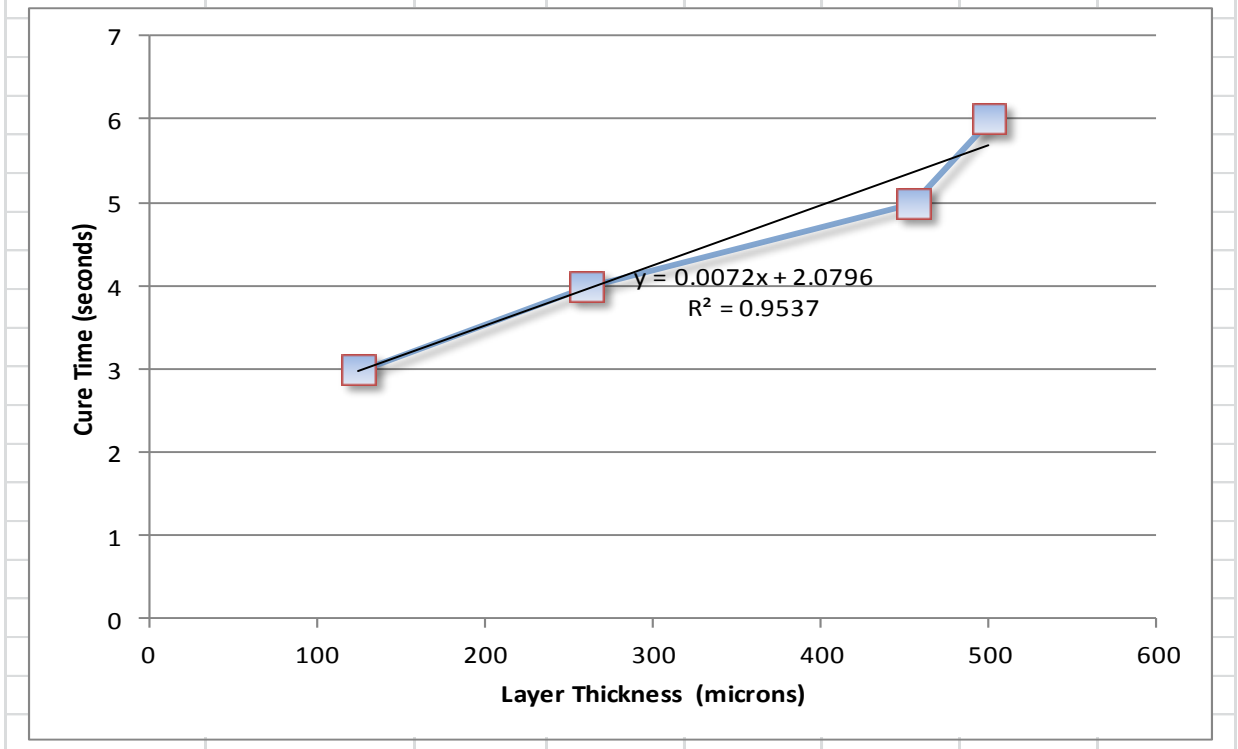
#### 3.1 Test Procedure

1. Fill the resin vat with photo-polymer even to the build platform
2. Lower the build platform a discrete amount into the resin
3. Expose the liquid layer of resin for a period of time
4. Remove the exposed layer from the vat and try to recover the layer from the build surface
5. If the layer is not cured enough, expose again and record the time it took to cure the layer totally

**3.2 Results**

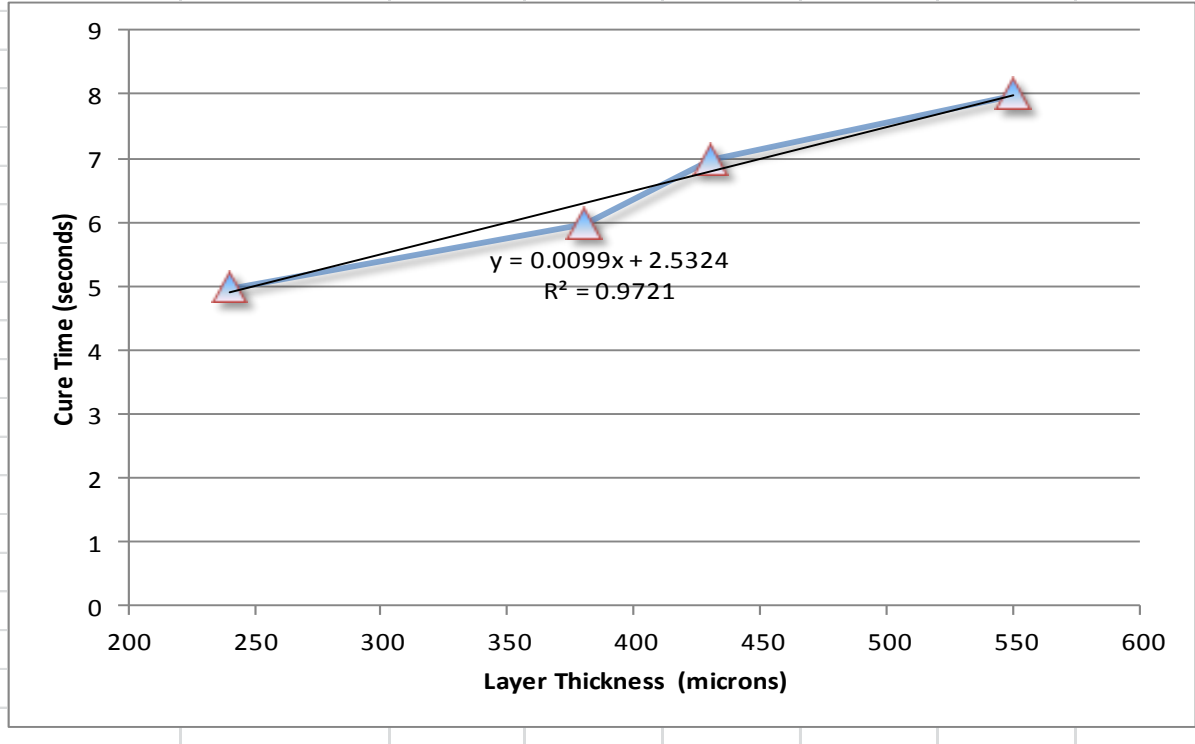
**Table 3. Cure times for maximum LED current PWM setting**

LED Current PWM Setting	Thickness (μm)	Time (s)
35	125	3
35	260	4
35	455	5
35	500	6

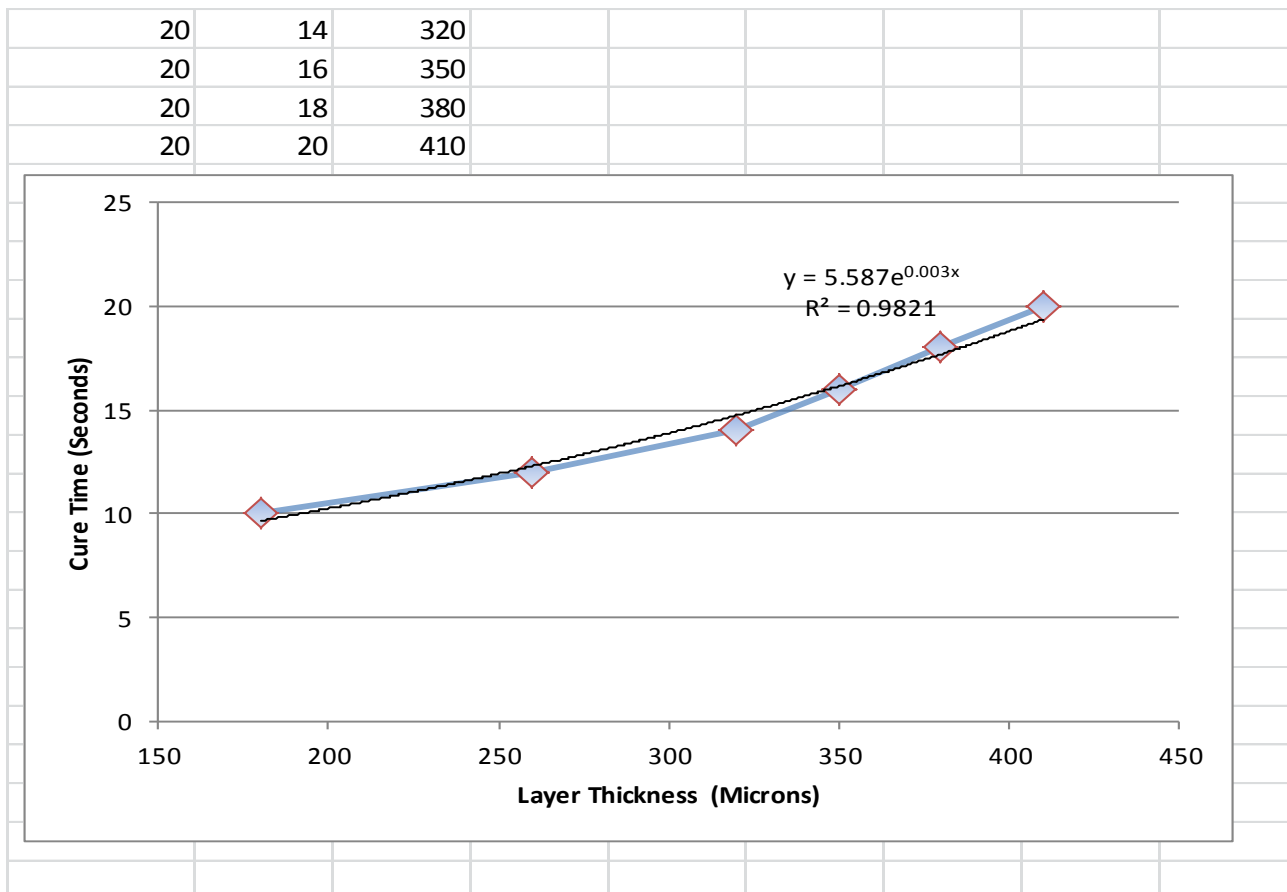


**Table 4. Cure times for a LED current PWM setting of 30**

LED Current PWM Setting	Thickness (μm)	Time (s)
30	240	5
30	380	6
30	430	7
30	550	8



**Table 5. Cure time for a LED current PWM setting of 20**



## 4 Model Printing

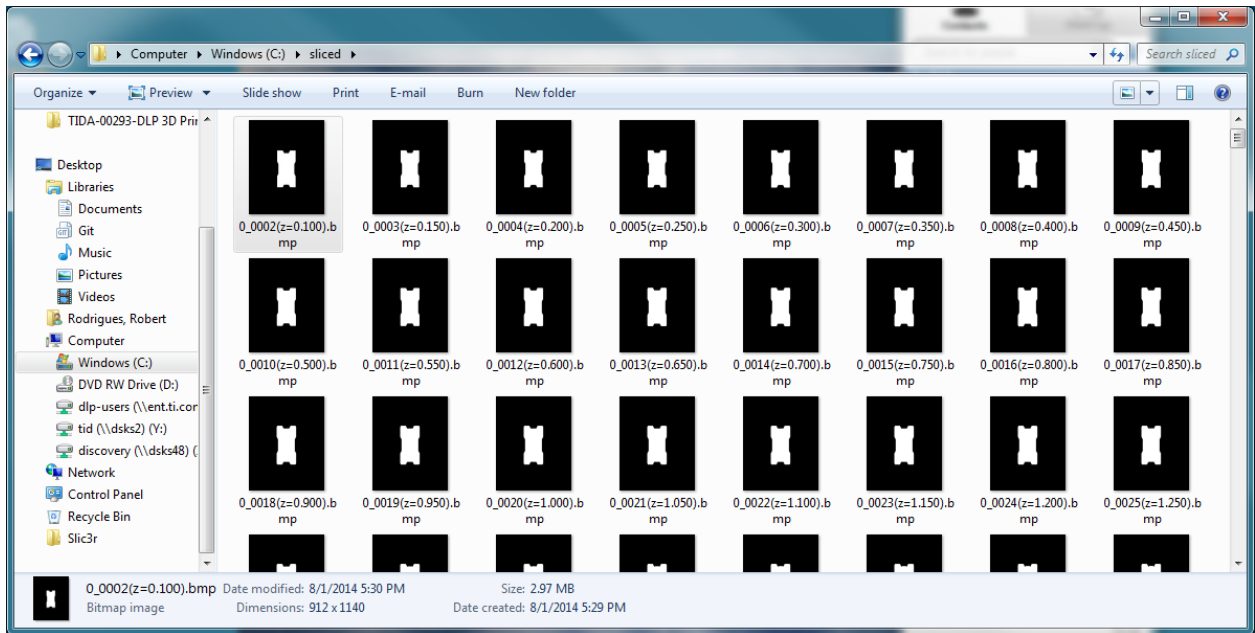
The final test results come from operational use of the DLP 3D Printer in the laboratory. A complex object, given in STL file format was printed using the procedure listed.

### 4.1 Test Procedure

1. Downloaded STL file
  - a. Object selected was a cube with several features on each surface
2. Slice STL file with Freestee Z-Level Slicer utility
  - a. 640 layer images were created of the model
3. Use the DLP 3D Printer GUI to upload the layer images to the DLP 3D Printer hardware
4. Wait a while as it prints!
5. Extract model from build platform, clean with alcohol, photograph

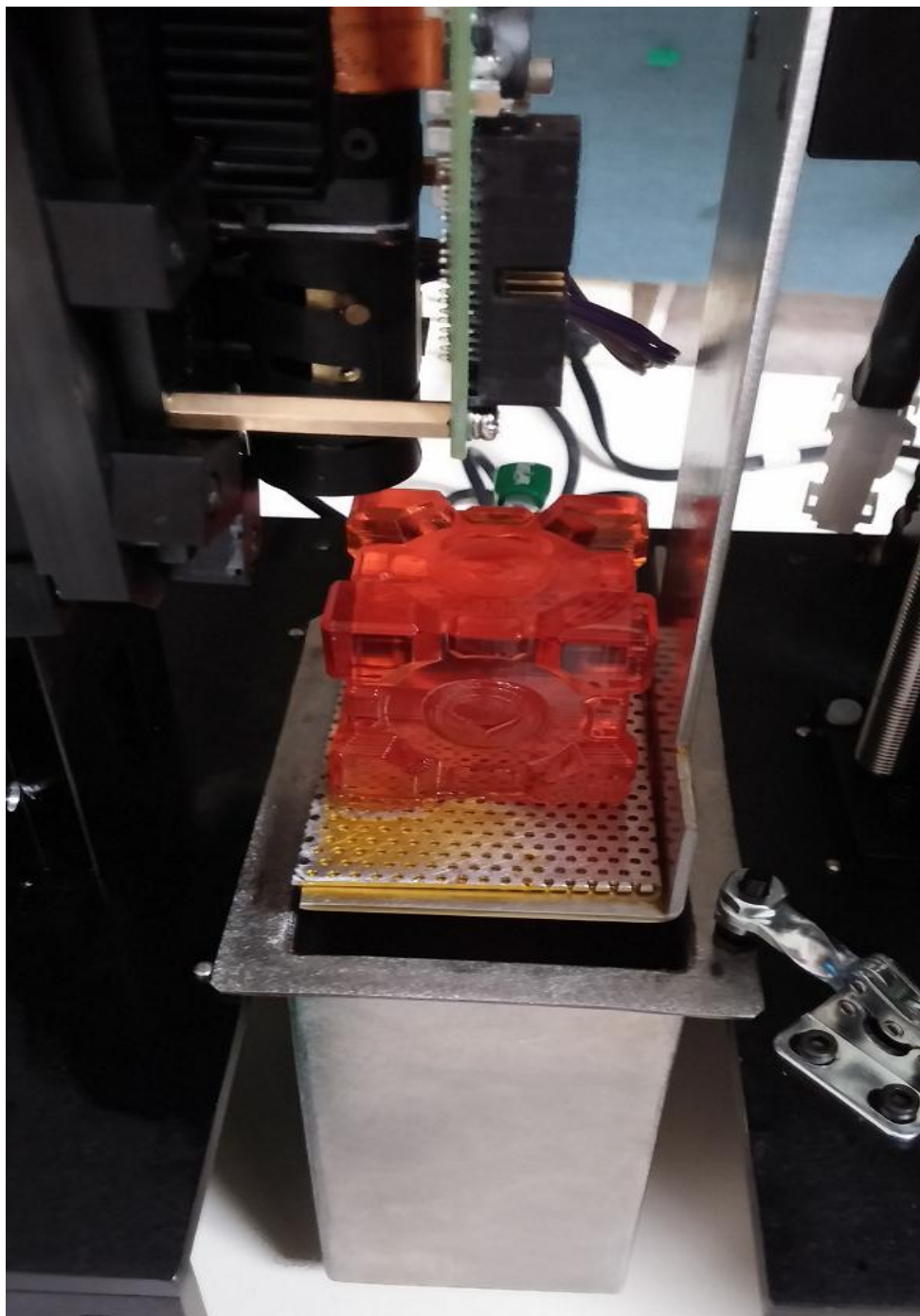
## 4.2 Results

A sample of the layer images:



**Figure 5. Cross-sectional slices of the cube model**

Photos of the printed model:



**Figure 6. Printed cube model on platform**

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