TIDA-00293 DLP 3D Printer Test Data

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

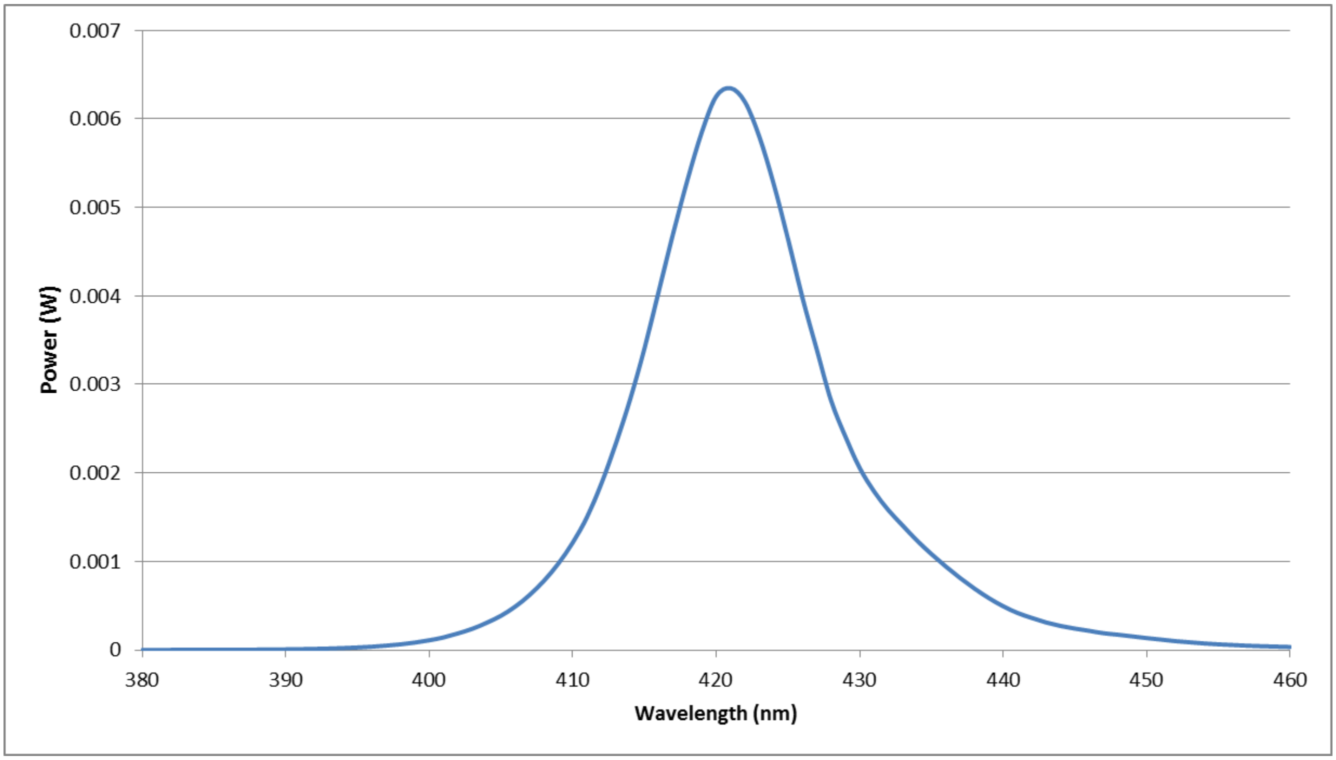


Figure 1. Wavelength distribution of Philips 420 nm LED

Table 1. Output of LED without optics

λ(nm)	W/cm^2/nm	W/nm				
380	7.85257E-08	3.55E-07		Total Opt Pwr (W):	0.09748699	
381	9.20462E-08	4.16E-07				
382	1.42201E-07	6.43E-07		=SUM(380nm:440nm)		
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				

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

Total Opt Pwr (W): 0.0692204

λ(nm)	W/cm^2/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

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:

$$PixelSize = \frac{(760x10^3 \mu m)}{(912 * \sqrt{2})} = 58.9 \mu m$$

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.

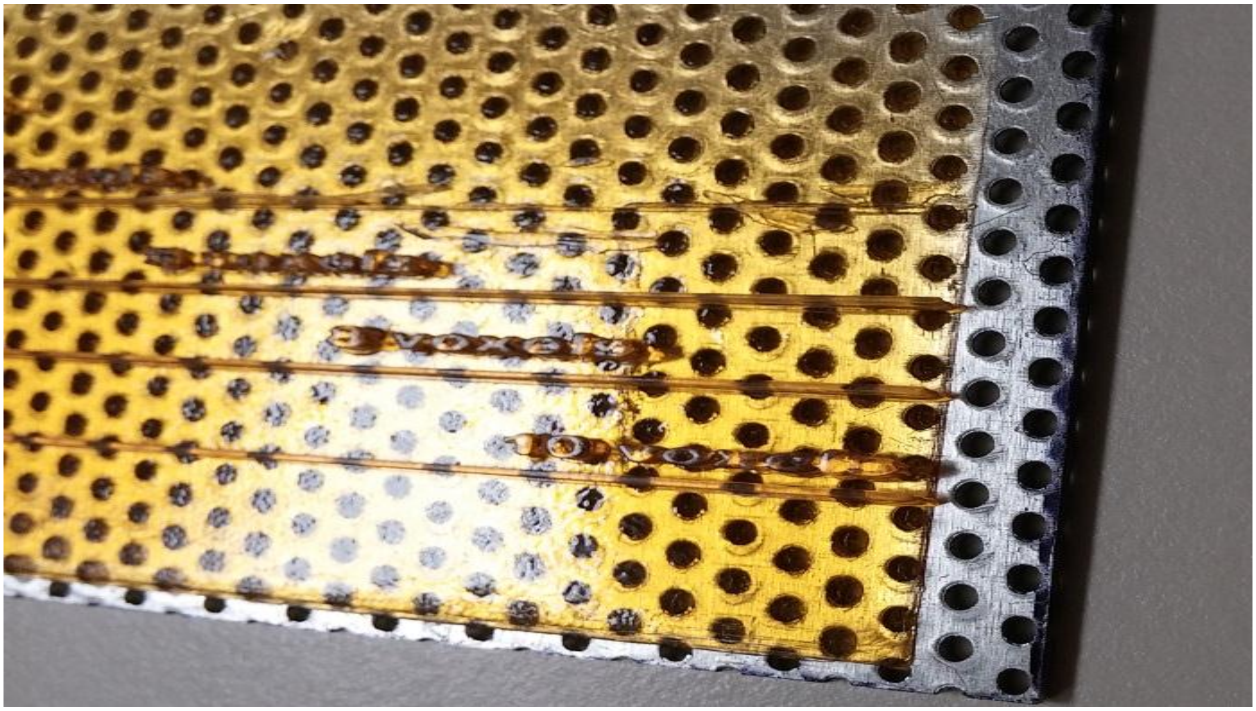


Figure 2. Determining minimum printable line width

The test image in figure 3 was created.

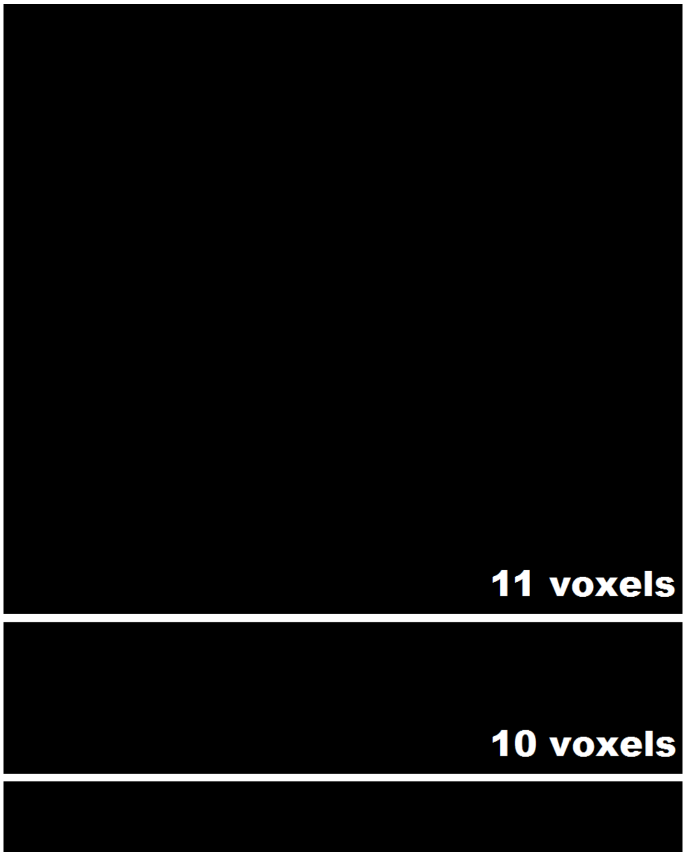


Figure 3. Minimum printable resolution test image

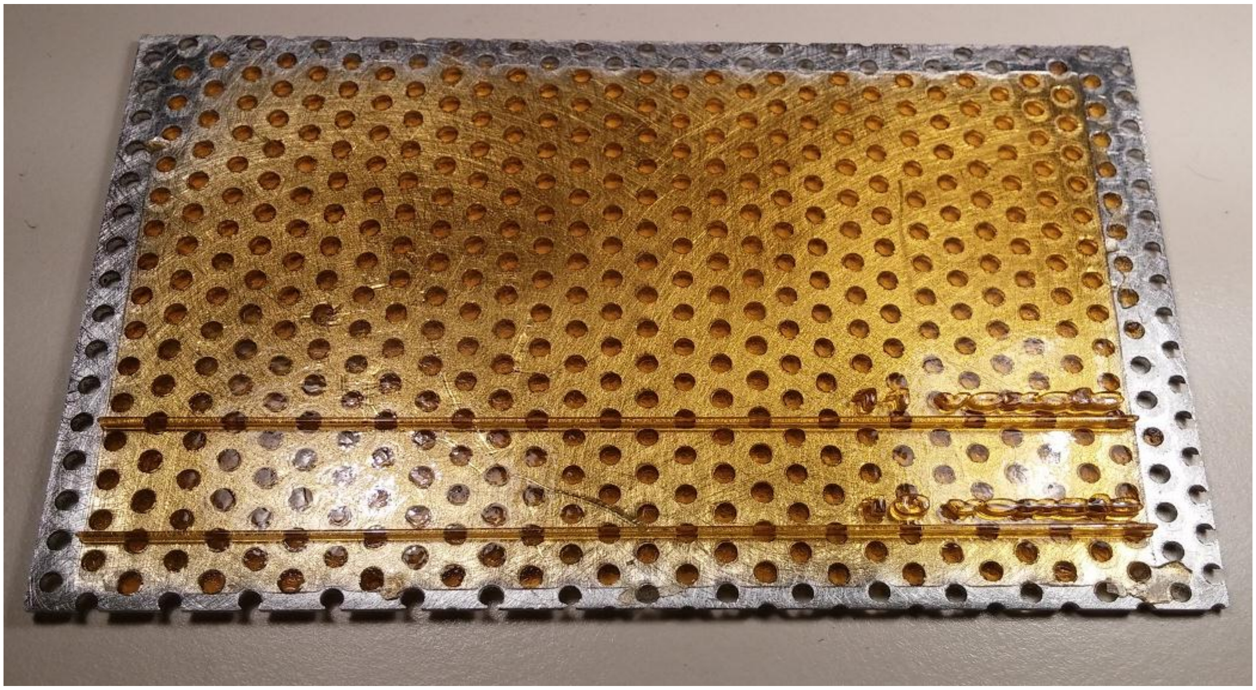


Figure 4. Minimum printable feature test object

The two lines were measured with the following results:

10 pixel stripe size: 0.59 mm = 590 µm

11 pixel stripe size 0.66 mm = 650 µm

Difference = Minumum printable resolution = 590 µm - 650 µm = 60 µm

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

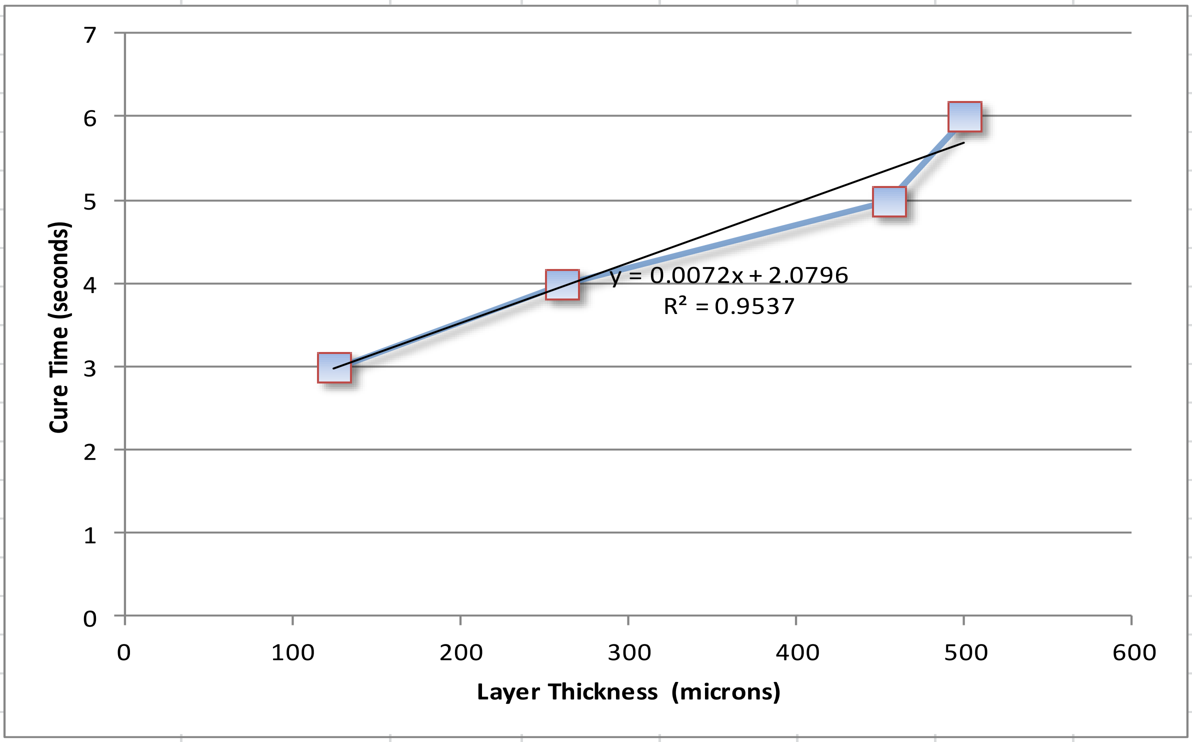


Table 4. Cure times for a LED current PWM setting of 30

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

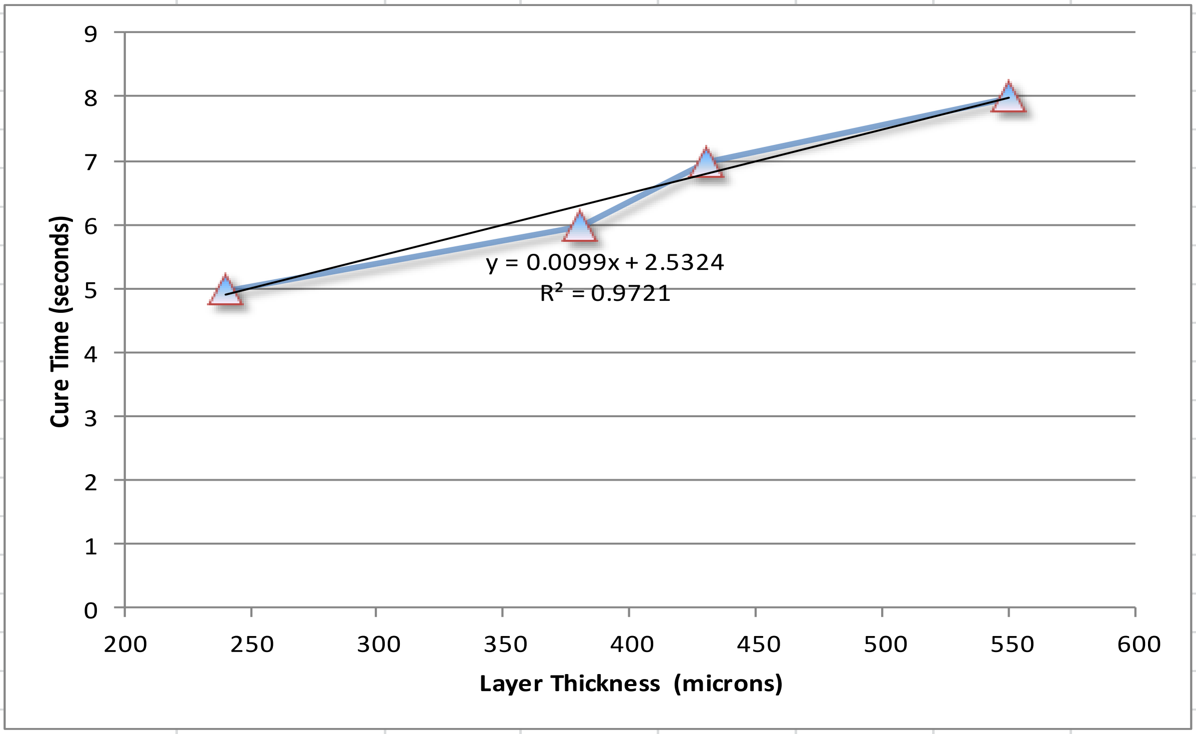
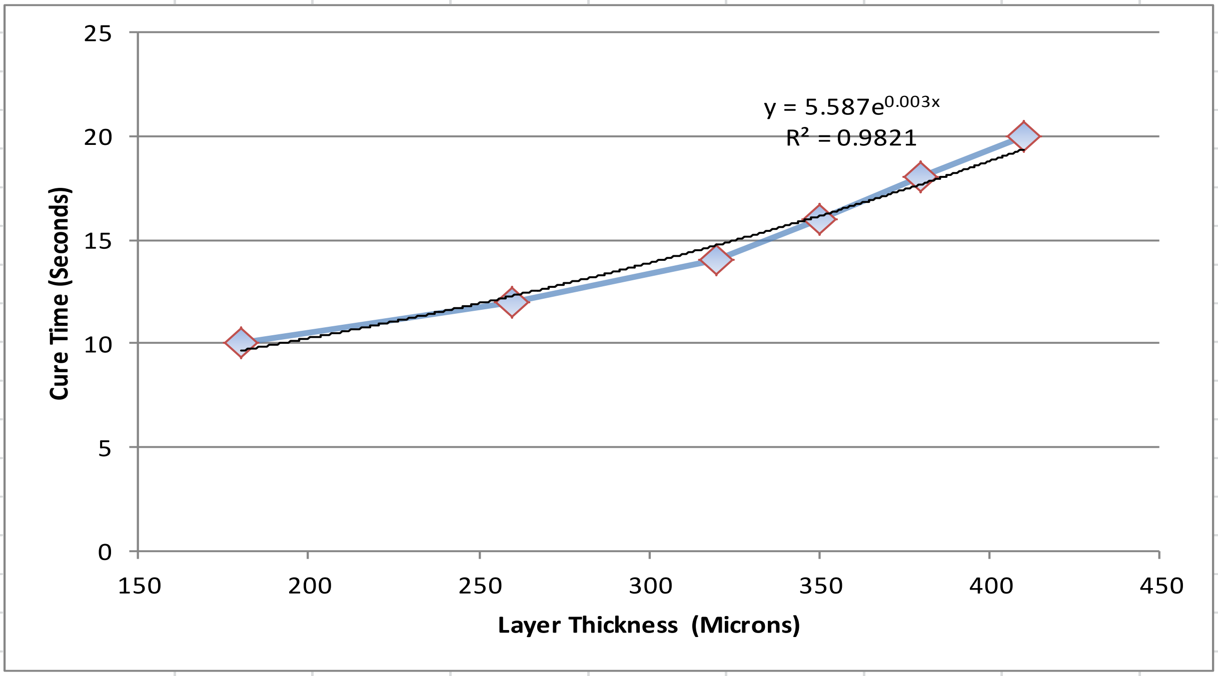


Table 5. Cure time for a LED current PWM setting of 20

20	14	320
20	16	350
20	18	380
20	20	410



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 Freesteel 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:

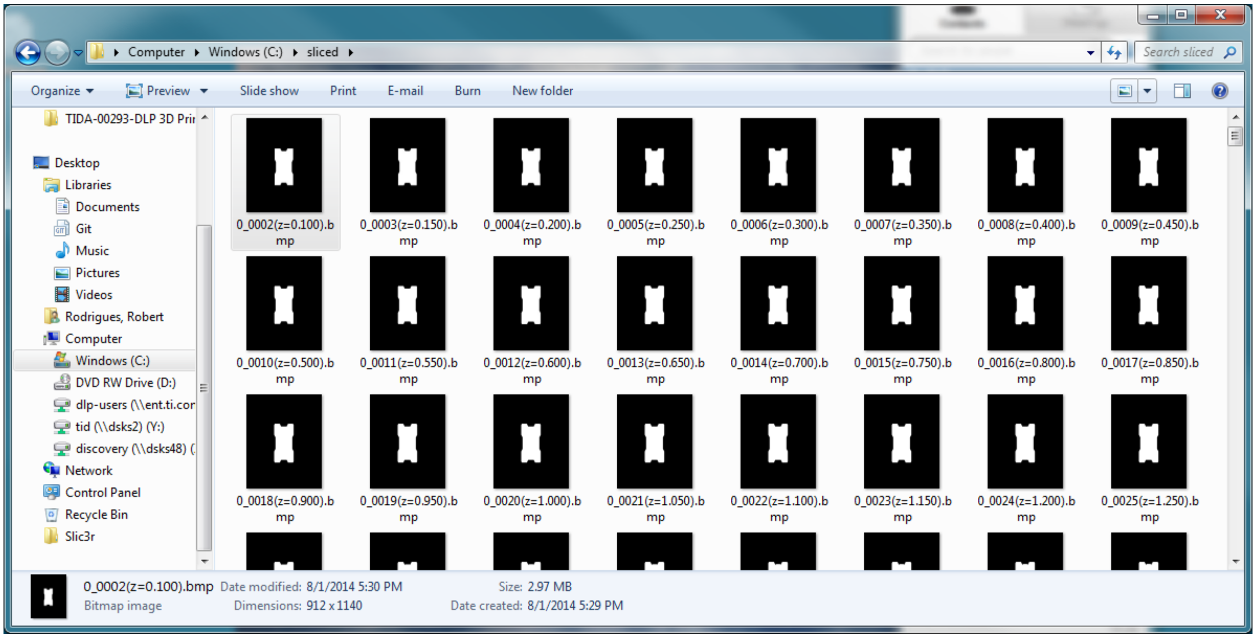


Figure 5. Cross-sectional slices of the cube model

Photos of the printed model:

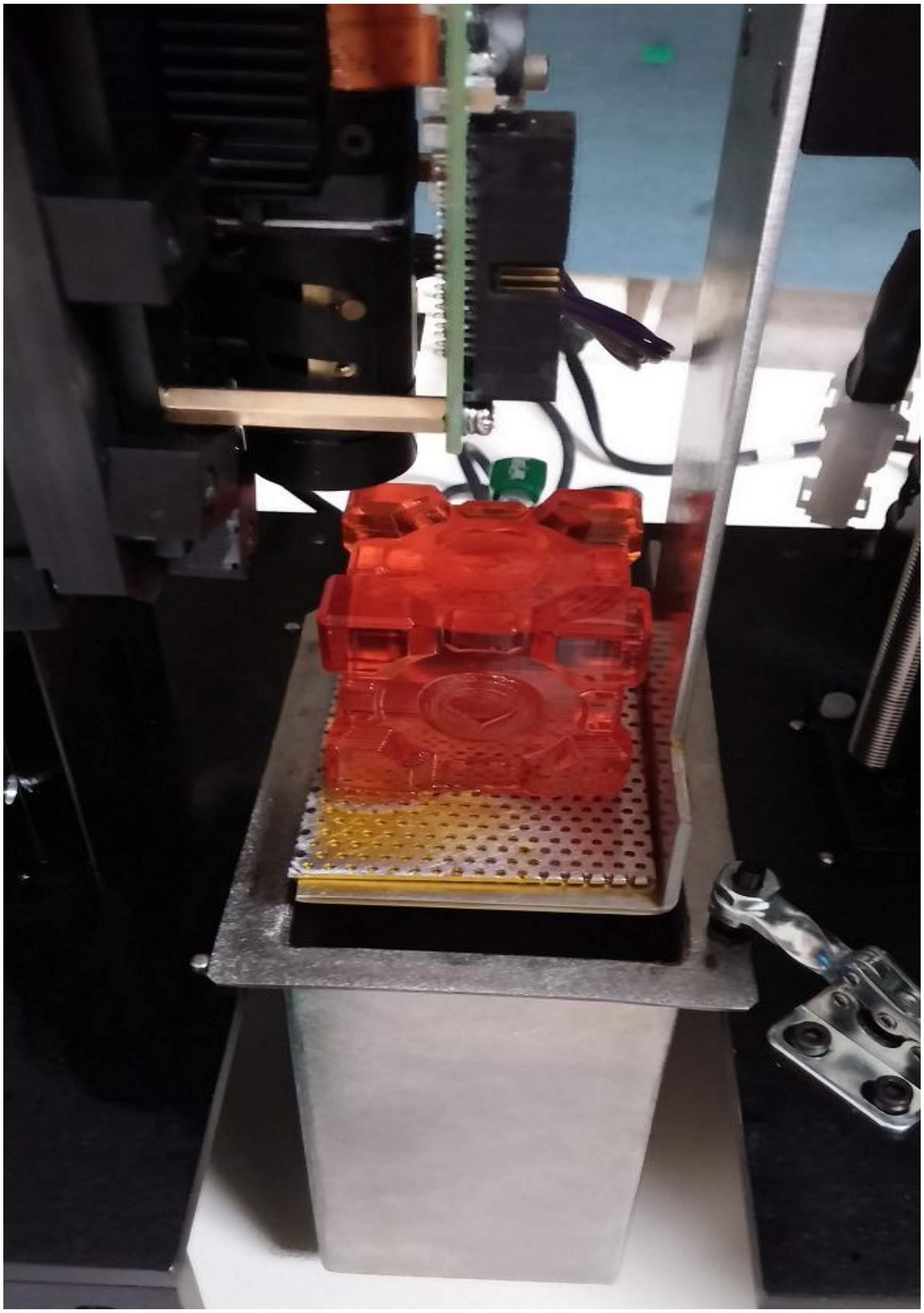


Figure 6. Printed cube model on platform