

Accurate Point Cloud Generation for 3D Machine Vision Applications using DLP® Technology and Industrial Camera

About Test Results

This DLP technology based TI Design provides a complete solution for 3D scanning and point cloud generation. The point cloud data below was generated using the software include with this TI Design, which is based on the DLP Advanced Light Control SDK with a DLP® LightCrafter™ 4500 EVM and Point Grey Flea3 USB camera. The generated point cloud data was visualized using MeshLab.

Related Documentation From Texas Instruments

- DLPC350 Data Sheet: DLP Digital Controller for Portable Advanced Light Control, TI literature number [DLPS029](#)
- DLP4500 Data Sheet: DLP 0.45 WXGA Visible DMD, TI literature number [DLPS028](#)
- DLP4500NIR Data Sheet: DLP 0.45 WXGA Near-Infrared DMD, TI literature number [DLPS032](#)
- User's Guide: DLPC350 Programmer's Guide, TI literature number [DLPU010](#)
- Application Note: Using DLP® Development Kits for 3D Optical Metrology Systems, TI literature number [DLPA026](#)
- Application Note: Using DLP® LightCrafter™ 4500 Triggers to Synchronize Cameras to Patterns, TI literature number [DLPA036](#)

If You Need Assistance

Refer to the [DLP and MEMS TI E2E Community support forums](#)

Calibration Results

This chapter provides test data from the TIDA-00254 software for camera and projector calibration module. When the camera and projector calibration parameters are found, the output is used to generate the system optical rays which ultimately allow line intersections to be calculated for point cloud generation.

To calibrate the system, the following procedure is used:

1. From main menu of software, select "1: Generate camera calibration board and enter feature measurements" and follow instructions
 - a. Note: Measure the height of one square on the calibration board in the desired units of the point cloud

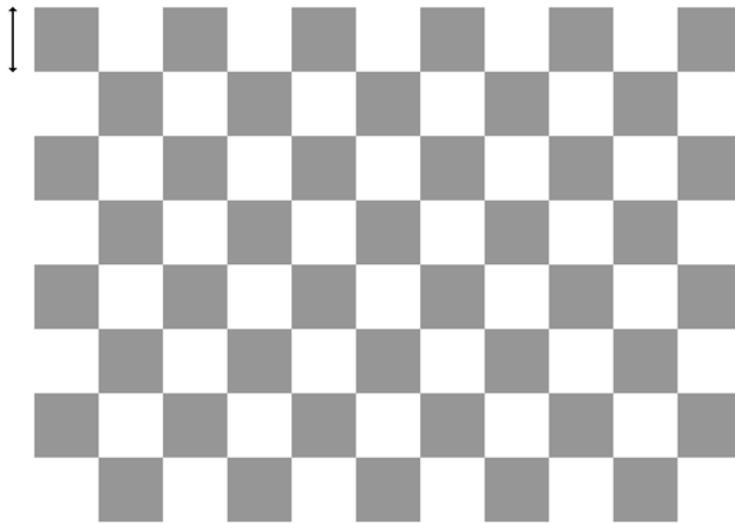


Figure 1 Camera calibration board measurement

2. From main menu of software, select "4: Calibrate camera" and follow instructions.
3. From main menu of software, select "5: Calibrate system" and follow instructions.

The following images show the camera captures of the printed calibration board and projected calibration board after removing the printed calibration board from the projected.

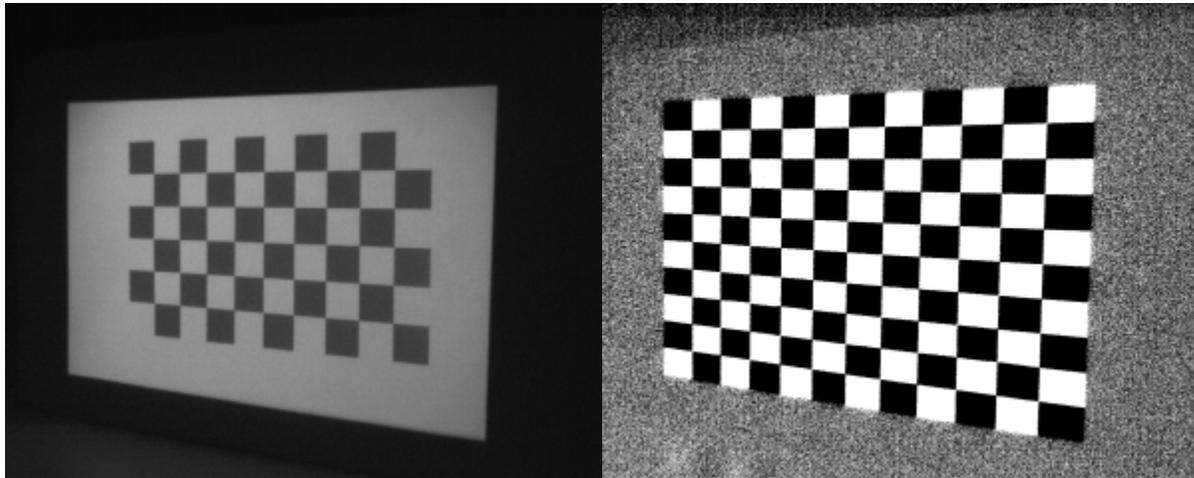


Figure 2 Printed calibration board and projected calibration board position 1

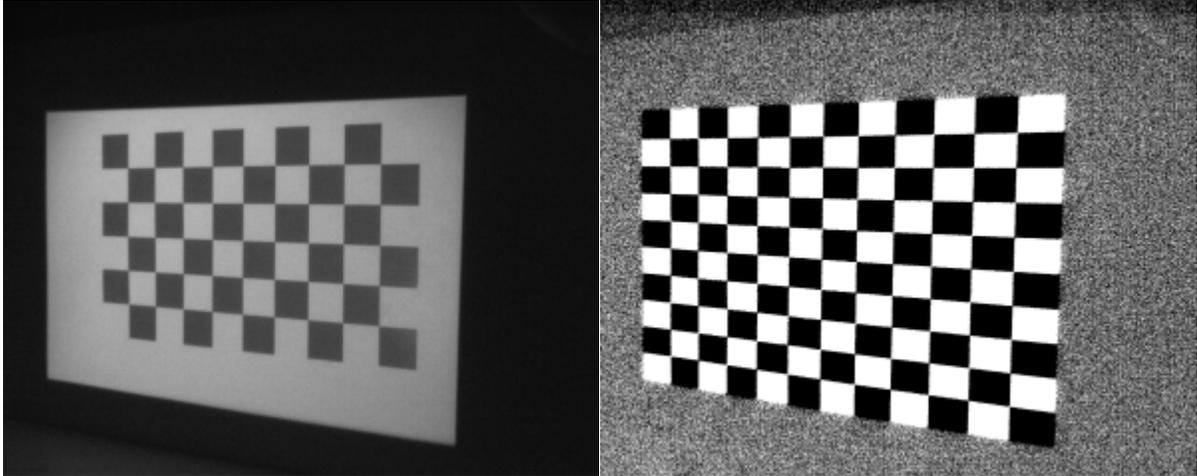


Figure 3 Printed calibration board and projected calibration board position 2

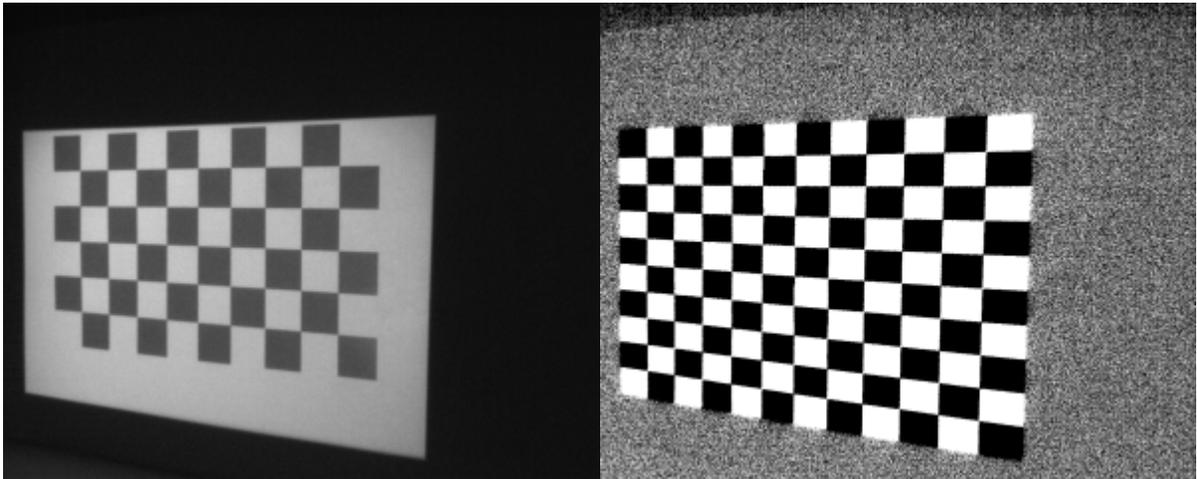


Figure 4 Printed calibration board and projected calibration board position 3

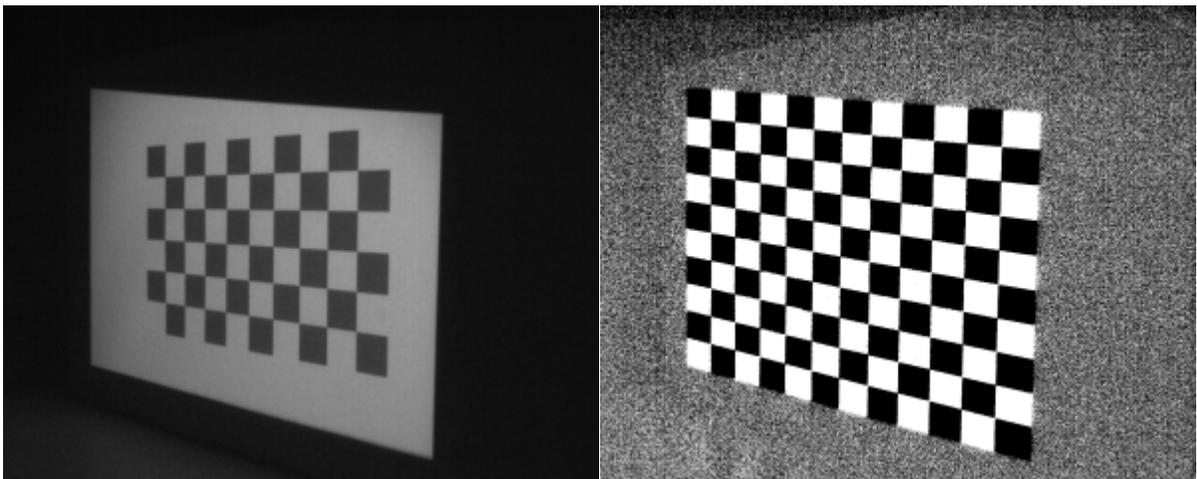


Figure 5 Printed calibration board and projected calibration board position 4

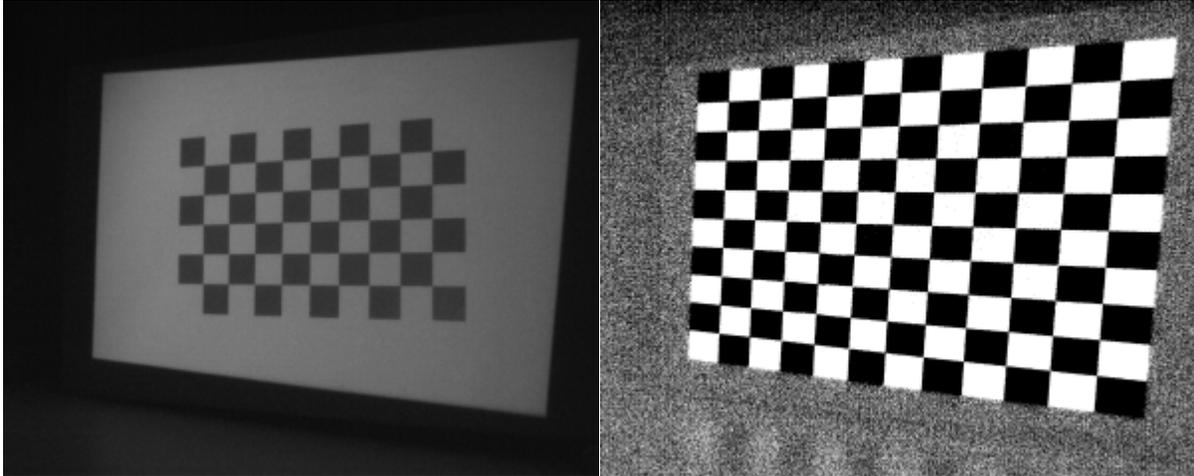


Figure 6 Printed calibration board and projected calibration board position 5

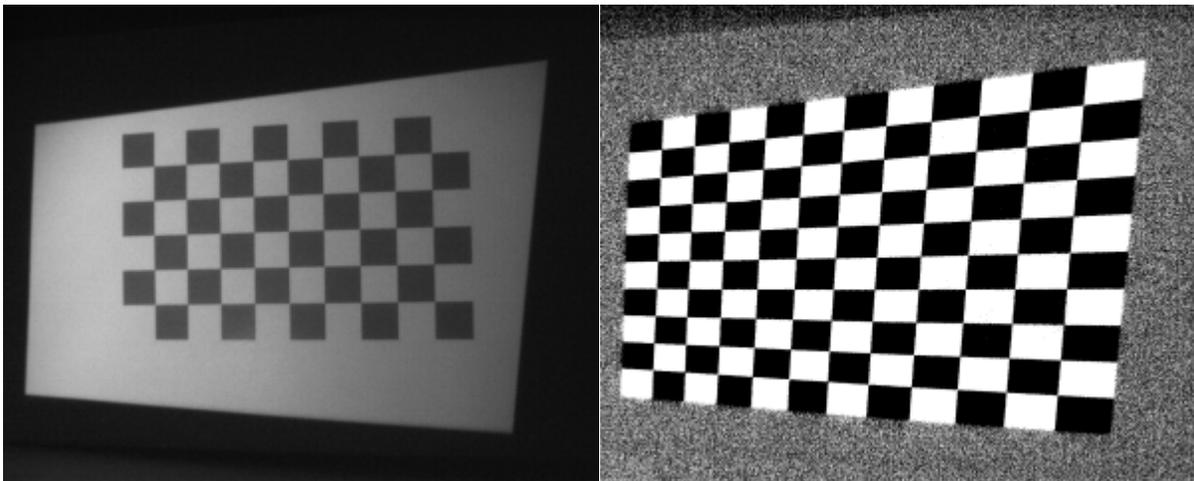


Figure 7 Printed calibration board and projected calibration board position 6

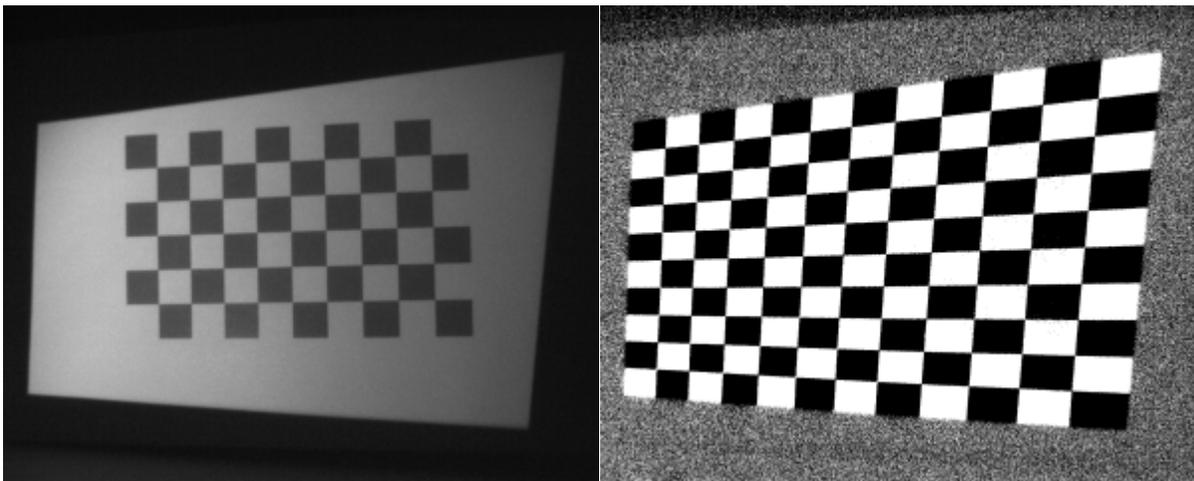


Figure 8 Printed calibration board and projected calibration board position 7

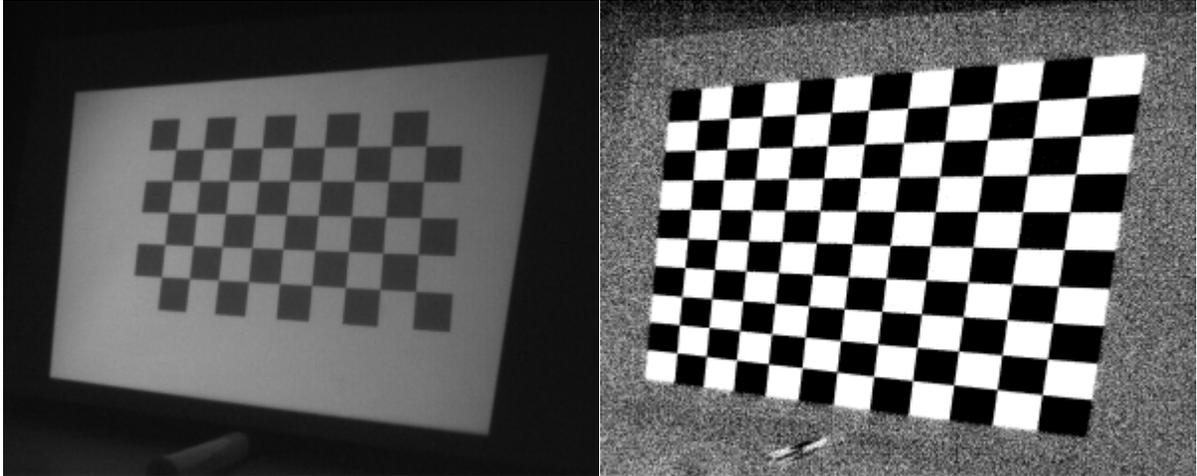


Figure 9 Printed calibration board and projected calibration board position 8

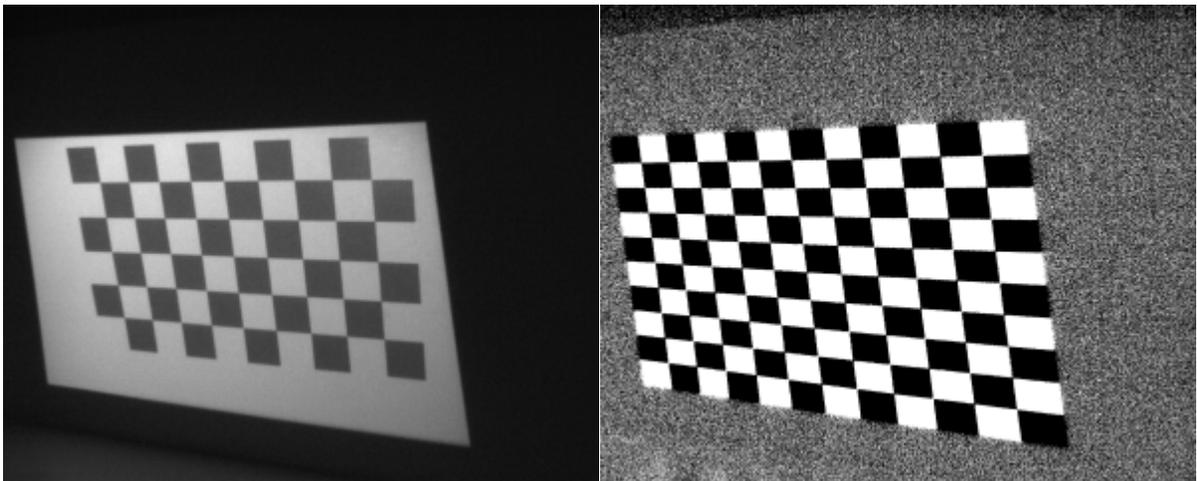


Figure 10 Printed calibration board and projected calibration board position 9

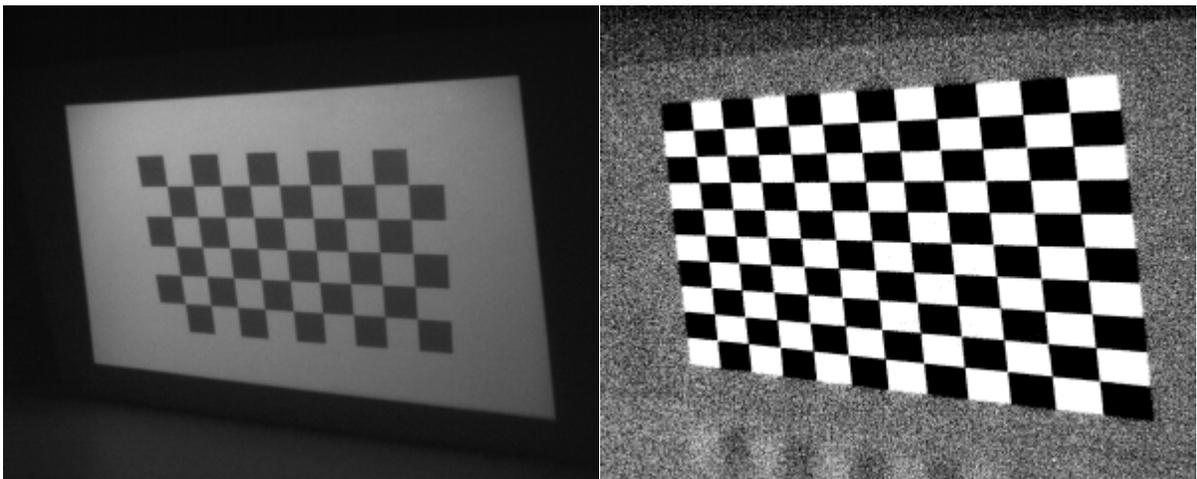


Figure 11 Printed calibration board and projected calibration board position 10

The following images should be the calibration XML files generated for the camera and projector.

```
<?xml version="1.0"?>
- <opencv_storage>
  <DLP_CALIBRATION_DATA>1</DLP_CALIBRATION_DATA>
  <calibration_complete>1</calibration_complete>
  <calibration_of_camera>1</calibration_of_camera>
  <image_columns>1280</image_columns>
  <image_rows>1024</image_rows>
  <model_columns>1280</model_columns>
  <model_rows>1024</model_rows>
  <reprojection_error>4.2828555805204710e-001</reprojection_error>
  - <intrinsic type_id="opencv-matrix">
    <rows>3</rows>
    <cols>3</cols>
    <dt>d</dt>
    <data> 1.6564273622487740e+003 0. 6.6745403364774097e+002 0. 1.6620729442050779e+003 4.5049020481526446e+002 0. 0.
    1.</data>
  </intrinsic>
  - <distortion type_id="opencv-matrix">
    <rows>5</rows>
    <cols>1</cols>
    <dt>d</dt>
    <data> -1.5313123564565867e-001 4.1366969886281424e-001 -7.6412243701293389e-003 3.7139263424618273e-003
    -1.1790977427749141e+000</data>
  </distortion>
  - <extrinsic type_id="opencv-matrix">
    <rows>2</rows>
    <cols>3</cols>
    <dt>d</dt>
    <data> 2.5433141989246610e-001 -2.4833607760152979e-002 1.0631203984677576e-002 -4.7751253076591871e+000
    -3.3181909684965980e+000 2.1445074696032794e+001</data>
  </extrinsic>
</opencv_storage>
```

Figure 12 Camera calibration XML output file

```
<?xml version="1.0"?>
- <opencv_storage>
  <DLP_CALIBRATION_DATA>1</DLP_CALIBRATION_DATA>
  <calibration_complete>1</calibration_complete>
  <calibration_of_camera>0</calibration_of_camera>
  <image_columns>1280</image_columns>
  <image_rows>1024</image_rows>
  <model_columns>912</model_columns>
  <model_rows>1140</model_rows>
  <reprojection_error>7.0780851604929285e-001</reprojection_error>
  - <intrinsic type_id="opencv-matrix">
    <rows>3</rows>
    <cols>3</cols>
    <dt>d</dt>
    <data> 1.1099161301256515e+003 0. 4.4295614686914325e+002 0. 1.1099161301256515e+003 5.8274359073192807e+002 0. 0.
    1.</data>
  </intrinsic>
  - <distortion type_id="opencv-matrix">
    <rows>5</rows>
    <cols>1</cols>
    <dt>d</dt>
    <data> -4.5330155215995895e-003 -9.4292609523394882e-002 -7.2173157139678928e-003 -6.3115676013341879e-004
    4.1370577504471470e-002</data>
  </distortion>
  - <extrinsic type_id="opencv-matrix">
    <rows>2</rows>
    <cols>3</cols>
    <dt>d</dt>
    <data> -2.8247819288421492e-003 -4.7425102195252401e-003 1.0690625637895450e-002 -4.2521674523107915e+000
    -7.9594581689262069e+000 1.9491513380134375e+001</data>
  </extrinsic>
</opencv_storage>
```

Figure 13 Projector calibration XML output file

Generated Point Cloud

This chapter provides test data from the TIDA-00254 software for structured light pattern decoding and point cloud generation. The structured light module generates patterns to determine which projector rays are intersecting with the scanned object and the geometry module finds the intersection between the projector and camera optical rays to generate a depth-map and point-cloud.

To calibrate the system, the following procedure is used:

1. Calibrate the camera and system
2. From main menu of software, select “3: Prepare system for calibration and scanning”
3. From main menu of software, select “8: Perform scan (vertical and horizontal patterns)”

The following images show the camera captures of the projected structured light patterns:

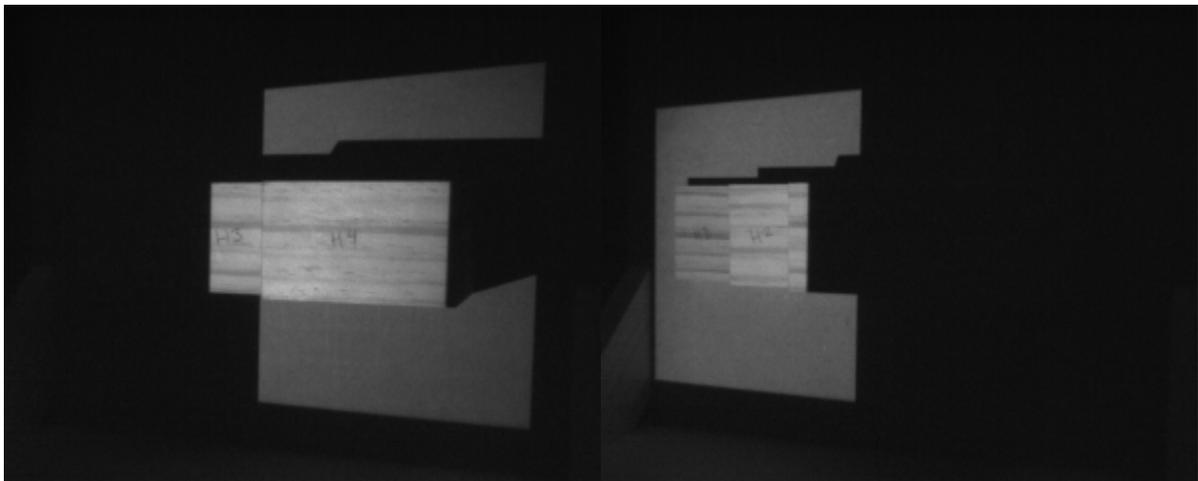


Figure 14 Non-inverted and inverted vertical gray code pattern 1 capture



Figure 15 Non-inverted and inverted vertical gray code pattern 2 capture

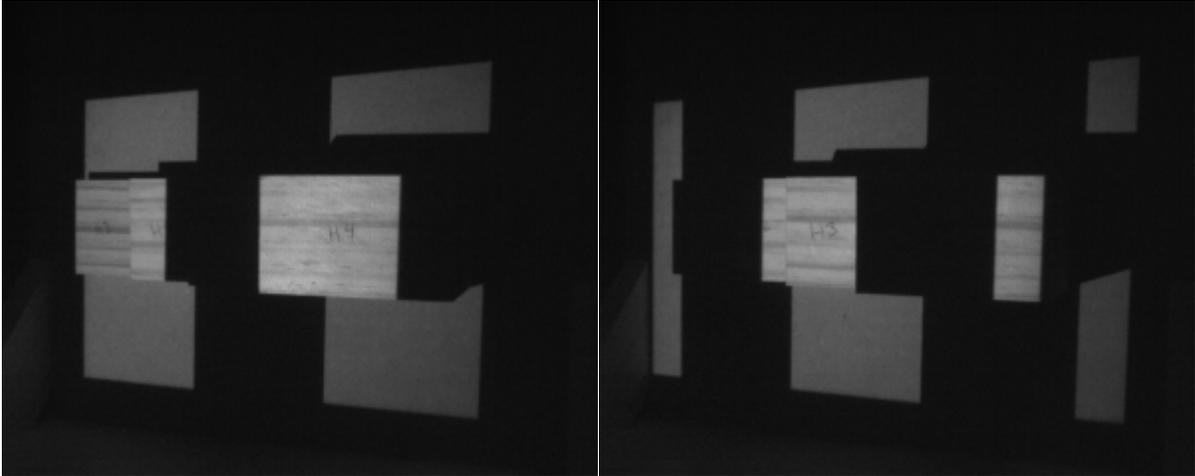


Figure 16 Non-inverted and inverted vertical gray code pattern 3 capture

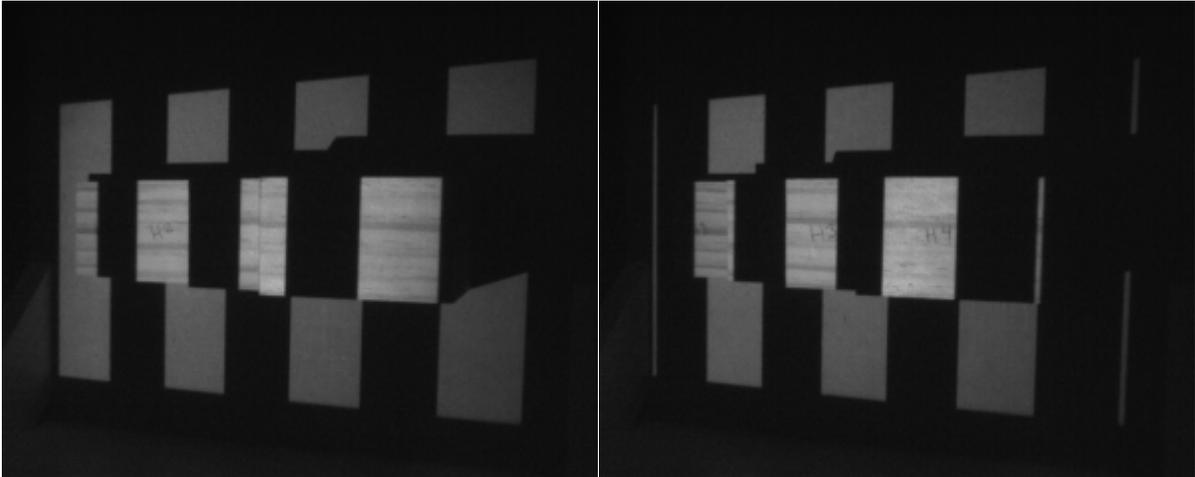


Figure 17 Non-inverted and inverted vertical gray code pattern 4 capture



Figure 18 Non-inverted and inverted vertical gray code pattern 5 capture

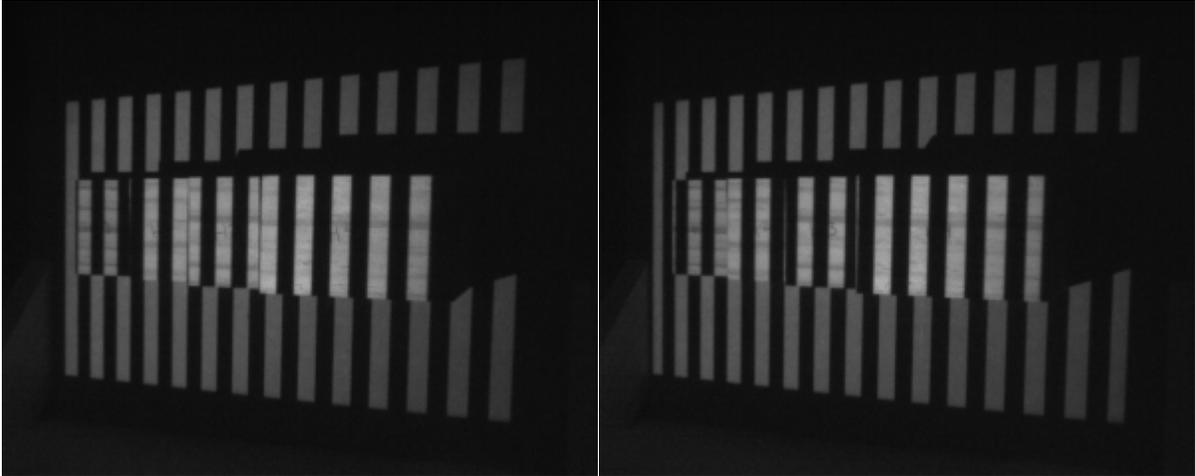


Figure 19 Non-inverted and inverted vertical gray code pattern 6 capture

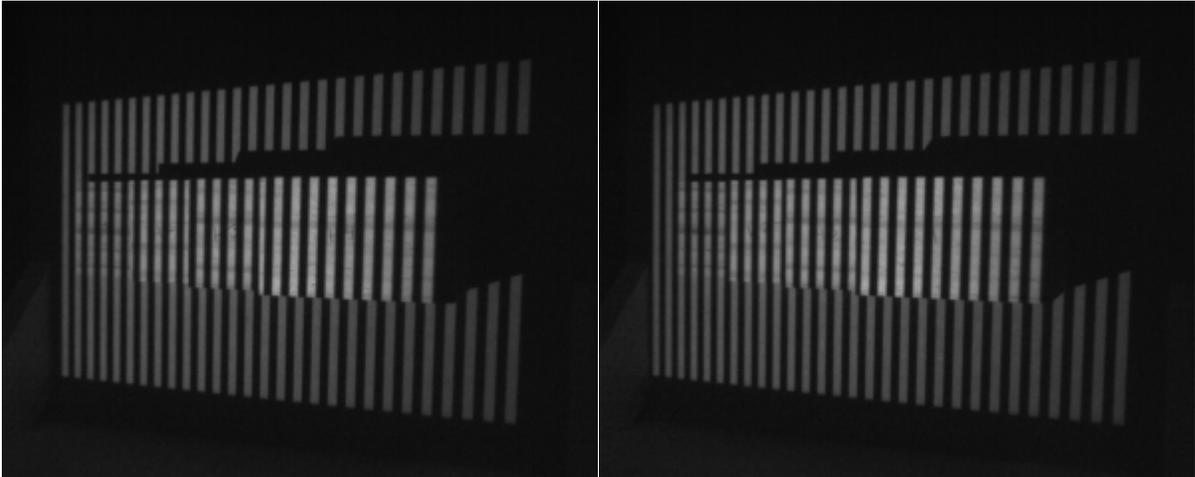


Figure 20 Non-inverted and inverted vertical gray code pattern 7 capture

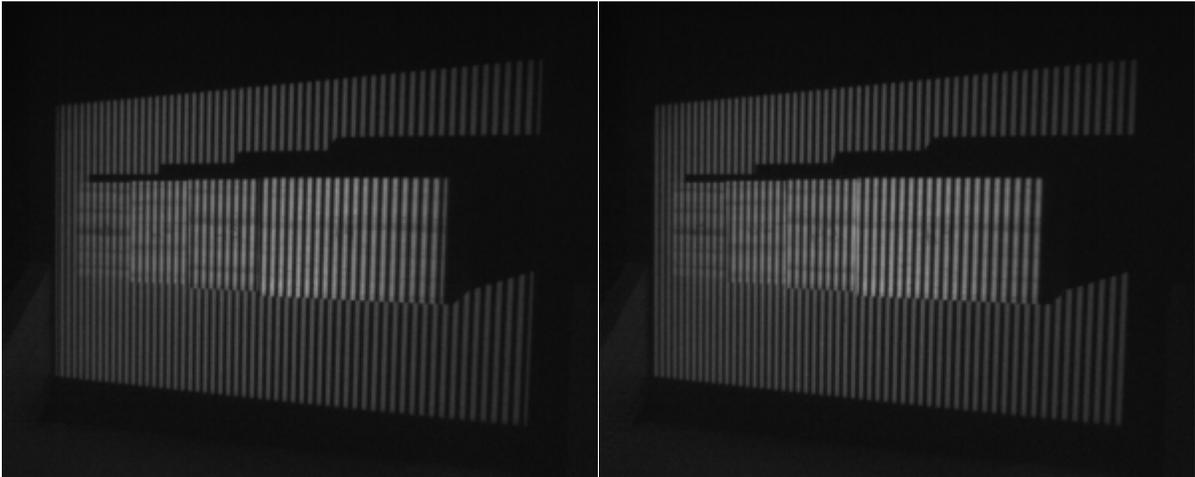


Figure 21 Non-inverted and inverted vertical gray code pattern 8 capture

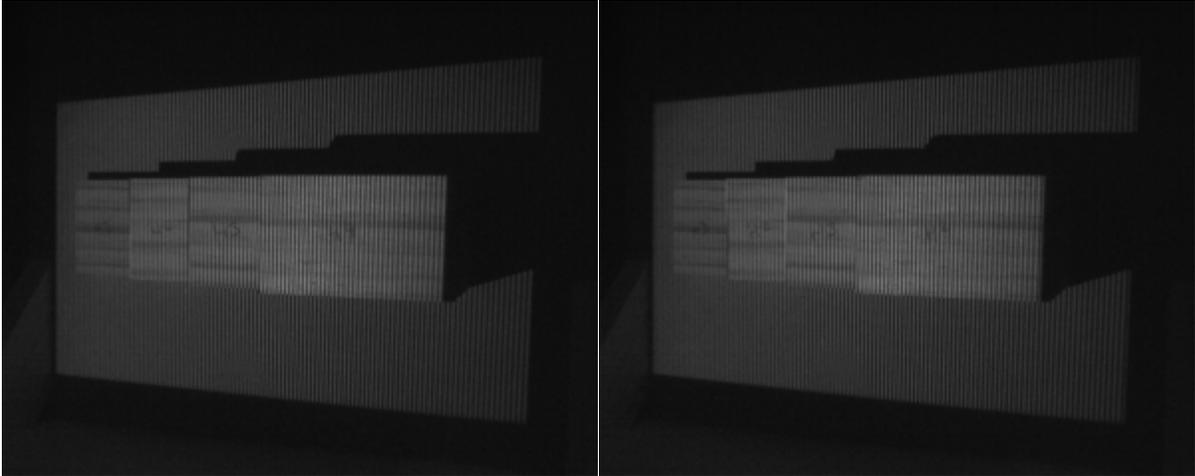


Figure 22 Non-inverted and inverted vertical gray code pattern 9 capture

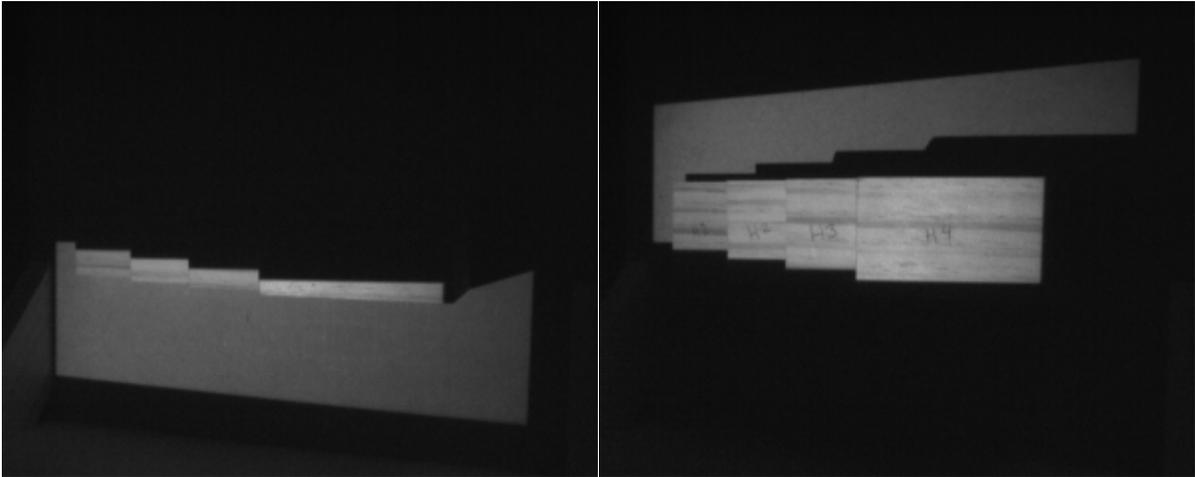


Figure 23 Non-inverted and inverted horizontal gray code pattern 1 capture

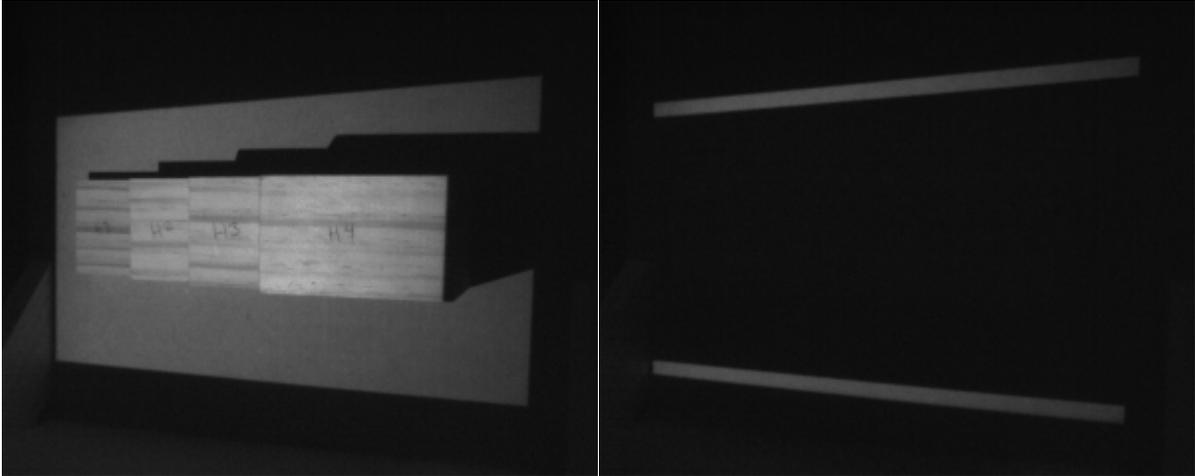


Figure 24 Non-inverted and inverted horizontal gray code pattern 2 capture

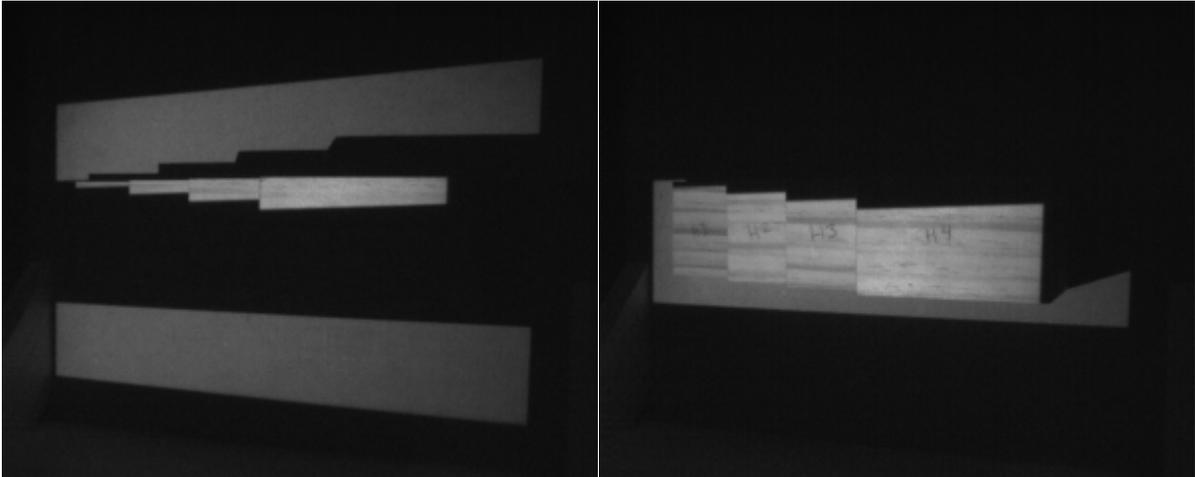


Figure 25 Non-inverted and inverted horizontal gray code pattern 3 capture

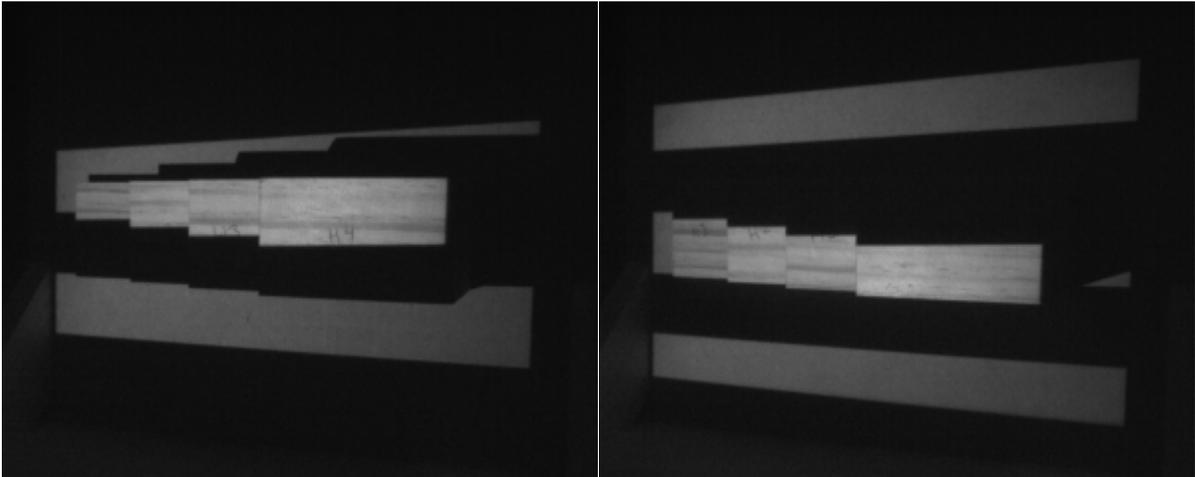


Figure 26 Non-inverted and inverted horizontal gray code pattern 4 capture

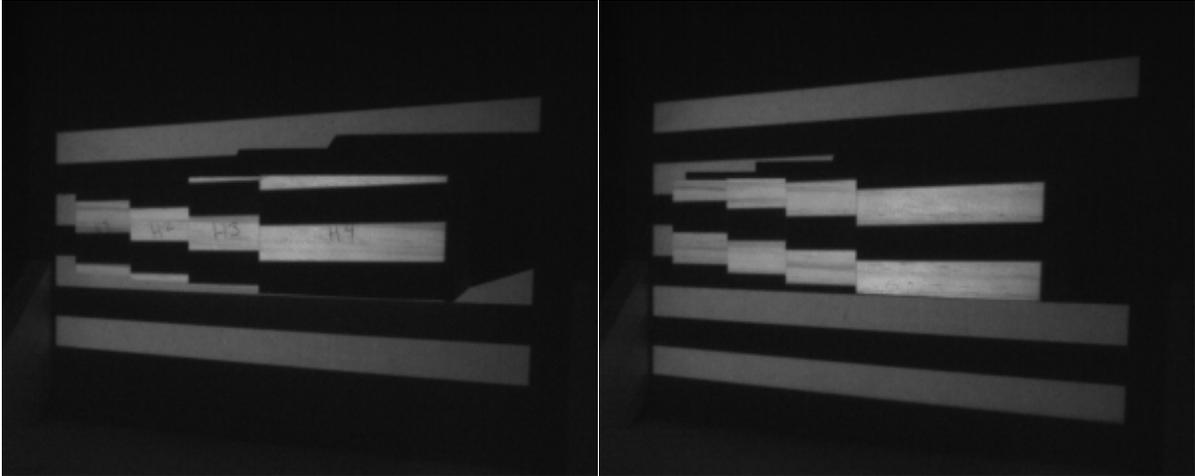


Figure 27 Non-inverted and inverted horizontal gray code pattern 5 capture

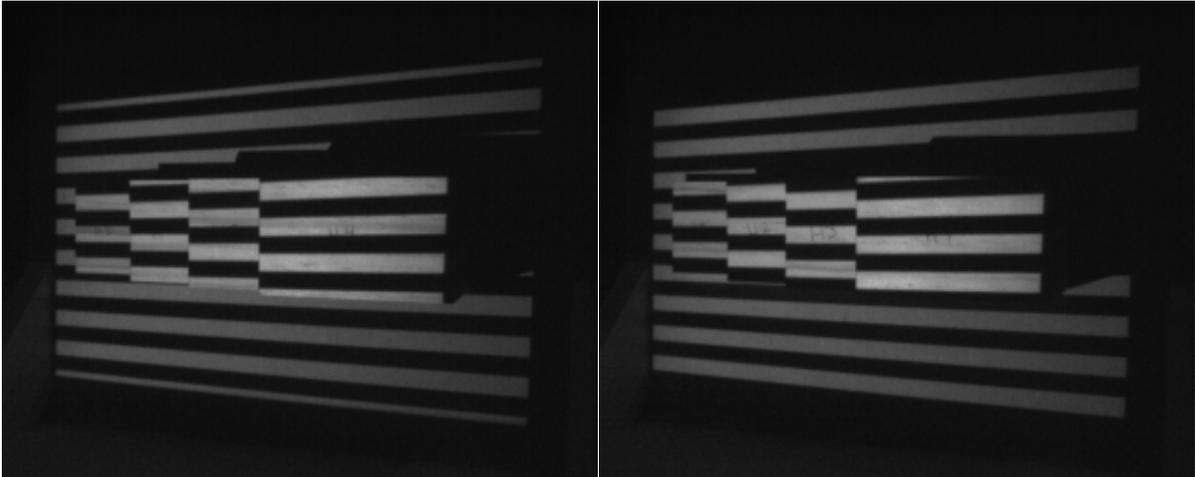


Figure 28 Non-inverted and inverted horizontal gray code pattern 6 capture

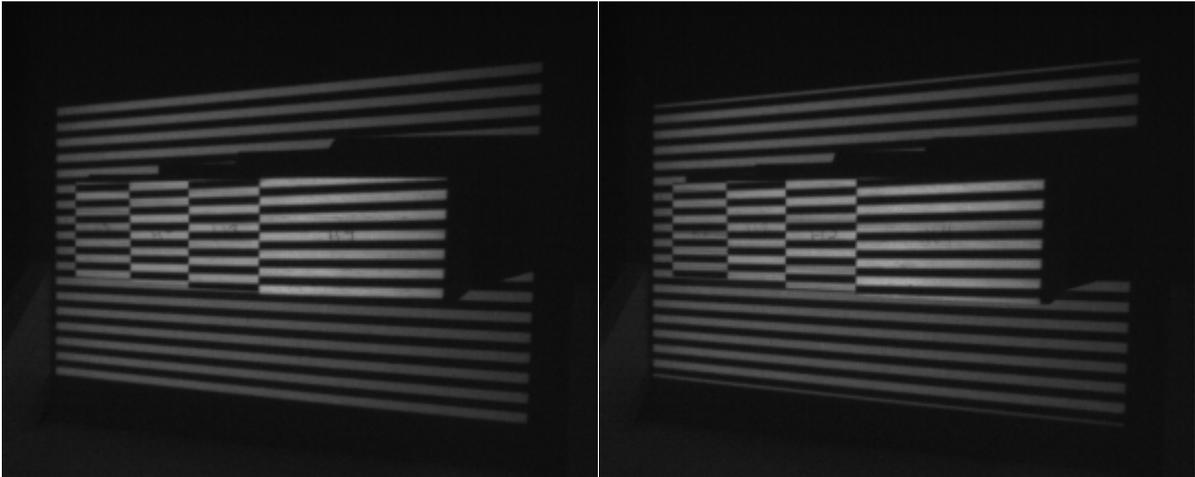


Figure 29 Non-inverted and inverted horizontal gray code pattern 7 capture

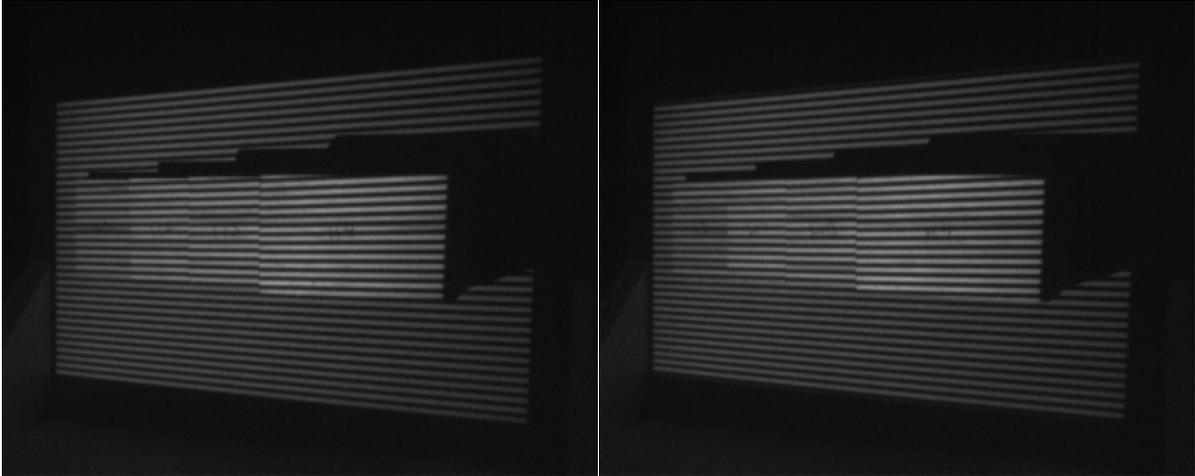


Figure 30 Non-inverted and inverted horizontal gray code pattern 8 capture

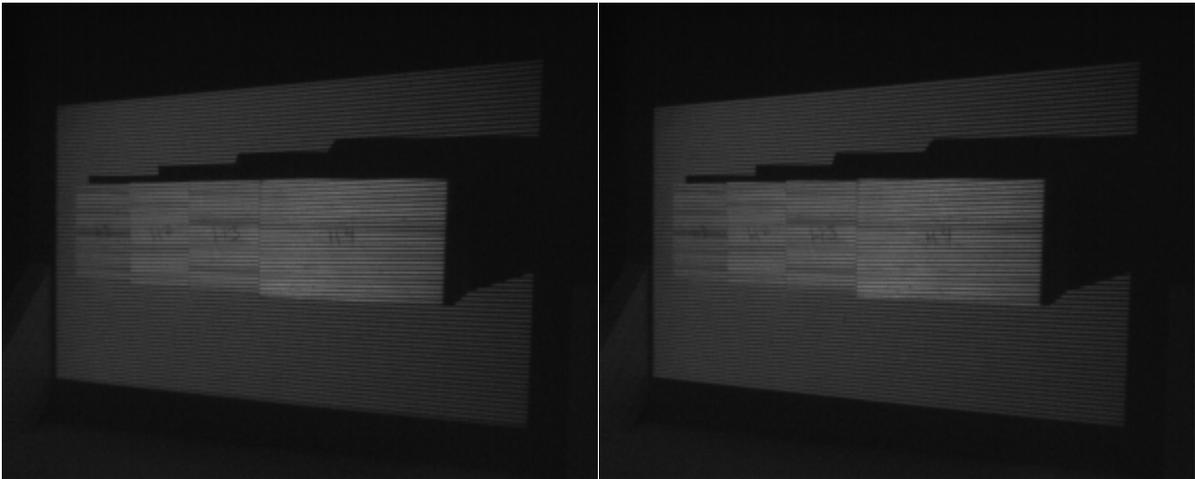


Figure 31 Non-inverted and inverted horizontal gray code pattern 9 capture

The following images show the depth-map and various views of the generated point cloud:

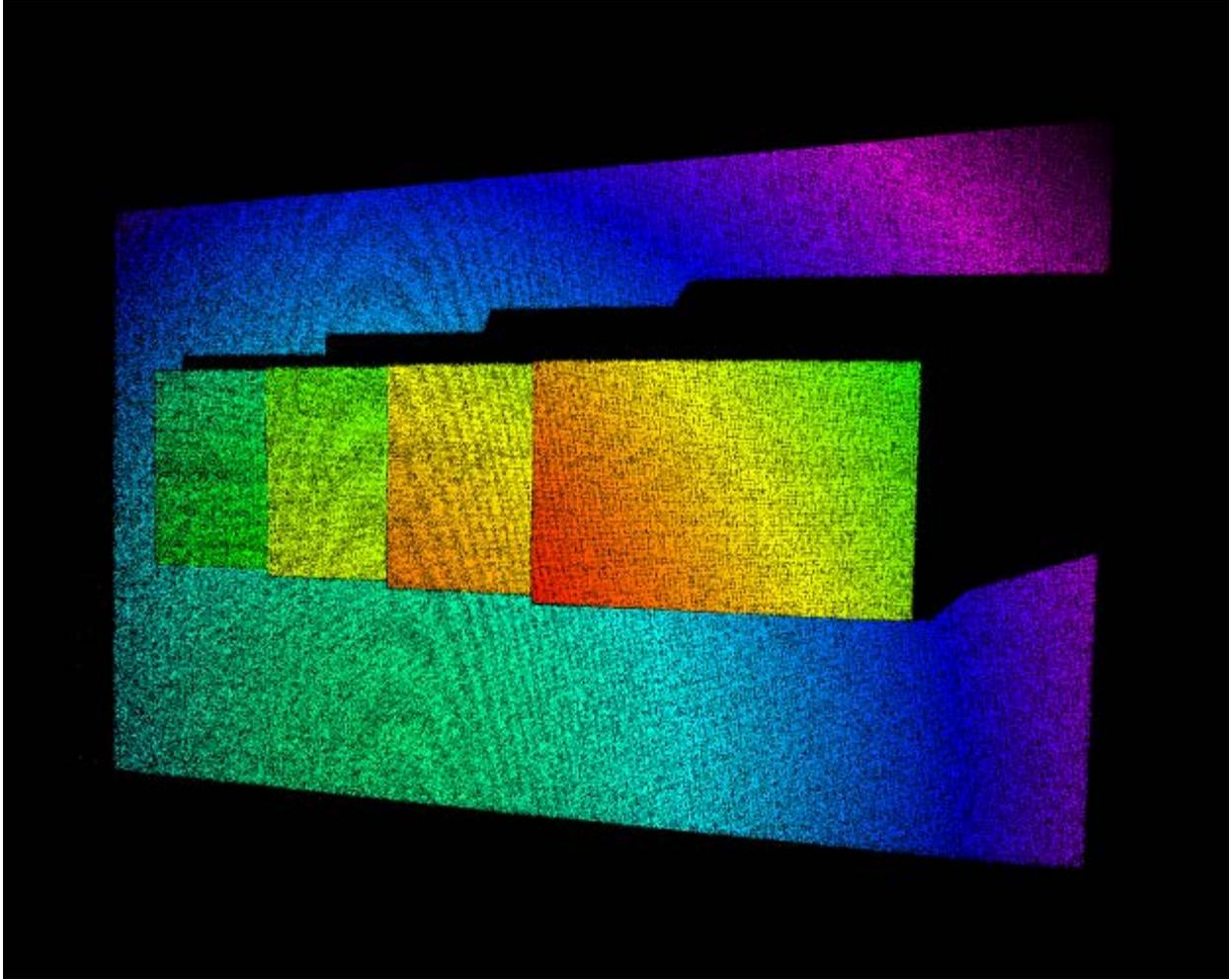


Figure 32 Depth-map of object from 3D scan

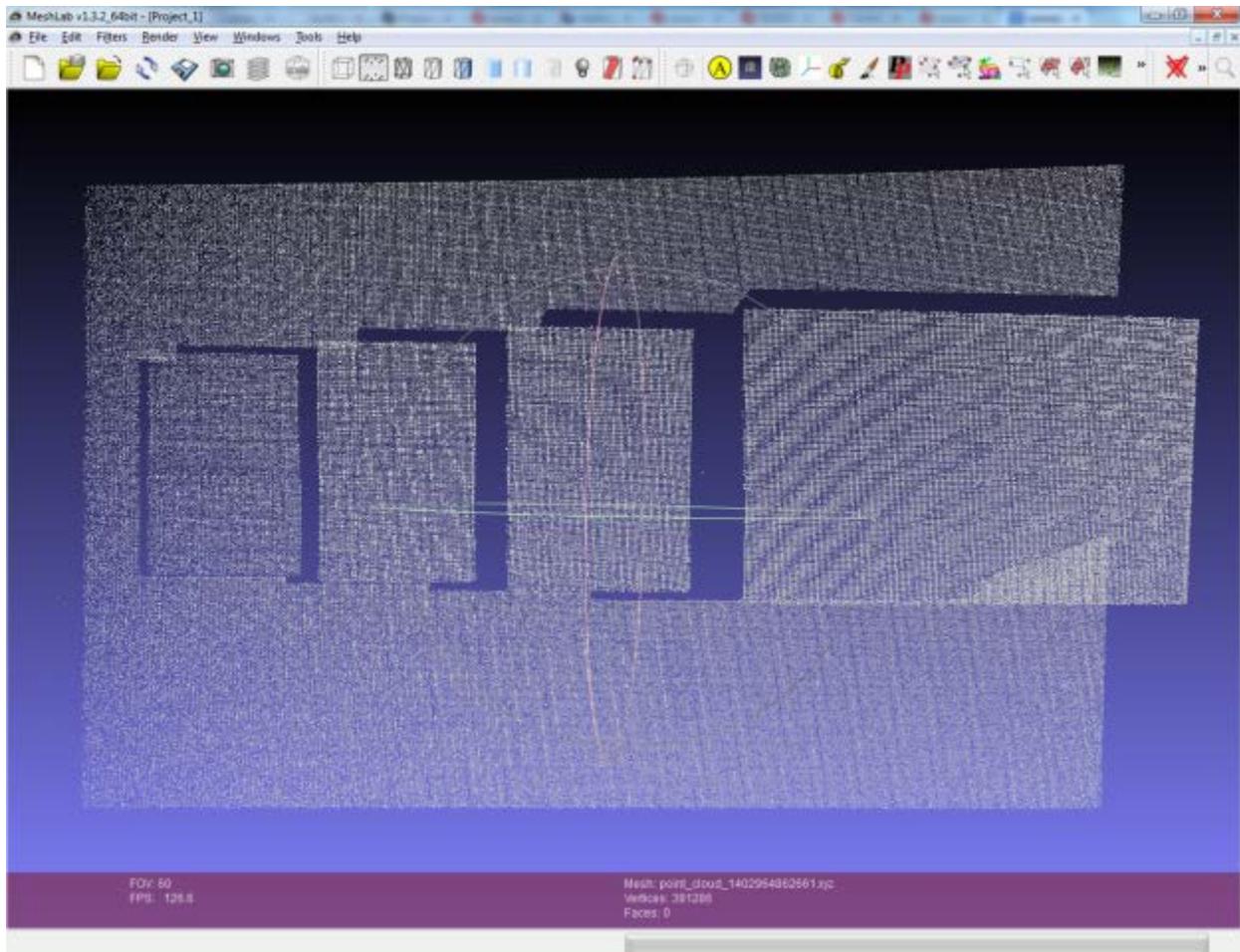


Figure 33 Front view of point-cloud from 3D scan

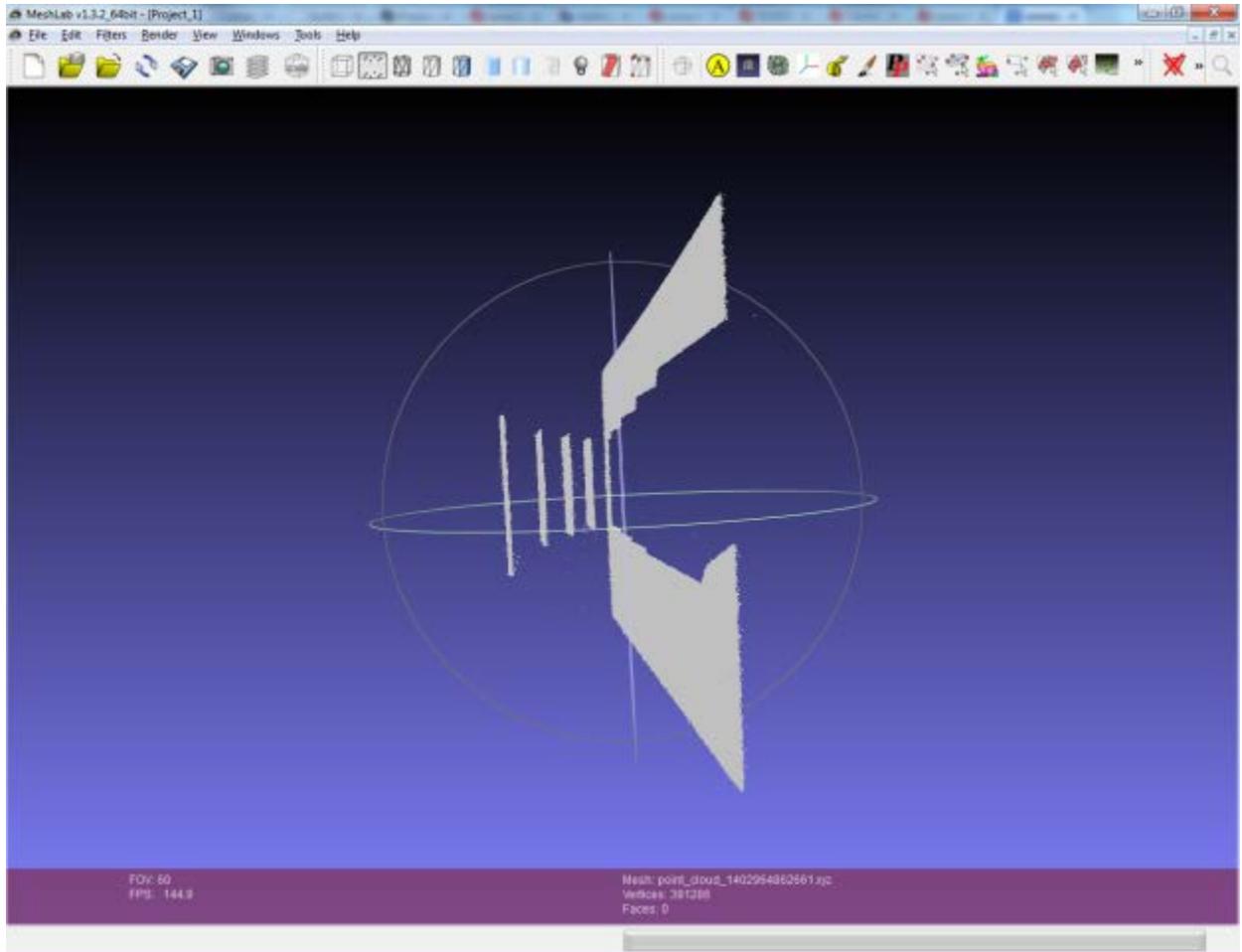


Figure 34 Side view of point-cloud from 3D scan

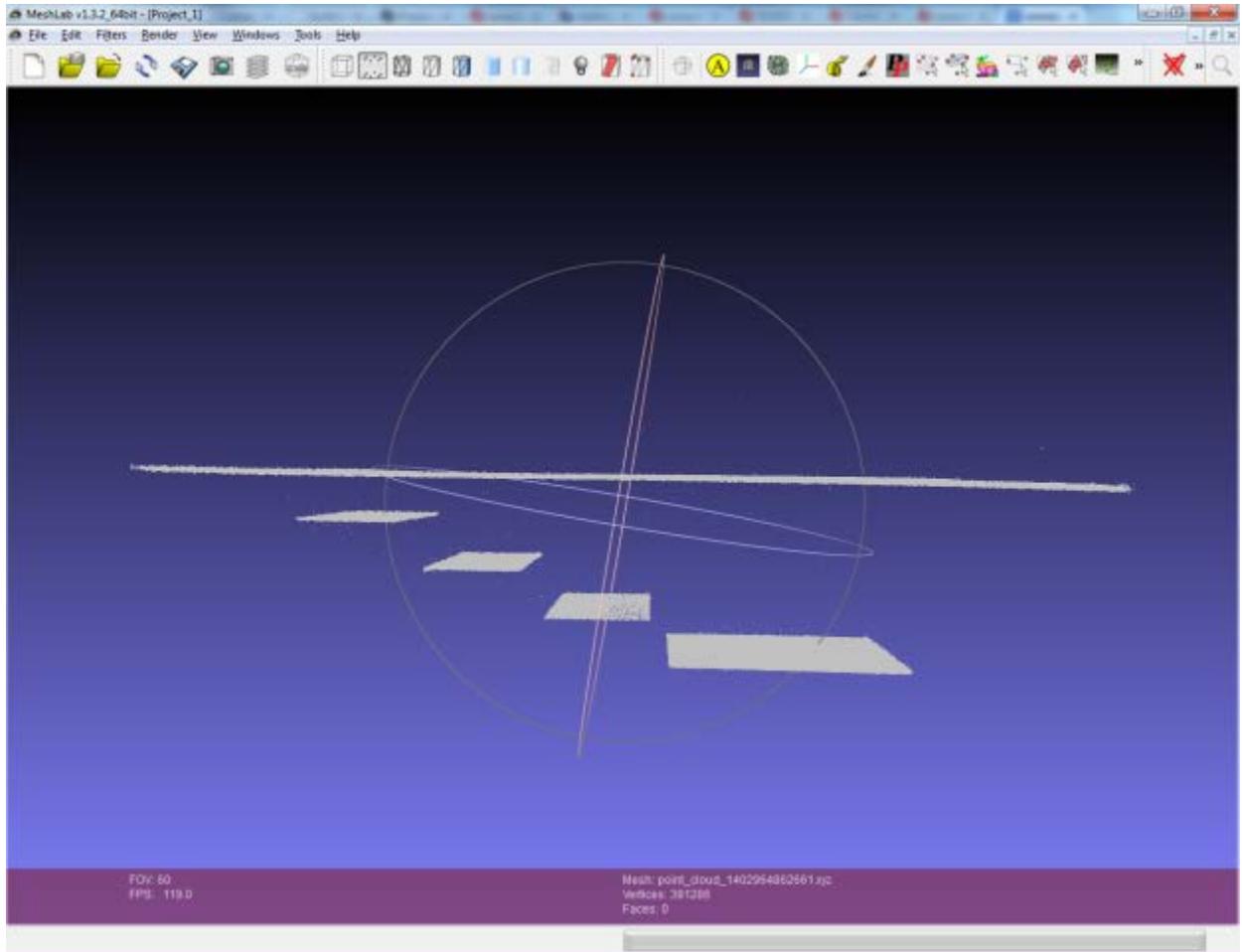


Figure 35 Top view of point-cloud from 3D scan

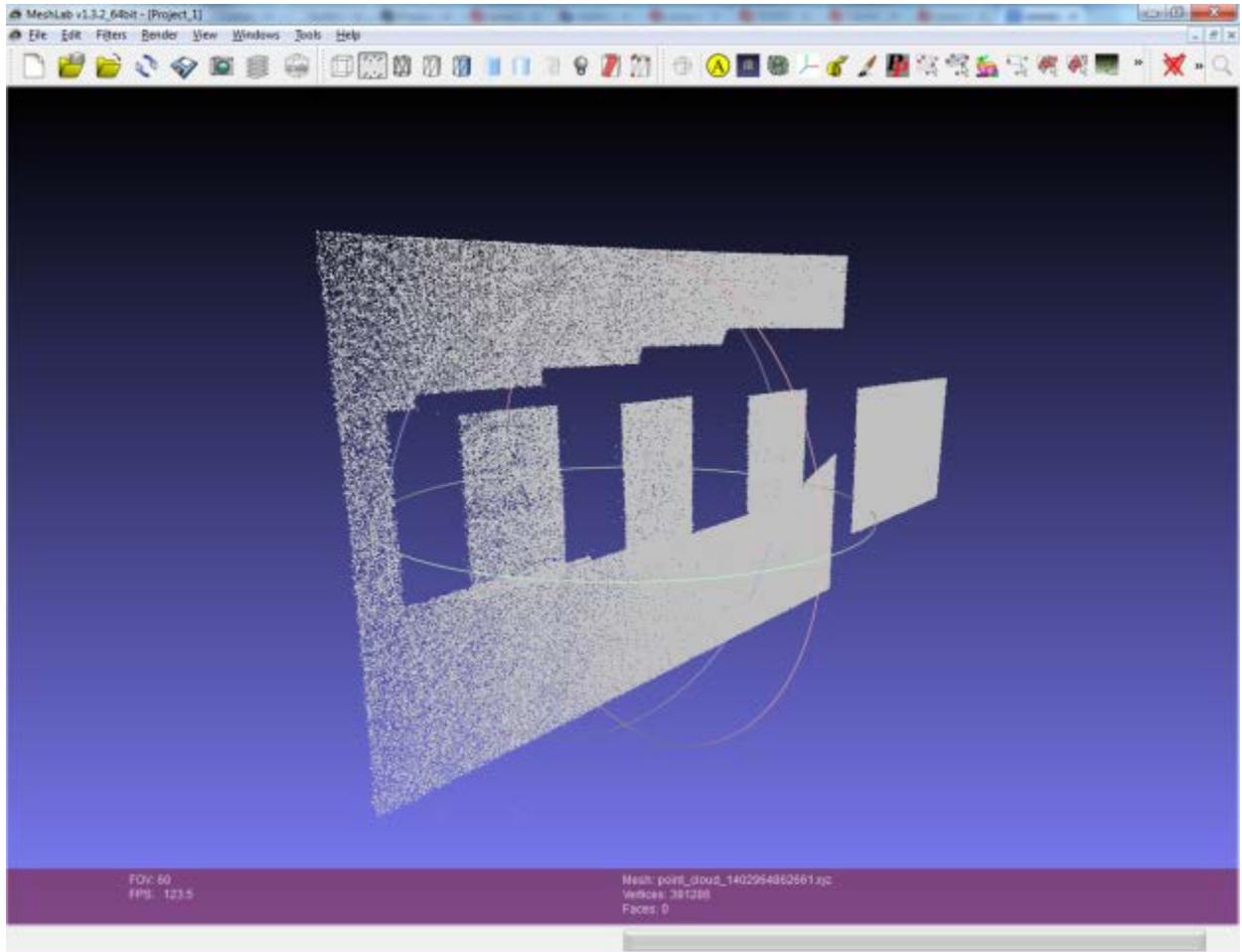


Figure 36 Isometric view of point-cloud from 3D scan

Generated Point Cloud from Hybrid Three Phase Scan

This chapter provides test data from the DLP ALC SDK for structured light pattern decoding and point cloud generation. In this test case a three-phase hybrid scan using horizontal patterns is demonstrated.

To calibrate the system, the following procedure is used:

1. Calibrate the camera and system
2. From main menu of software, select “3: Prepare system for calibration and scanning”
3. From main menu of software, select “7: Perform scan (horizontal patterns only)”

The following images show the camera captures of the projected structured light patterns:

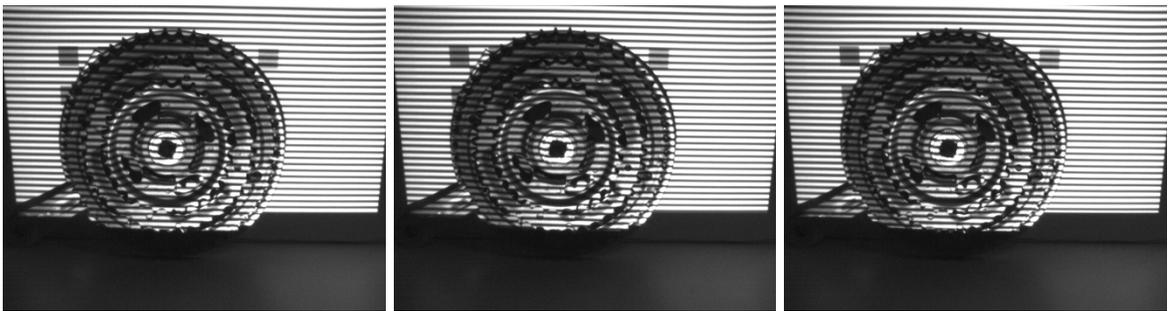


Figure 37 Three phase patterns

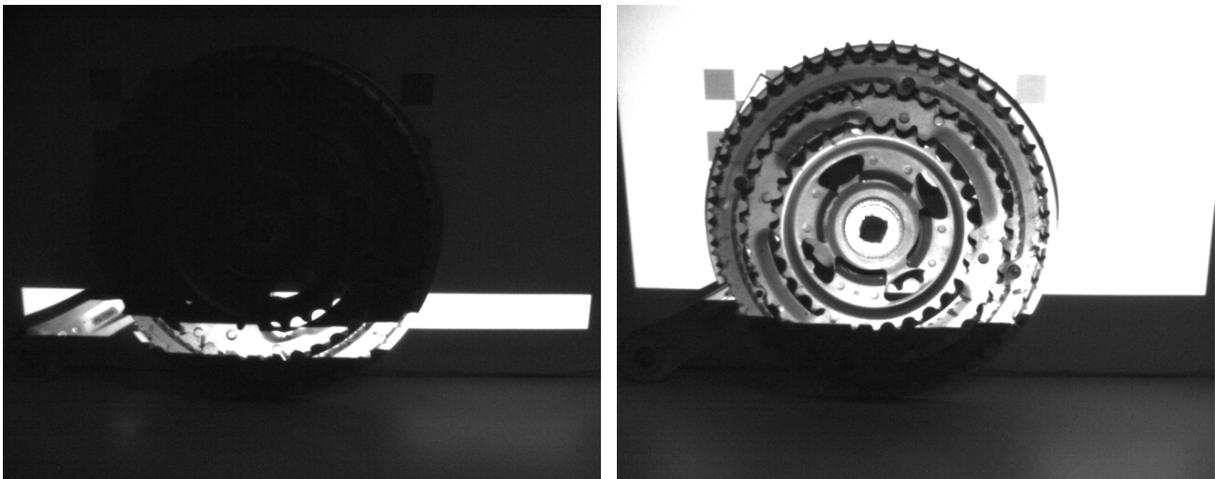


Figure 38 Non-inverted and inverted horizontal gray code pattern 1 capture

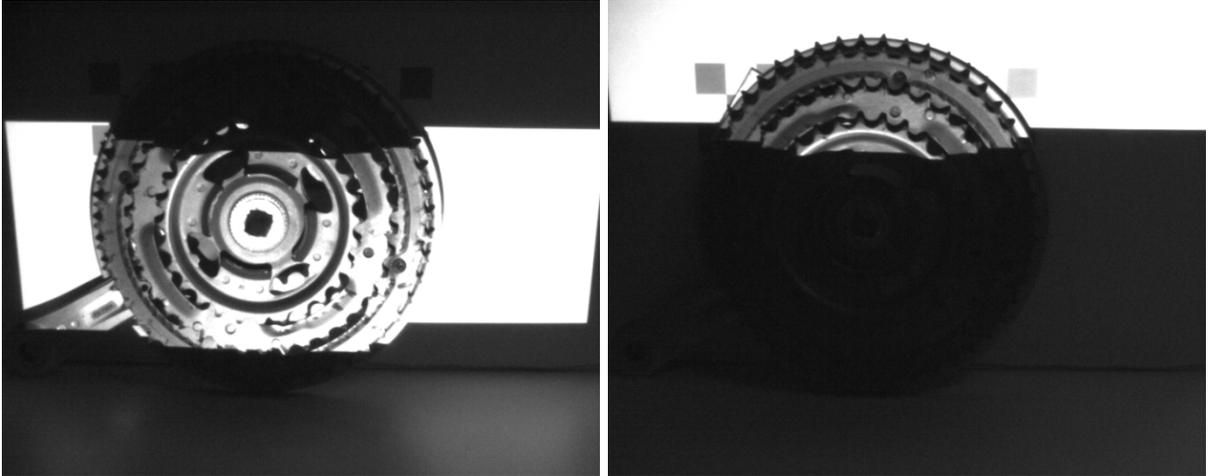


Figure 39 Non-inverted and inverted horizontal gray code pattern 2 capture

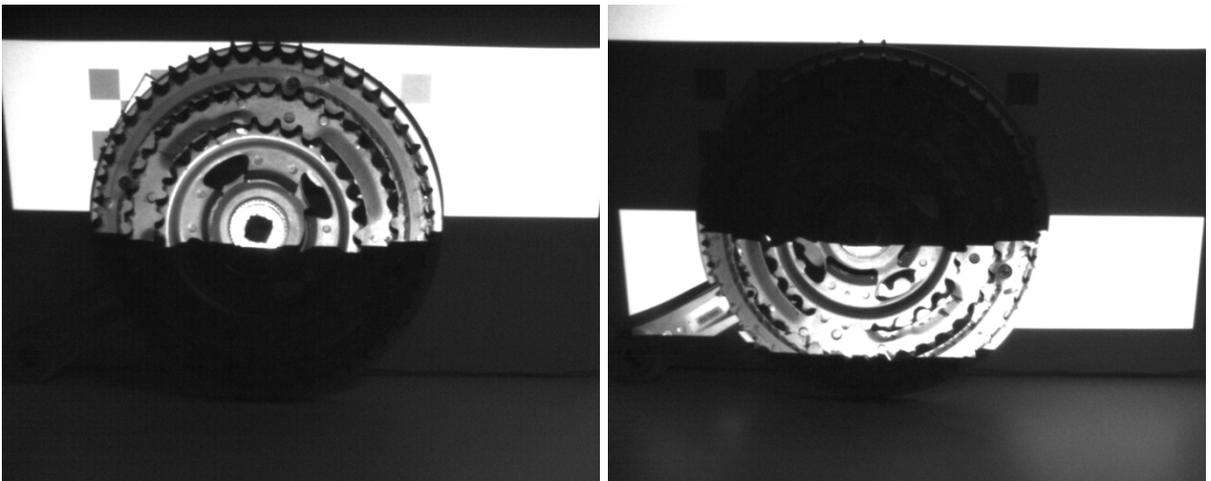


Figure 40 Non-inverted and inverted horizontal gray code pattern 3 capture

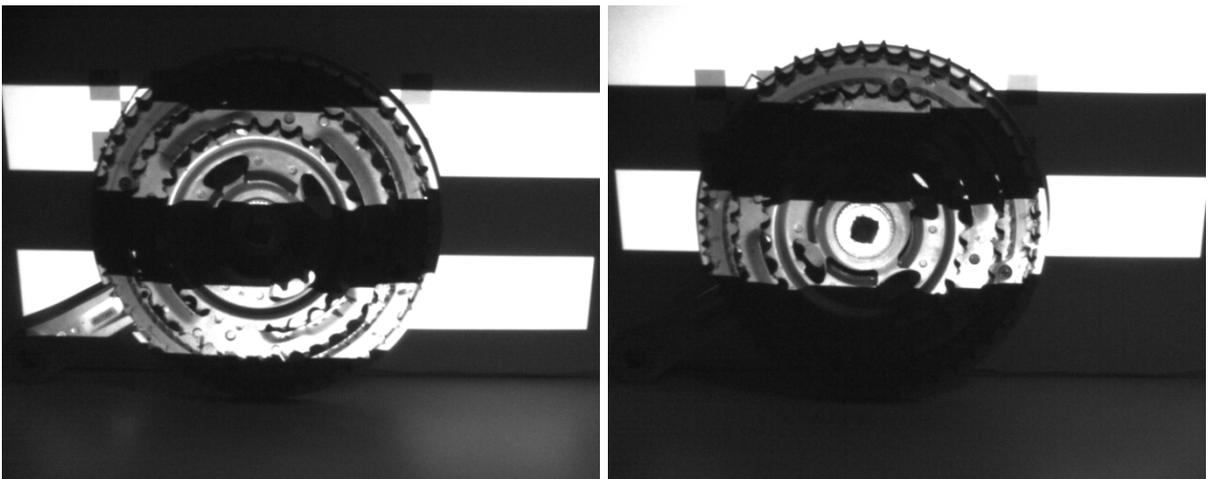


Figure 41 Non-inverted and inverted horizontal gray code pattern 4 capture

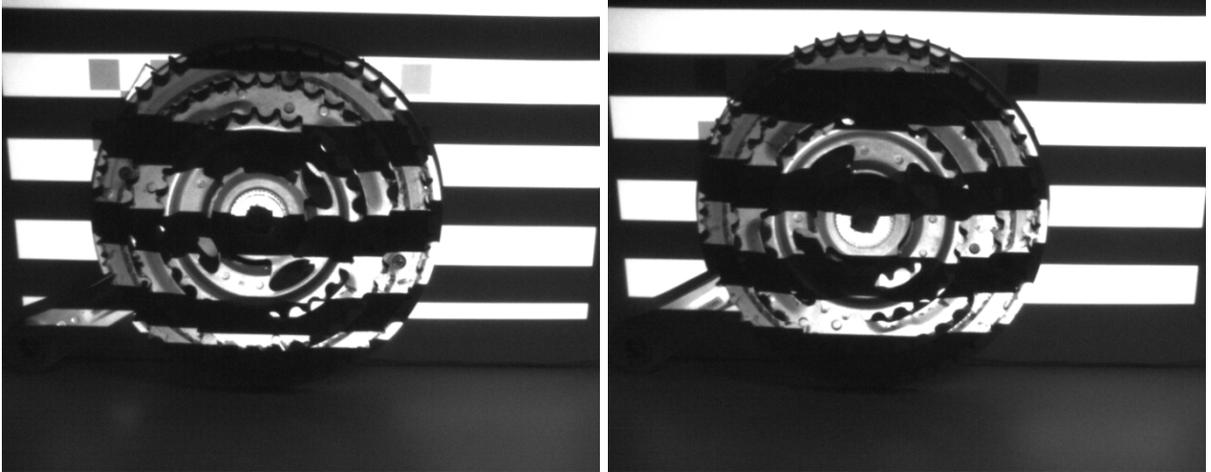


Figure 42 Non-inverted and inverted horizontal gray code pattern 5 capture

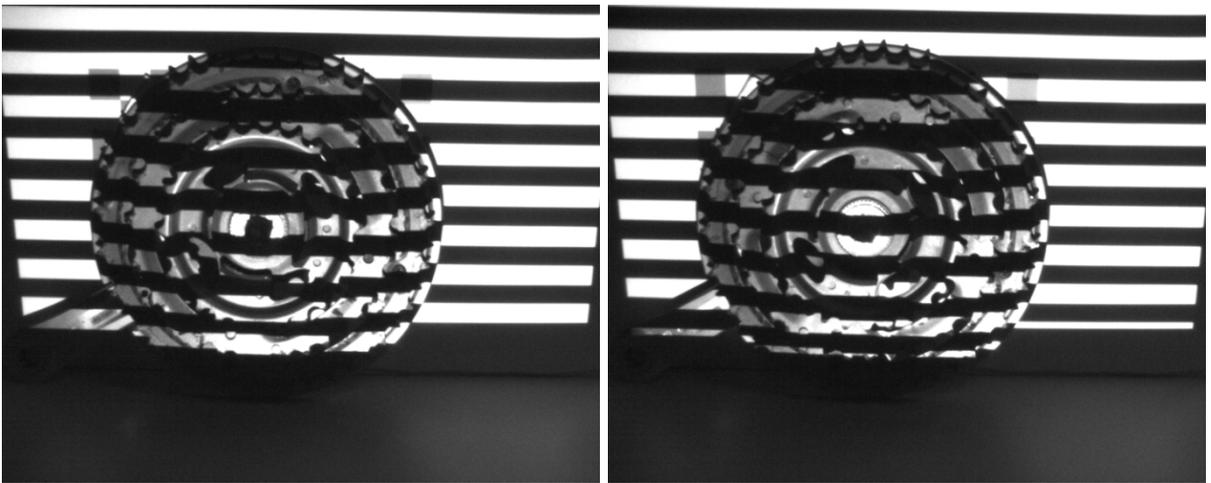


Figure 43 Non-inverted and inverted horizontal gray code pattern 6 capture

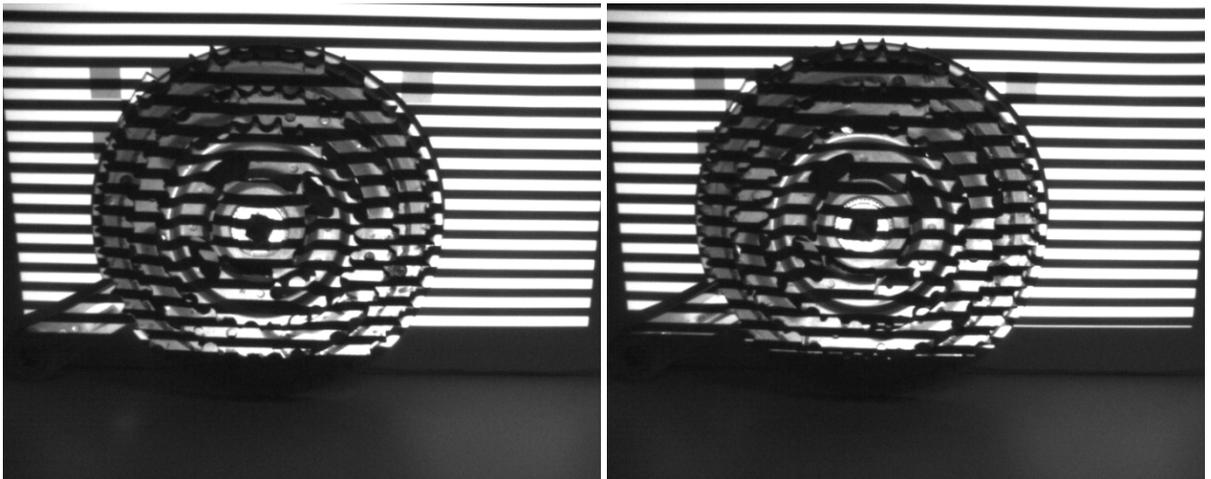


Figure 44 Non-inverted and inverted horizontal gray code pattern 7 capture

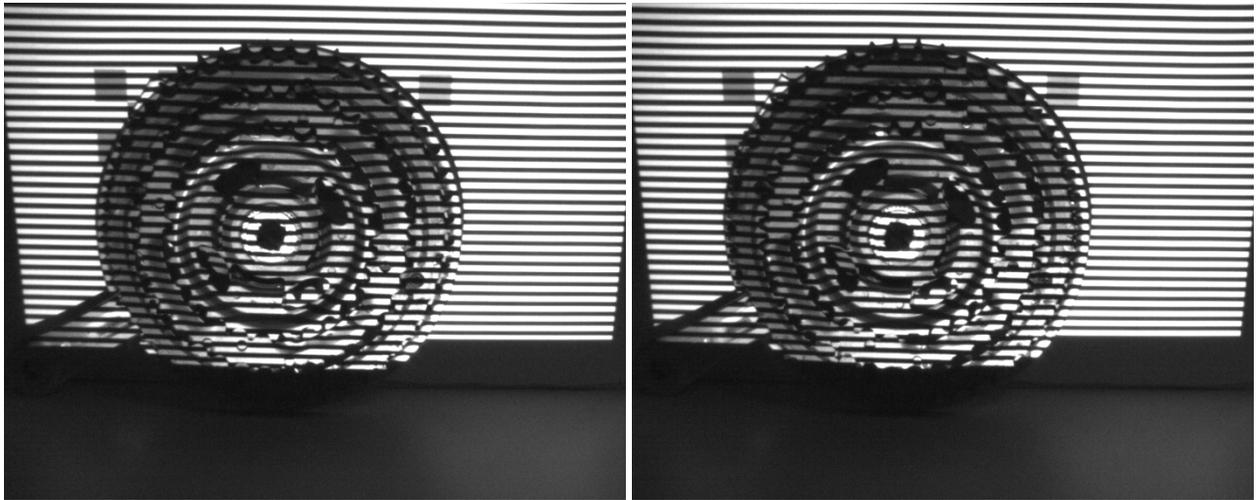


Figure 45 Non-inverted and inverted horizontal gray code pattern 8 capture

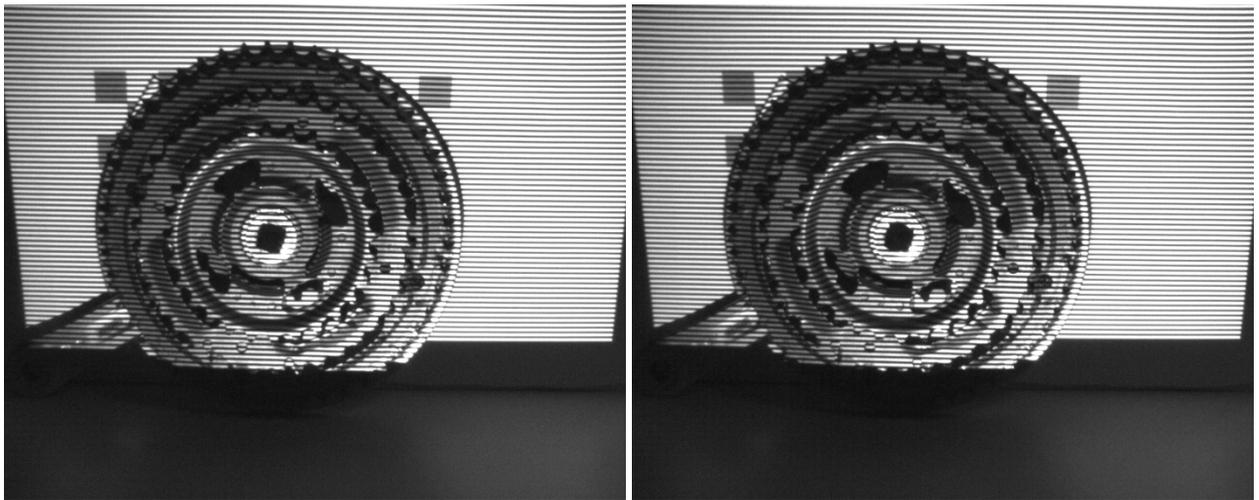


Figure 46 Non-inverted and inverted horizontal gray code pattern 9 capture

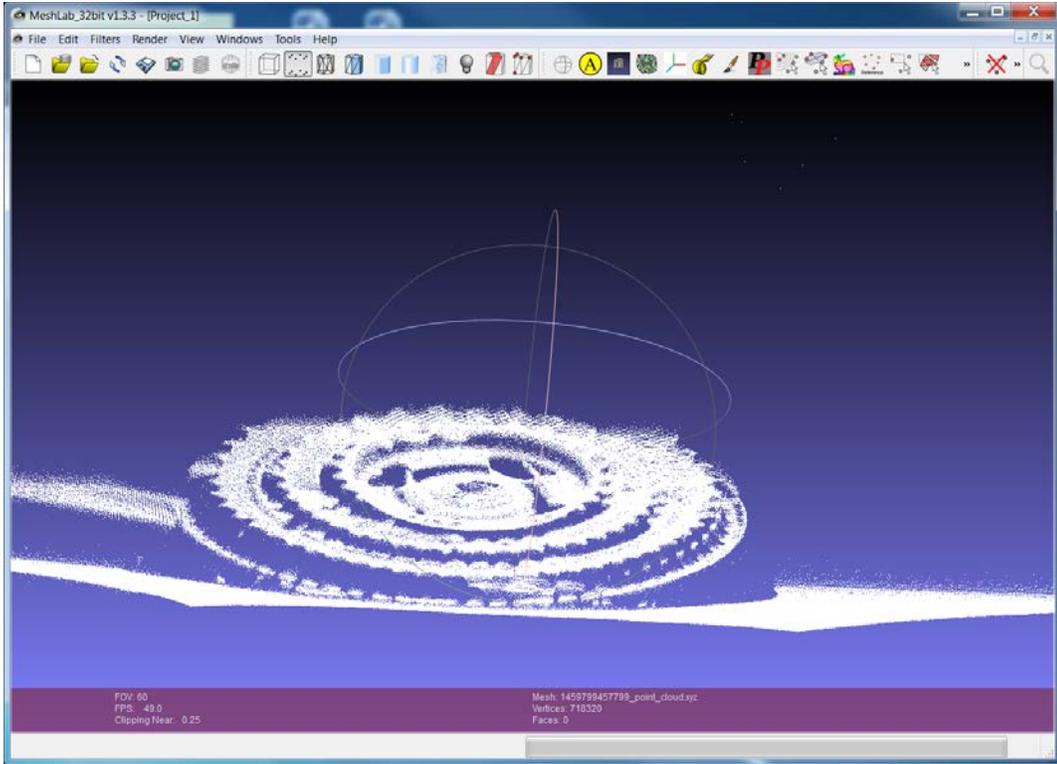


Figure 47 Bottom view of point cloud

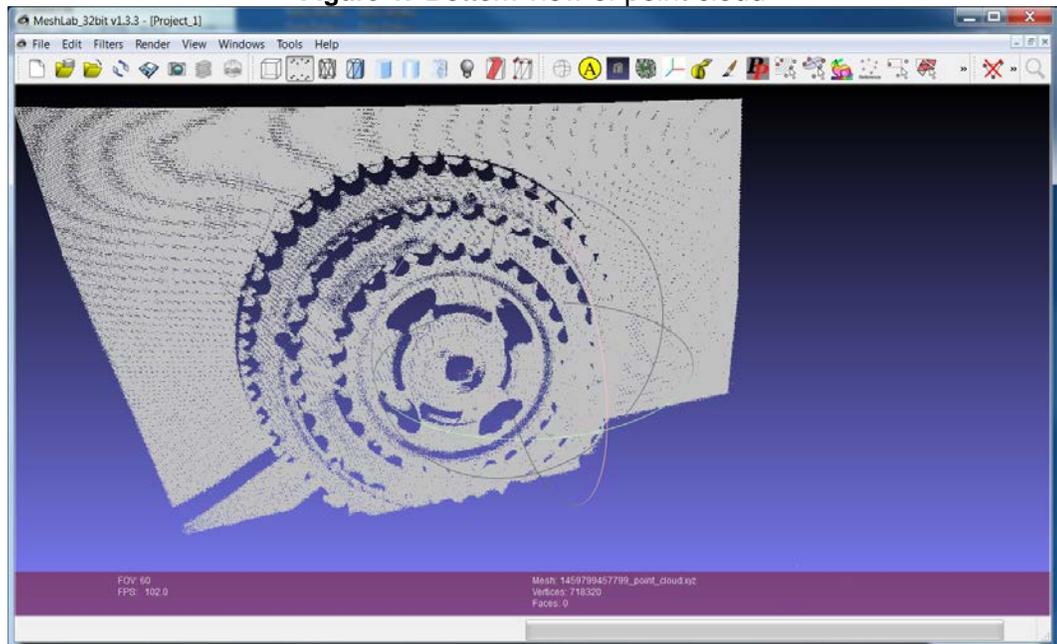


Figure 48 Isometric view of point cloud

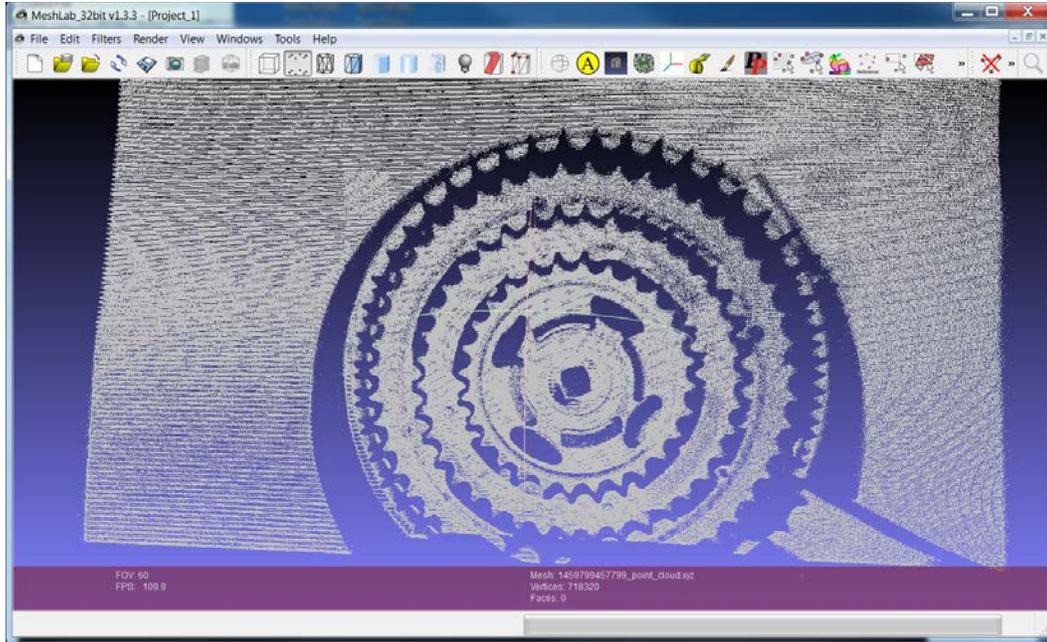


Figure 49 Rear view of point cloud

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](#) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2021, Texas Instruments Incorporated