High Resolution 3D Scanner for Factory Automation using DLP® Technology and Industrial Camera

About Test Results

The DLP 3D Scanner Reference Design offers a complete software solution for 3D scanning and 3D point cloud generation. The point cloud data below was generated using the DLP 3D Scanner Reference Design with a DLP® LightCrafter™ 6500 and Point Grey Grasshopper3 USB camera. The generated point cloud data was visualized using MeshLab.

Related Documentation From Texas Instruments

- DLPC900 Data Sheet: DLPC900 Digital Controller for Advanced Light Control, TI literature number DLPS037
- DLP6500 s600 package Data Sheet: DLP6500FYE DMD, TI literature number DLPS053
- DLP6500 Type A package Data Sheet: DLP6500FLQ 0.65 1080p MVSP Type A DMD, TI literature number DLPS040
- User's Guide: DLPC900 Programmer's Guide, TI literature number DLPU018
- Application Note: Using DLP® Development Kits for 3D Optical Metrology Systems, TI literature number DLPA026

If You Need Assistance

Please search the DLP & MEMS TI E2E Community support forums

Calibration Results

This chapter provides test data from the DLP 3D Scanner Reference Design for camera and projector calibration. 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 single square on the calibration board in the desired units of the point cloud (e.g. inches, millimeters)

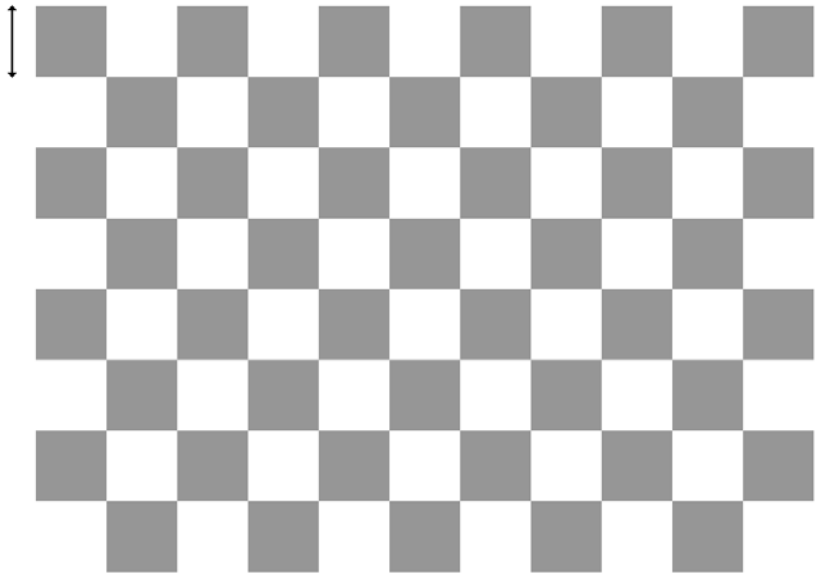

Figure 1 Camera calibration board measurement

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

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

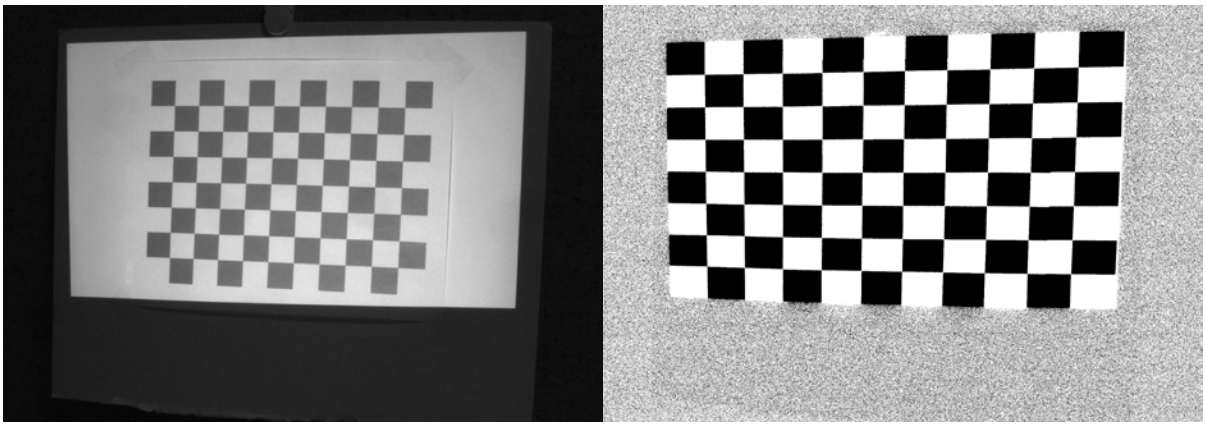

Figure 2 Printed calibration board and projected calibration board position 1

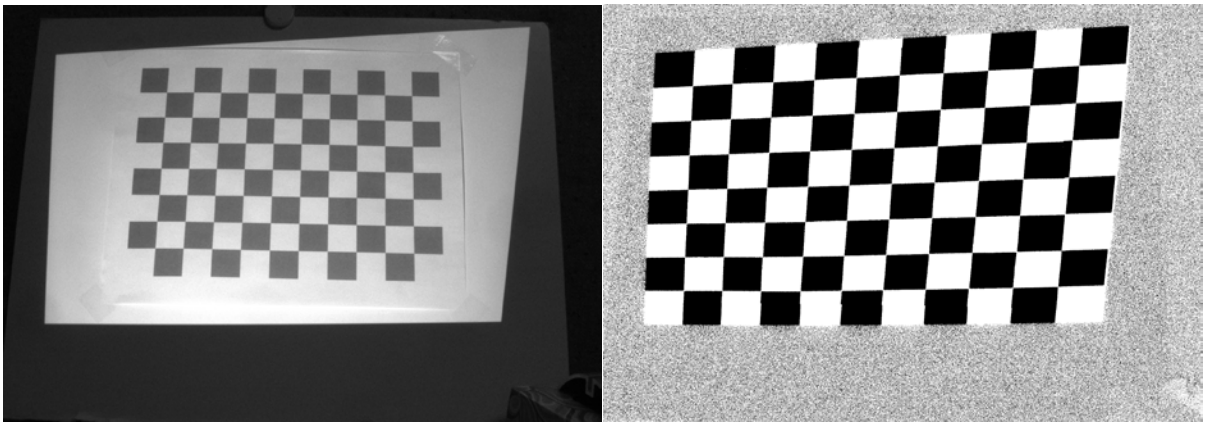

Figure 3 Printed calibration board and projected calibration board position 2

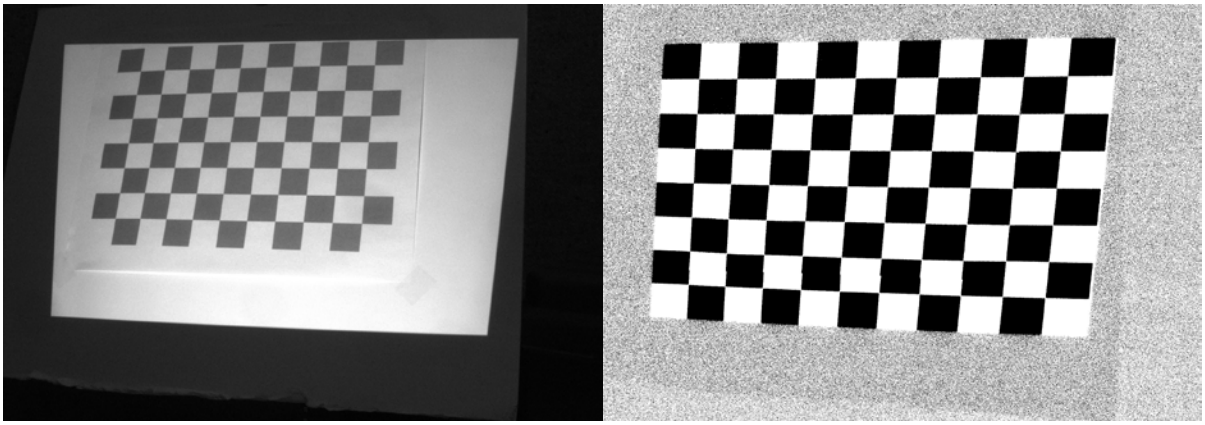

Figure 4 Printed calibration board and projected calibration board position 3

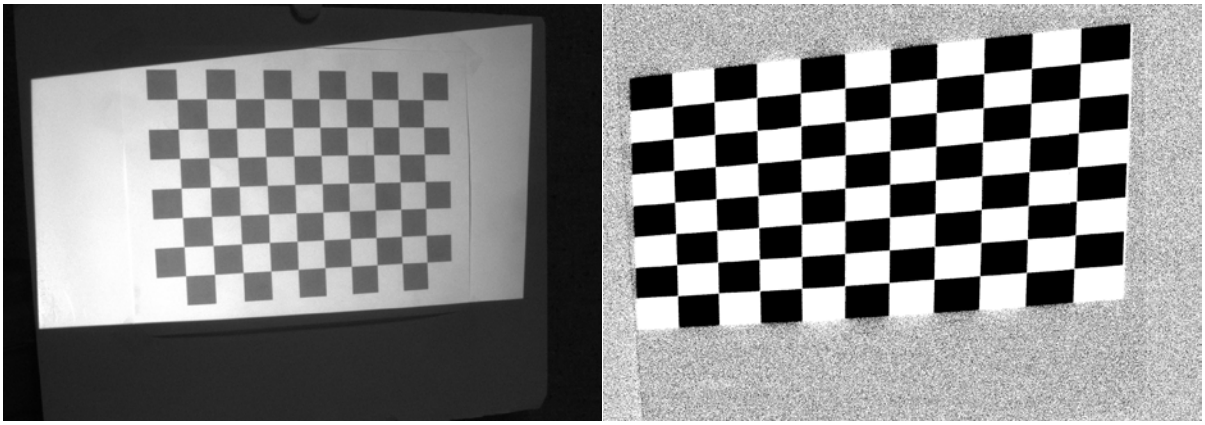

Figure 5 Printed calibration board and projected calibration board position 4

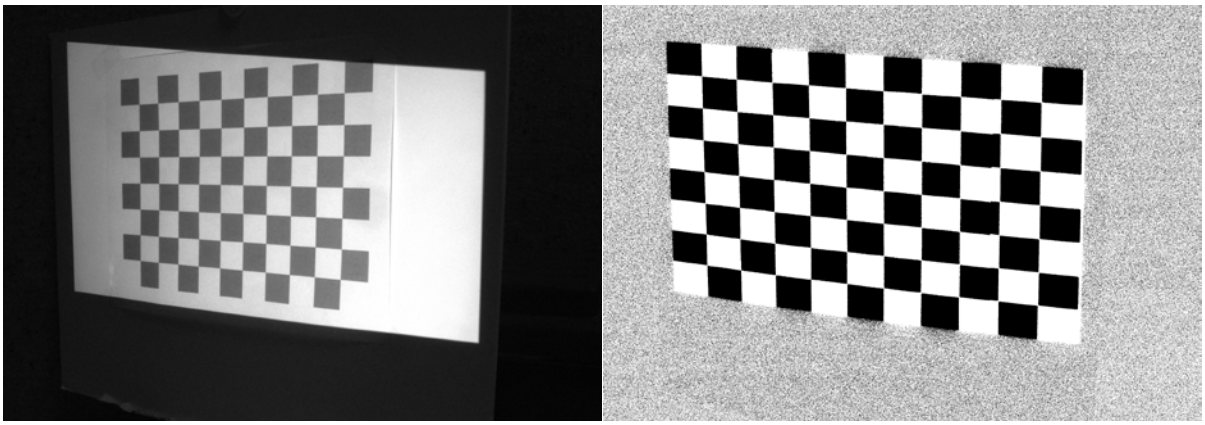

Figure 6 Printed calibration board and projected calibration board position 5

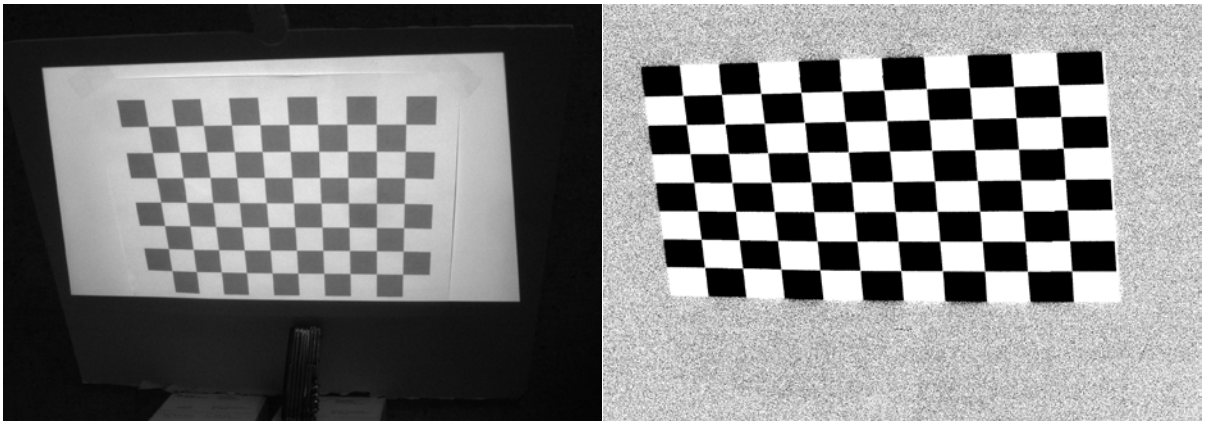

Figure 7 Printed calibration board and projected calibration board position 6

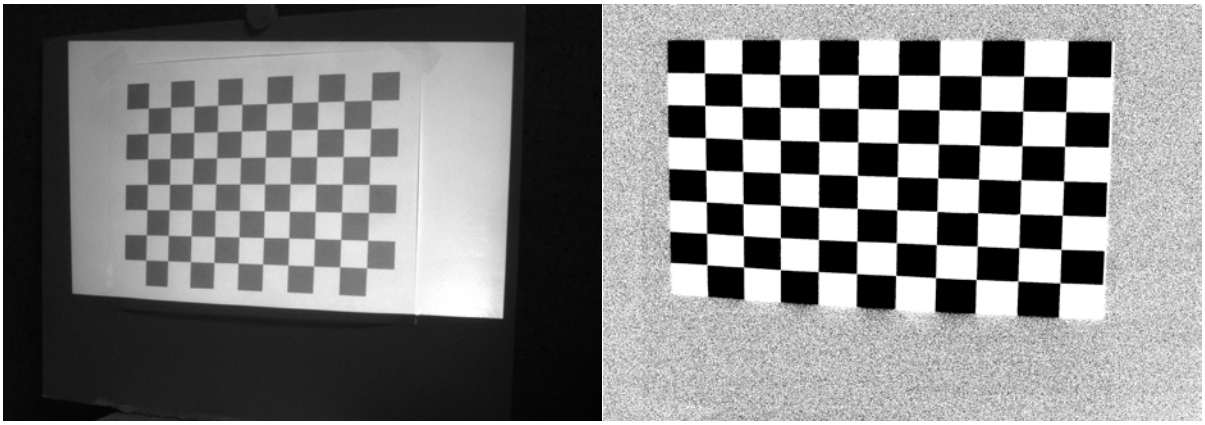

Figure 8 Printed calibration board and projected calibration board position 7

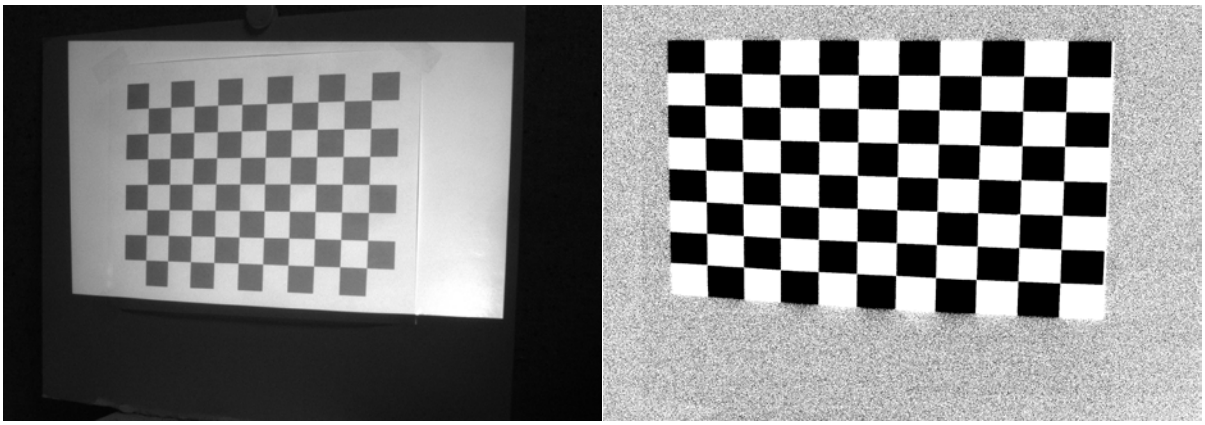

Figure 9 Printed calibration board and projected calibration board position 8

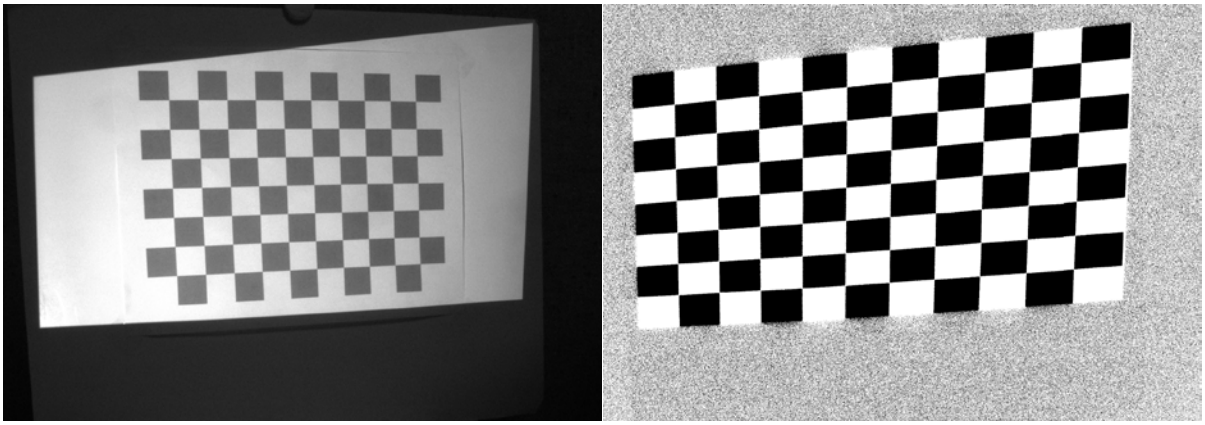

Figure 10 Printed calibration board and projected calibration board position 9

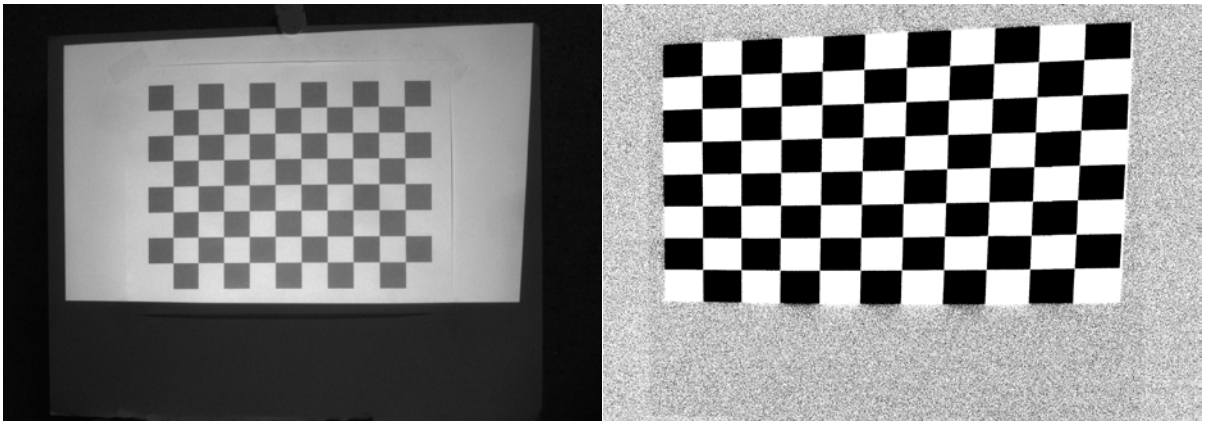

Figure 11 Printed calibration board and projected calibration board position 10

The following images show examples of 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>2016</image_columns>
    <image_rows>1400</image_rows>
    <model_columns>2016</model_columns>
    <model_rows>1400</model_rows>
    <reprojection_error>5.7857778532124060e-001</reprojection_error>
  - <intrinsic type_id="opencv-matrix">
      <rows>3</rows>
      <cols>3</cols>
      <dt>d</dt>
      <data>2.6457639107969694e+003 0. 1.0203918110479486e+003 0. 2.6380434103392467e+003
        1.0175320453856729e+003 0. 0. 1.</data>
    </intrinsic>
  - <distortion type_id="opencv-matrix">
      <rows>5</rows>
      <cols>1</cols>
      <dt>d</dt>
      <data>-1.5183494478720302e-001 2.2839168906940696e-001 4.1186926274568712e-004 -
        6.4691724537225322e-004 -2.8481711827125306e-001</data>
    </distortion>
  - <extrinsic type_id="opencv-matrix">
      <rows>2</rows>
      <cols>3</cols>
      <dt>d</dt>
      <data>6.6058835514149733e-002 1.8972188165263321e-001 4.7740032302532494e-002 -
        1.0407660185246924e+002 -1.7269029532555254e+002 6.7099407438063611e+002</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>2016</image_columns>
    <image_rows>1400</image_rows>
    <model_columns>1920</model_columns>
    <model_rows>1080</model_rows>
    <reprojection_error>1.1922658745732175e+000</reprojection_error>
  - <intrinsic type_id="opencv-matrix">
      <rows>3</rows>
      <cols>3</cols>
      <dt>d</dt>
      <data>3.3691147240740588e+003 0. 9.4476174461776475e+002 0. 3.3691147240740588e+003
        1.4560807847927424e+003 0. 0. 1.</data>
    </intrinsic>
  - <distortion type_id="opencv-matrix">
      <rows>5</rows>
      <cols>1</cols>
      <dt>d</dt>
      <data>-2.2805379799933401e-001 7.1997126858185301e-001 5.9984656394572872e-003 -
        1.4603215525778711e-003 -1.1448811976243933e+000</data>
    </distortion>
  - <extrinsic type_id="opencv-matrix">
      <rows>2</rows>
      <cols>3</cols>
      <dt>d</dt>
      <data>-7.2094073915566067e-003 2.6531386630603161e-002 2.8425000464309527e-002 -
        9.3546155366607962e+001 -2.4445416011951511e+002 6.7340120727406475e+002</data>
    </extrinsic>
</opencv_storage>
```


Figure 13 Projector calibration XML output file

Generated Point Cloud

This chapter provides test data from the DLP 3D Scanner Reference Design for structured light pattern decoding and point cloud generation. The patterns are generated to determine which projector rays are intersecting with the scanned object and the intersection between the projector and camera optical rays are calculated to generate a depth-map and point-cloud of 3D measurements.

The following procedure is used, which assumes the system is calibrated:

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

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

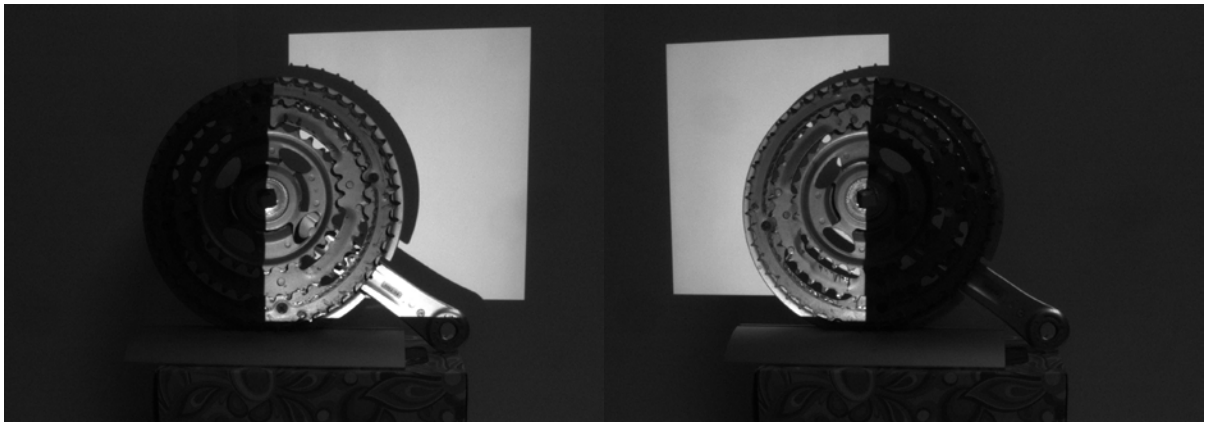

Figure 14 Non-inverted and inverted vertical gray code pattern 1 capture

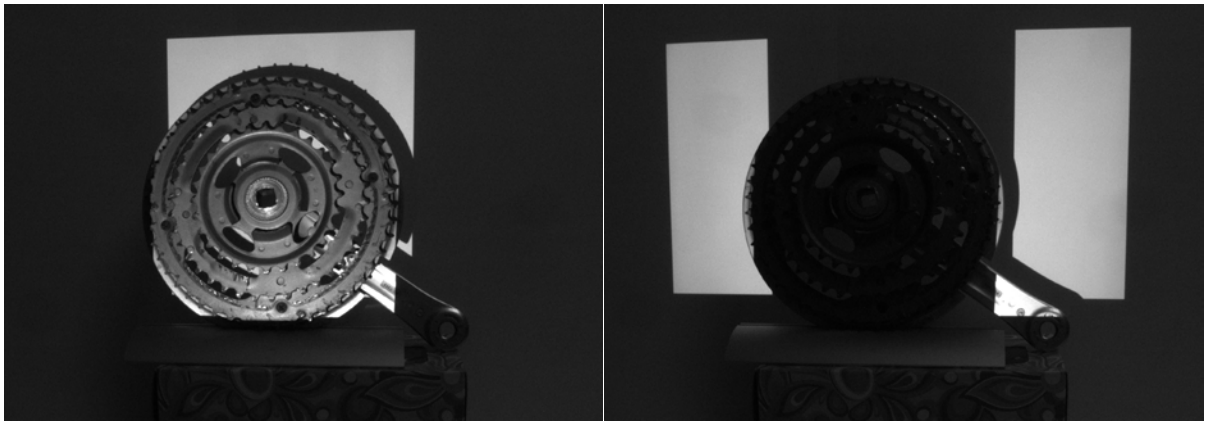

Figure 15 Non-inverted and inverted vertical gray code pattern 2 capture

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

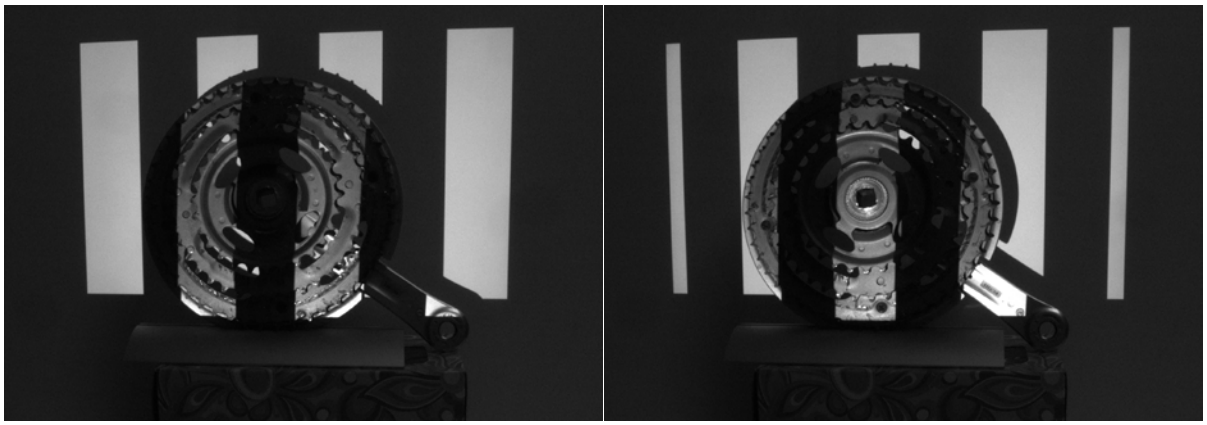

Figure 17 Non-inverted and inverted vertical gray code pattern 4 capture

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

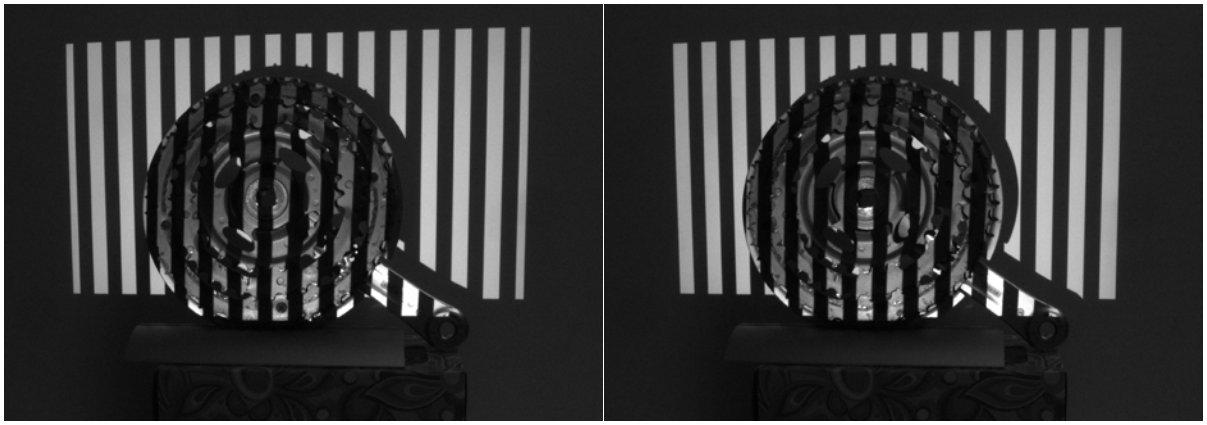

Figure 19 Non-inverted and inverted vertical gray code pattern 6 capture

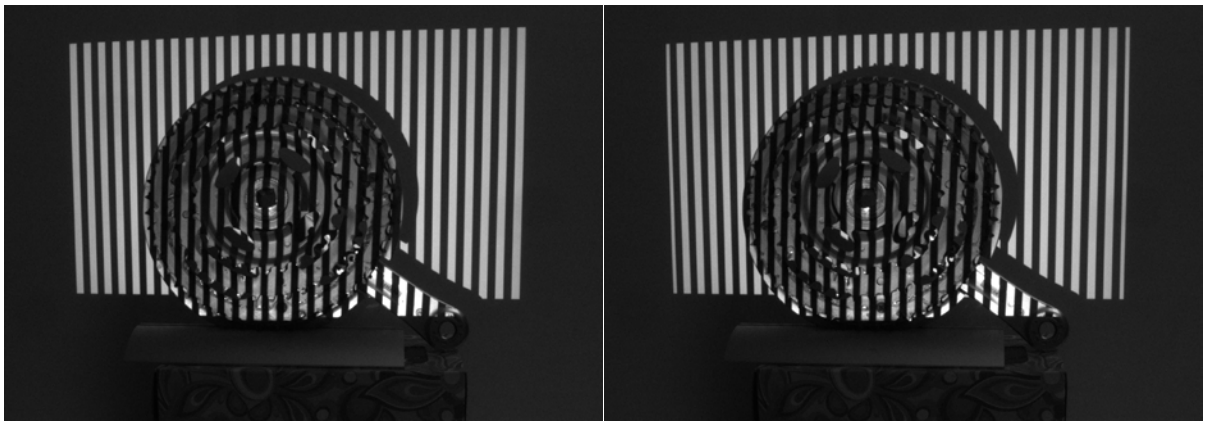

Figure 20 Non-inverted and inverted vertical gray code pattern 7 capture

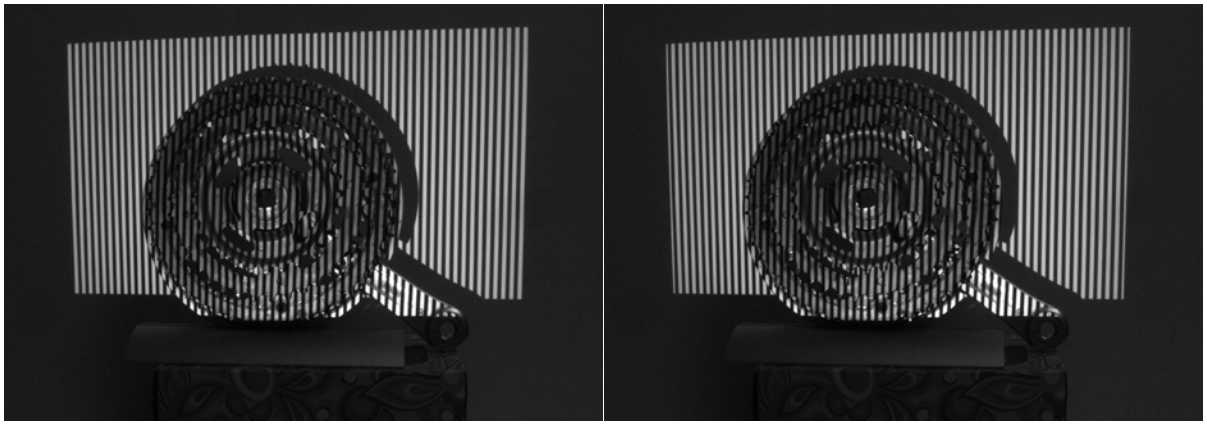

Figure 21 Non-inverted and inverted vertical gray code pattern 8 capture

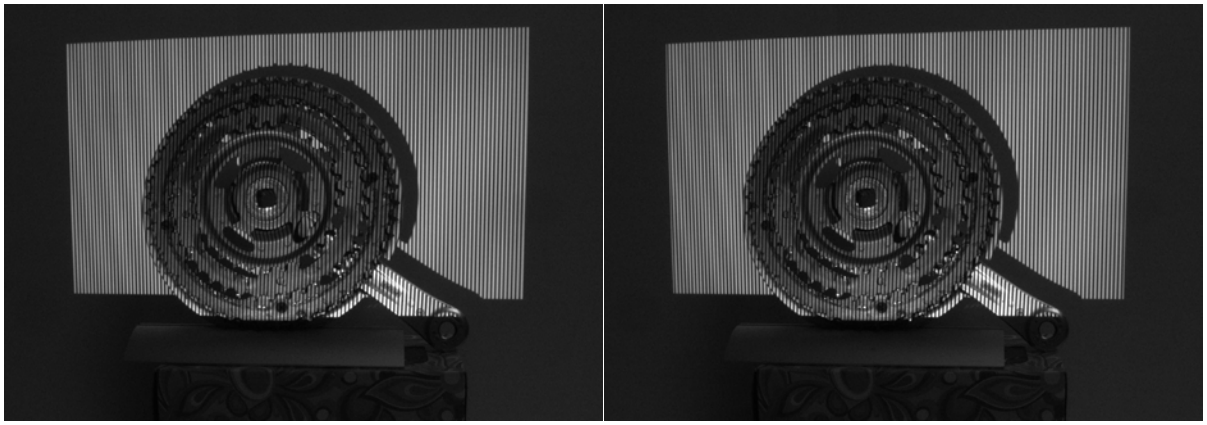

Figure 22 Non-inverted and inverted vertical gray code pattern 9 capture

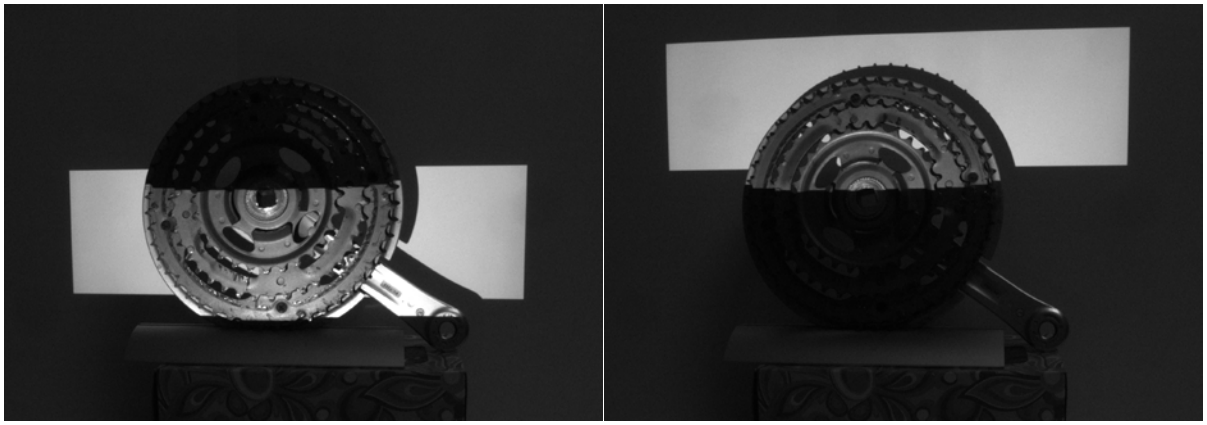

Figure 23 Non-inverted and inverted horizontal gray code pattern 1 capture

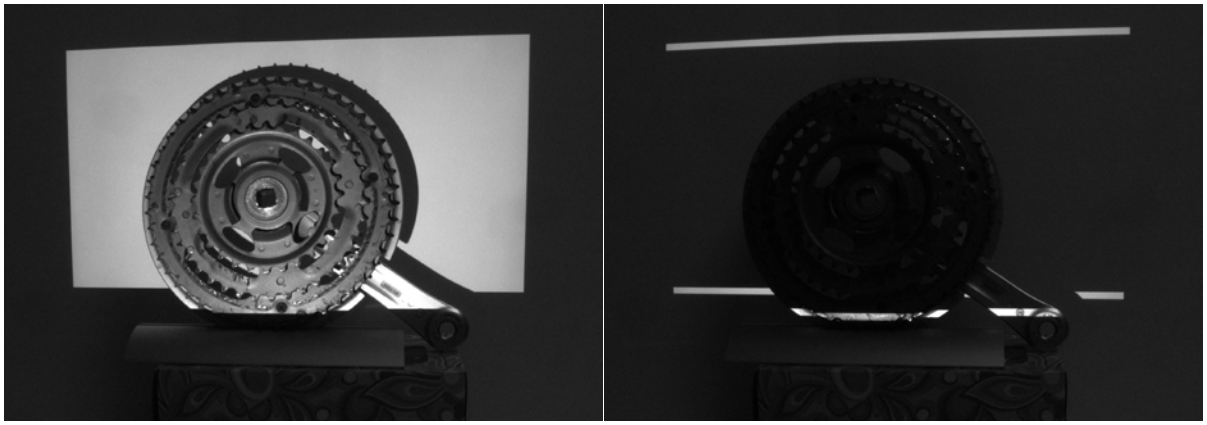

Figure 24 Non-inverted and inverted horizontal gray code pattern 2 capture

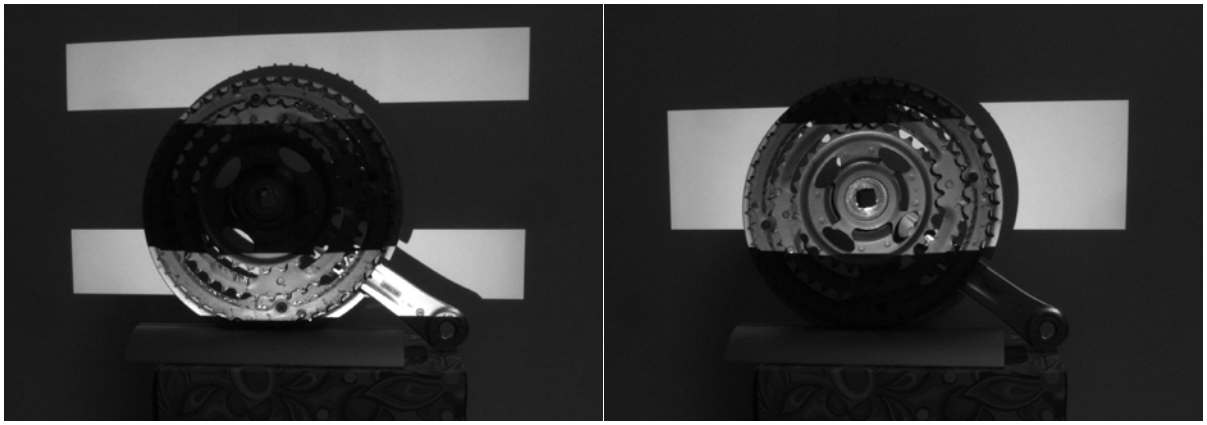

Figure 25 Non-inverted and inverted horizontal gray code pattern 3 capture

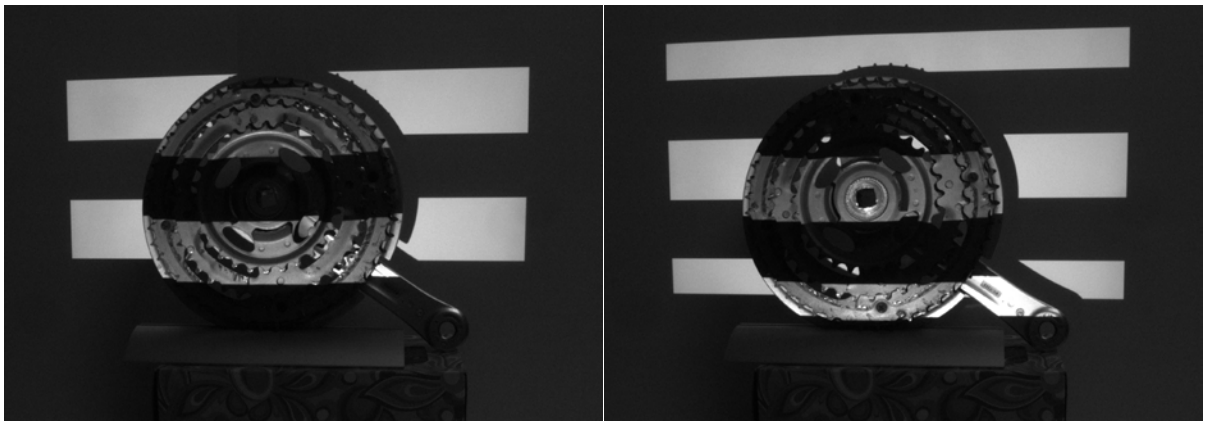

Figure 26 Non-inverted and inverted horizontal gray code pattern 4 capture

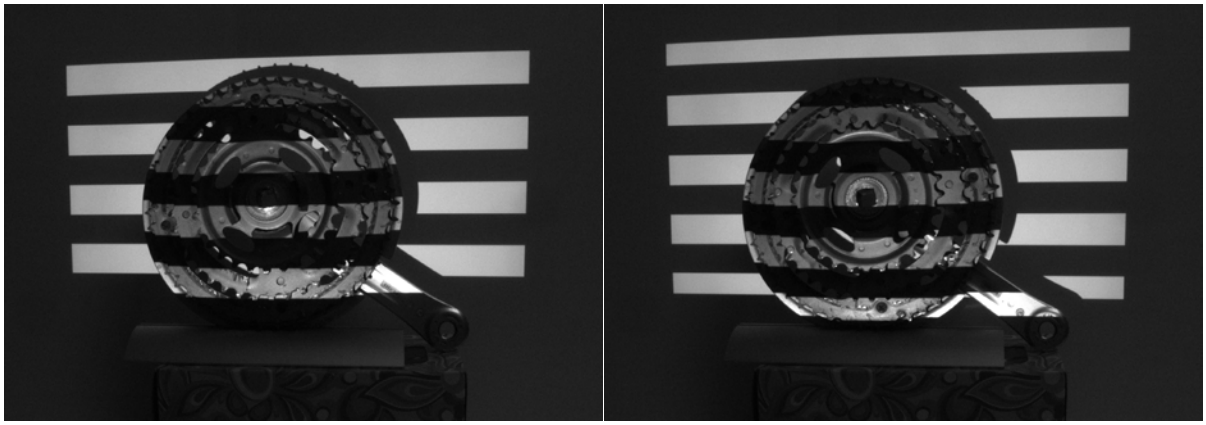

Figure 27 Non-inverted and inverted horizontal gray code pattern 5 capture

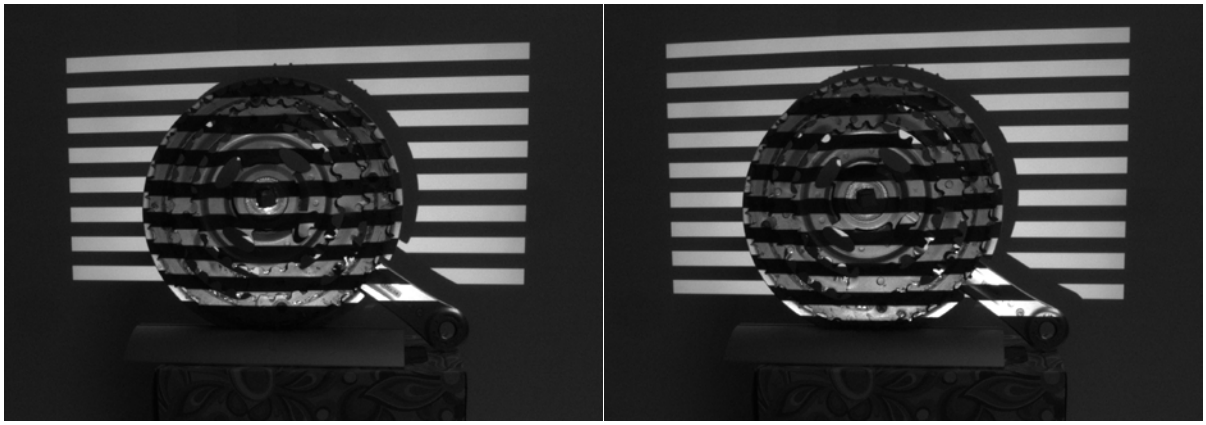

Figure 28 Non-inverted and inverted horizontal gray code pattern 6 capture

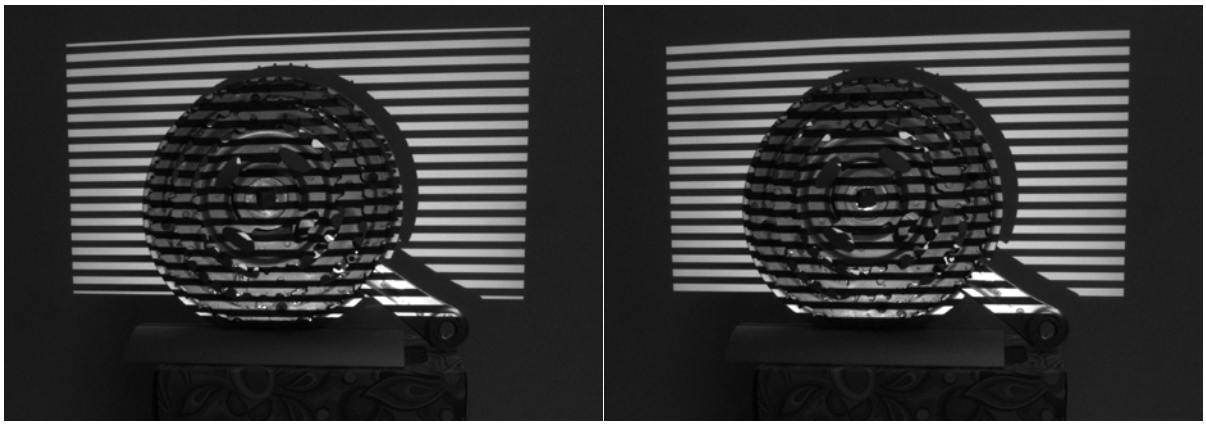

Figure 29 Non-inverted and inverted horizontal gray code pattern 7 capture

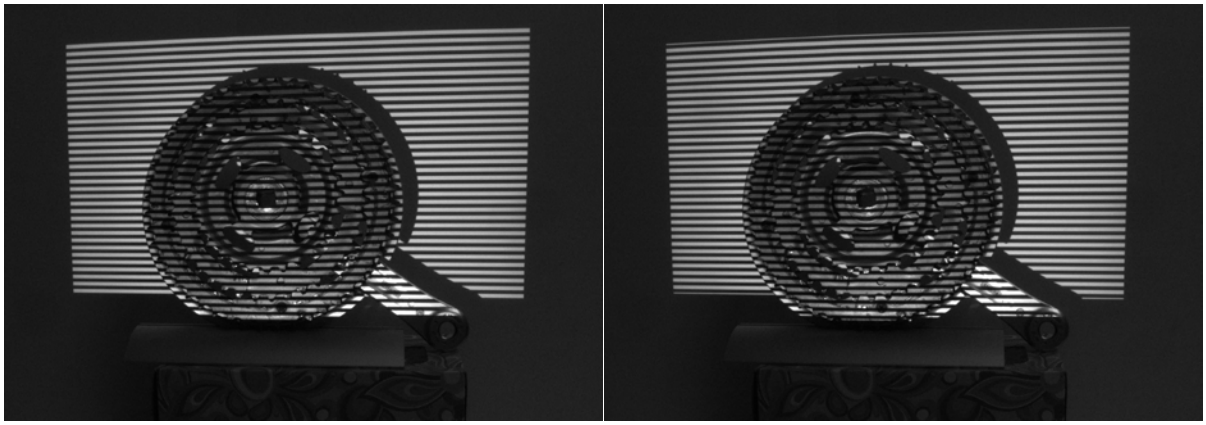

Figure 30 Non-inverted and inverted horizontal gray code pattern 8 capture

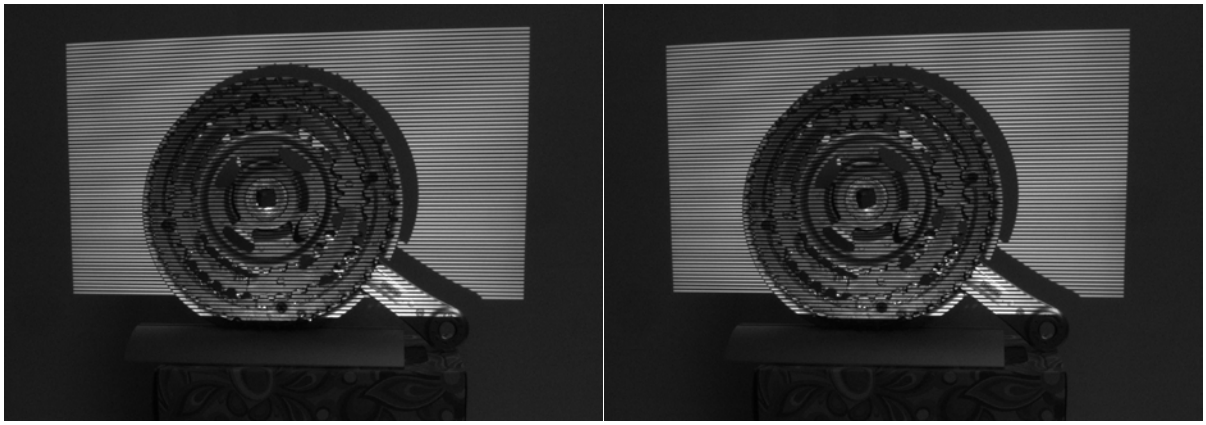

Figure 31 Non-inverted and inverted horizontal gray code pattern 9 capture

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

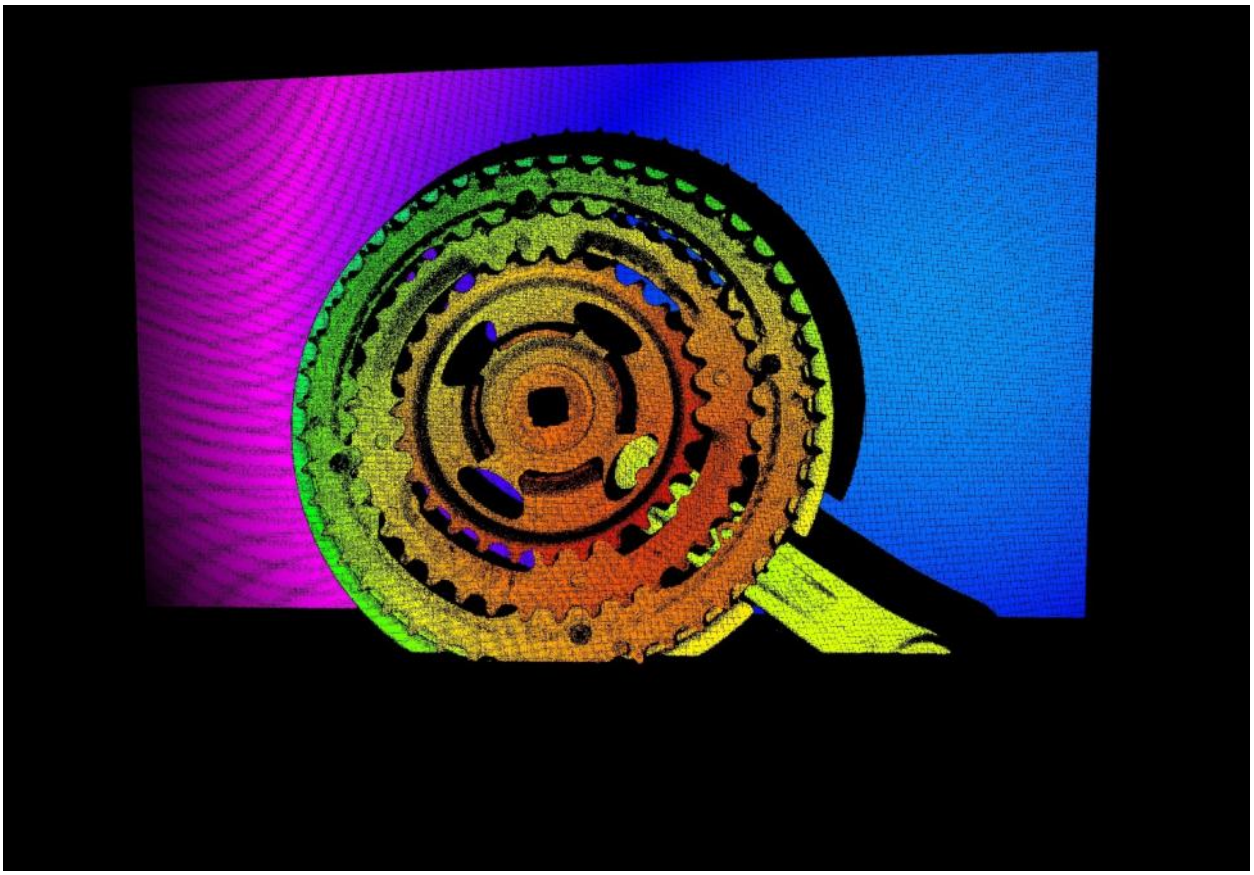

Figure 32 Depth-map of object from 3D scan

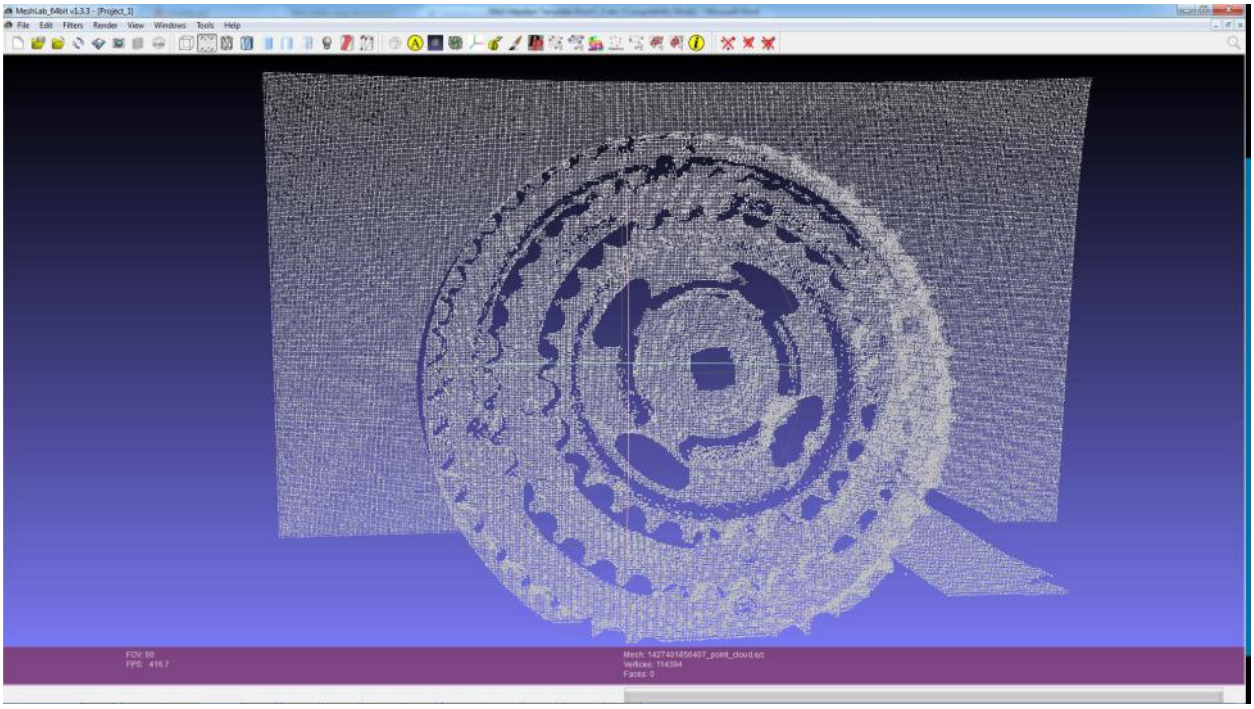

Figure 33 Front view of point-cloud from 3D scan

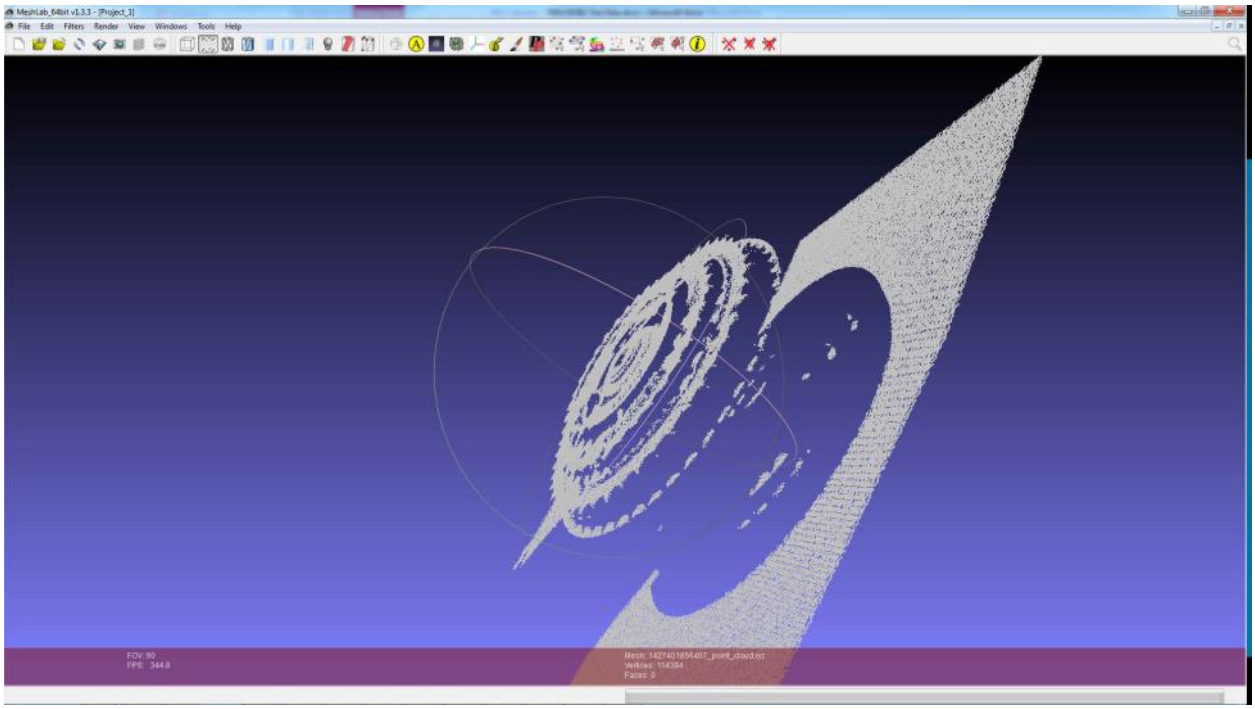

Figure 34 Isometric view of point-cloud from 3D scan

Hybrid Scan: Generated Point Cloud

This chapter provides test data from the DLP 3D Scanner Reference Design for structured light pattern decoding and point cloud generation. The patterns are generated using a hybrid three phase scan.

The following procedure is used, which assumes the system is calibrated:

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

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

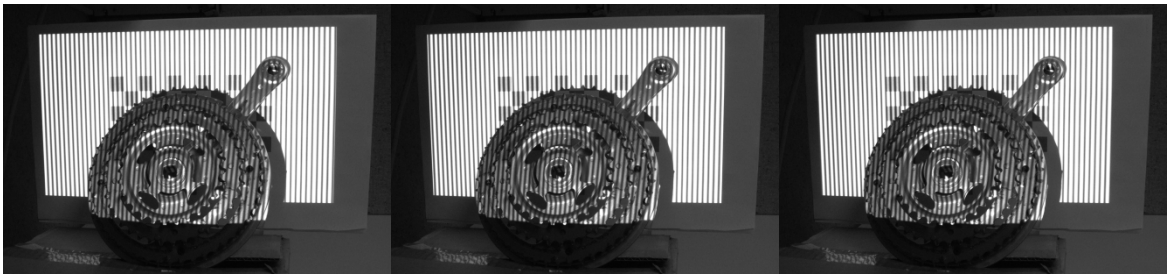

Figure 35 Vertical three phase patterns

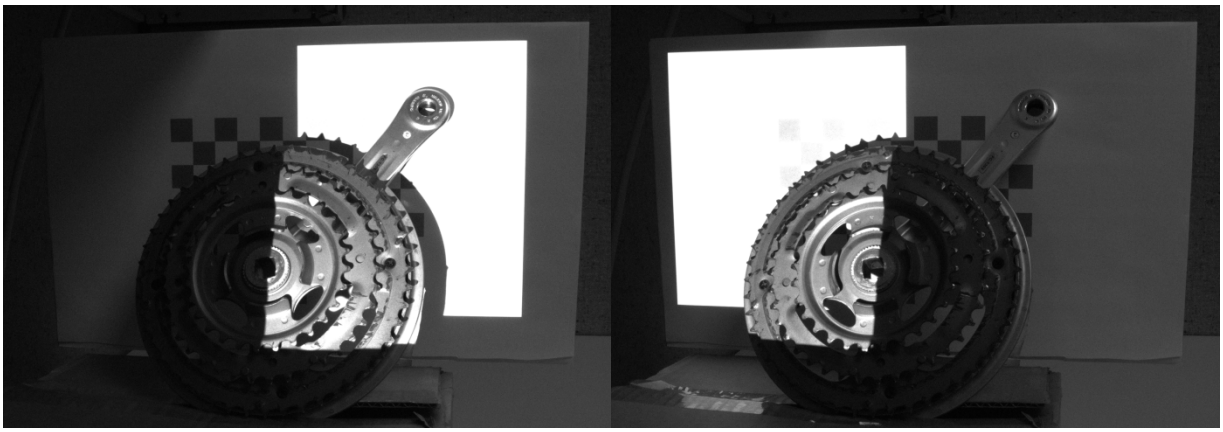

Figure 36 Non-inverted and inverted vertical gray code pattern 1 capture

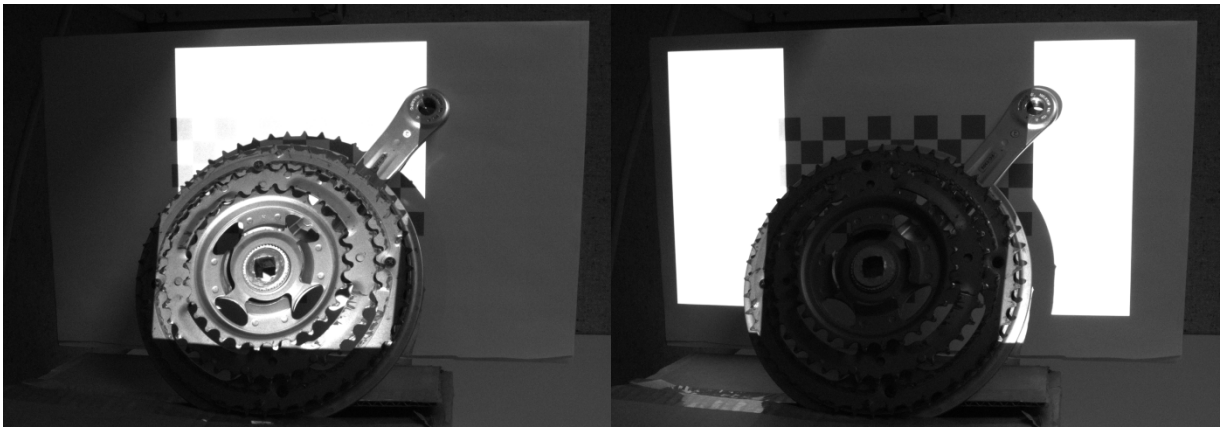

Figure 37 Non-inverted and inverted vertical gray code pattern 2 capture

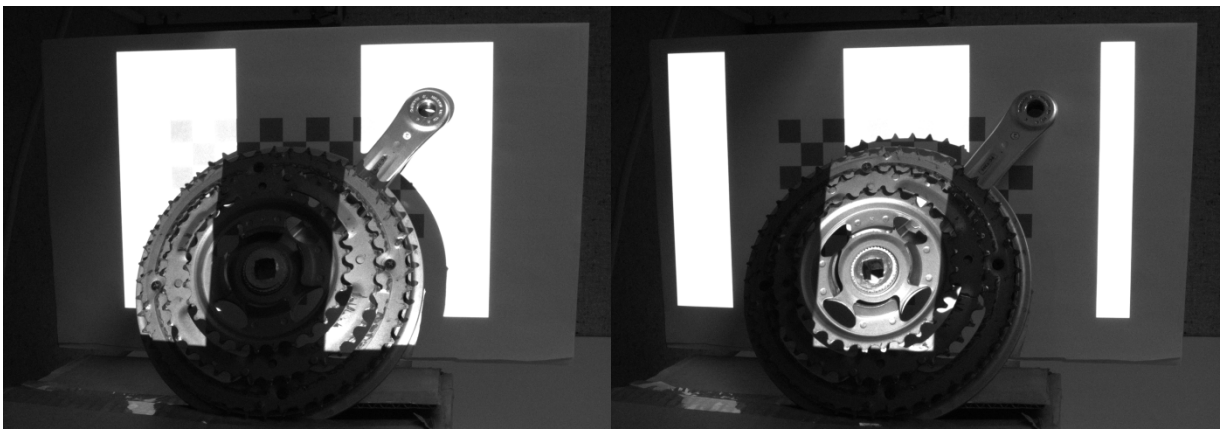

Figure 38 Non-inverted and inverted vertical gray code pattern 3 capture

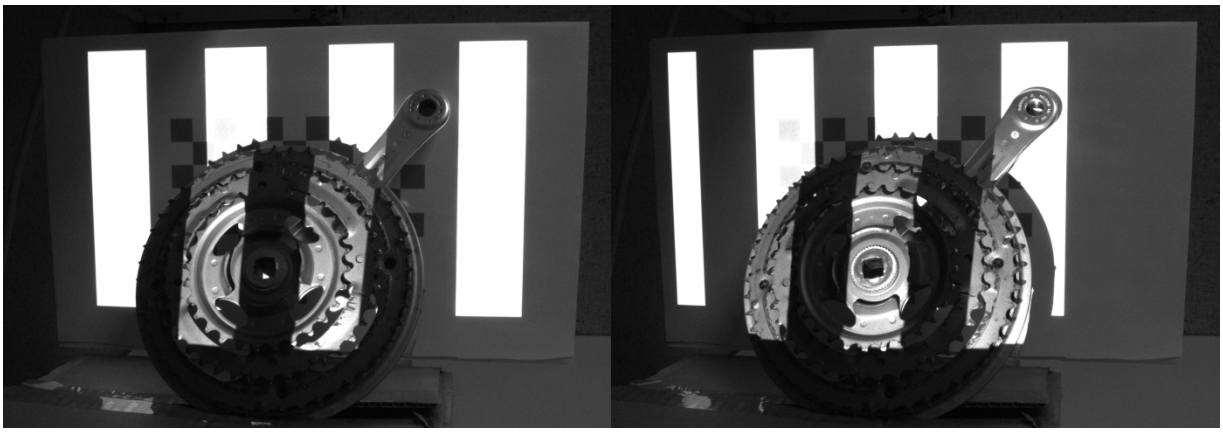

Figure 39 Non-inverted and inverted vertical gray code pattern 4 capture

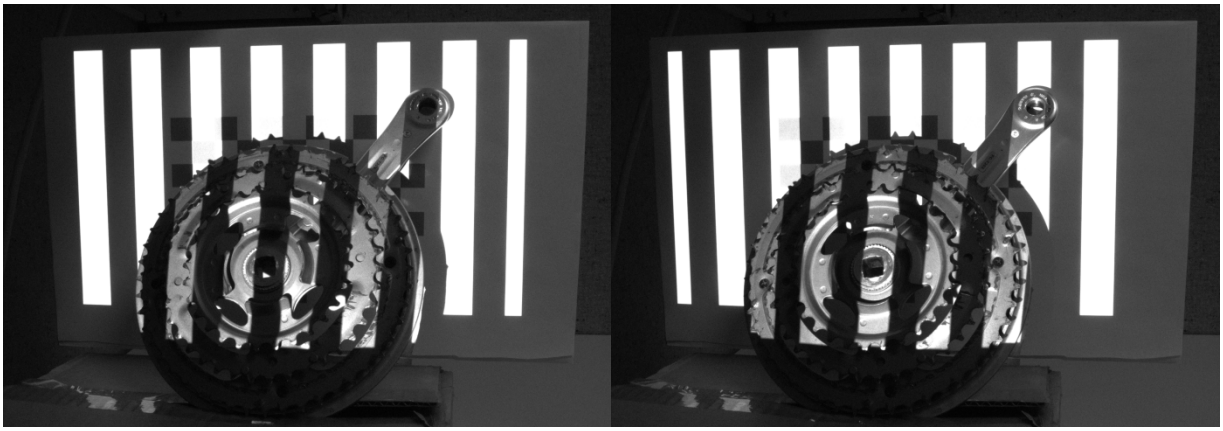

Figure 40 Non-inverted and inverted vertical gray code pattern 5 capture

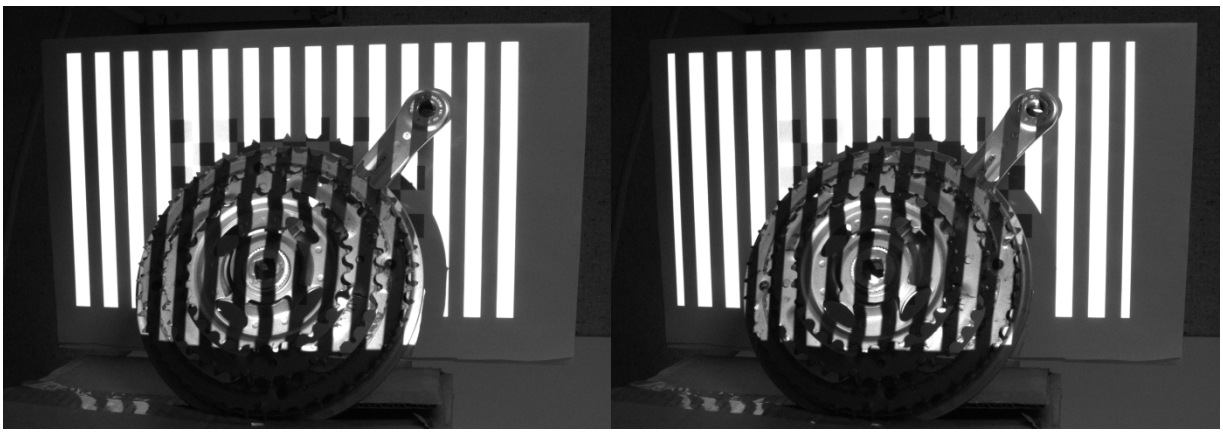

Figure 41 Non-inverted and inverted vertical gray code pattern 6 capture

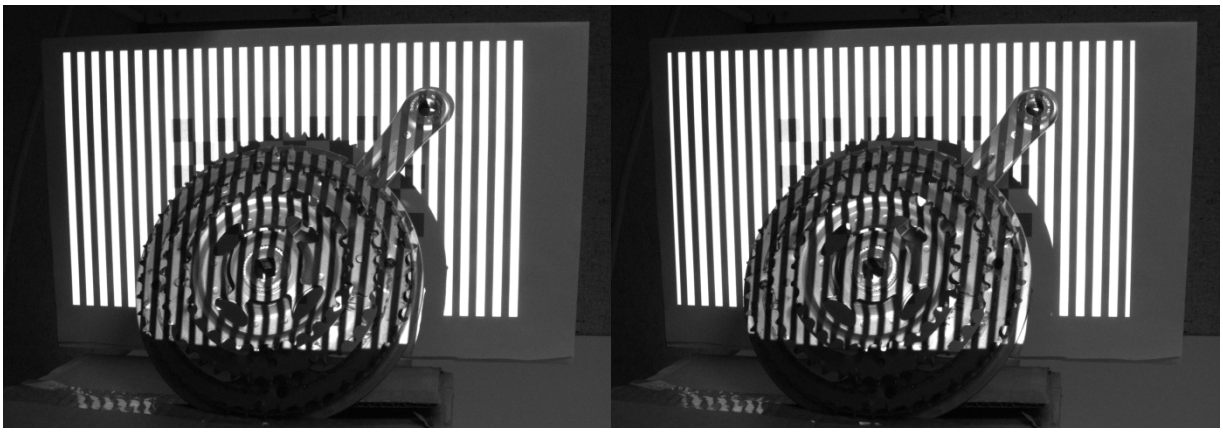

Figure 42 Non-inverted and inverted vertical gray code pattern 7 capture

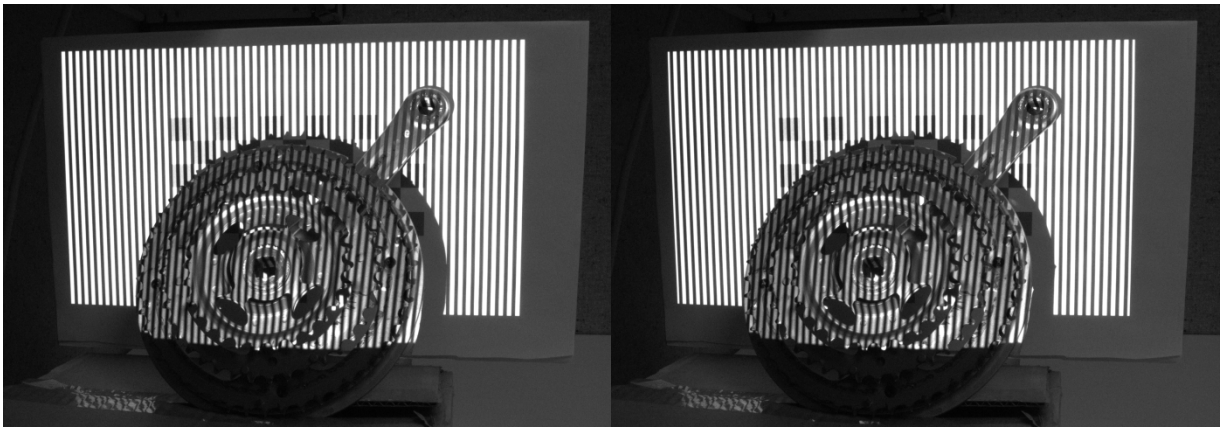

Figure 43 Non-inverted and inverted vertical gray code pattern 8 capture

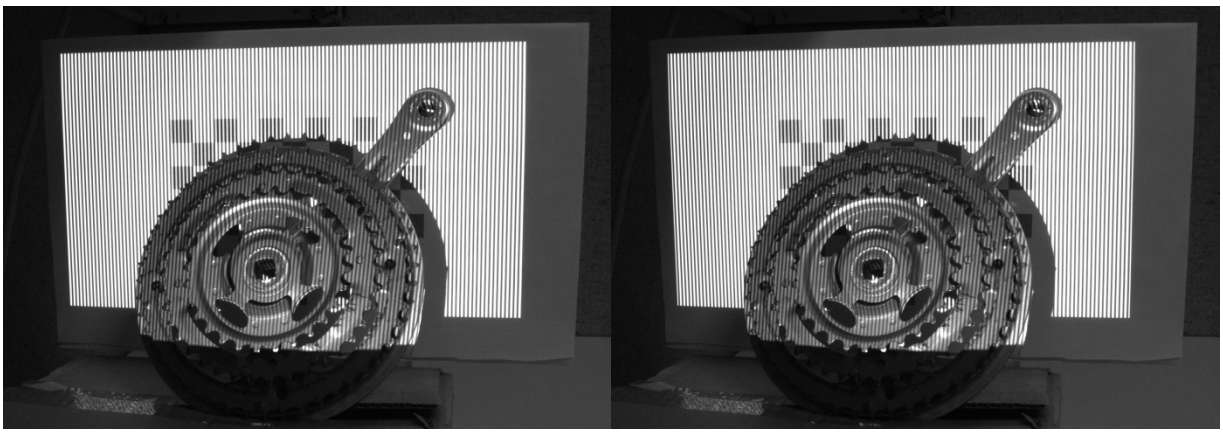

Figure 44 Non-inverted and inverted vertical gray code pattern 9 capture

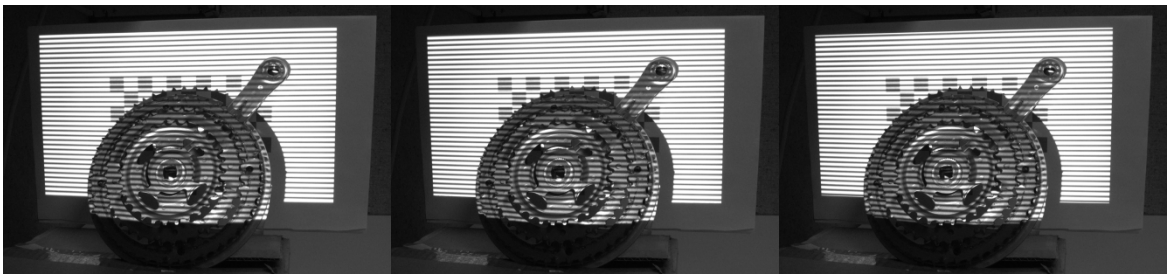

Figure 45 Horizontal three phase patterns

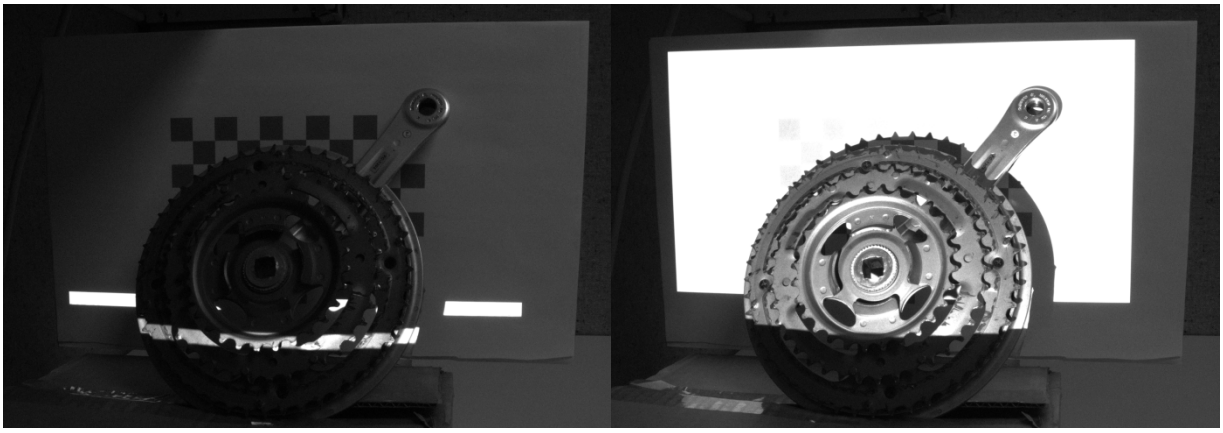

Figure 46 Non-inverted and inverted horizontal gray code pattern 1 capture

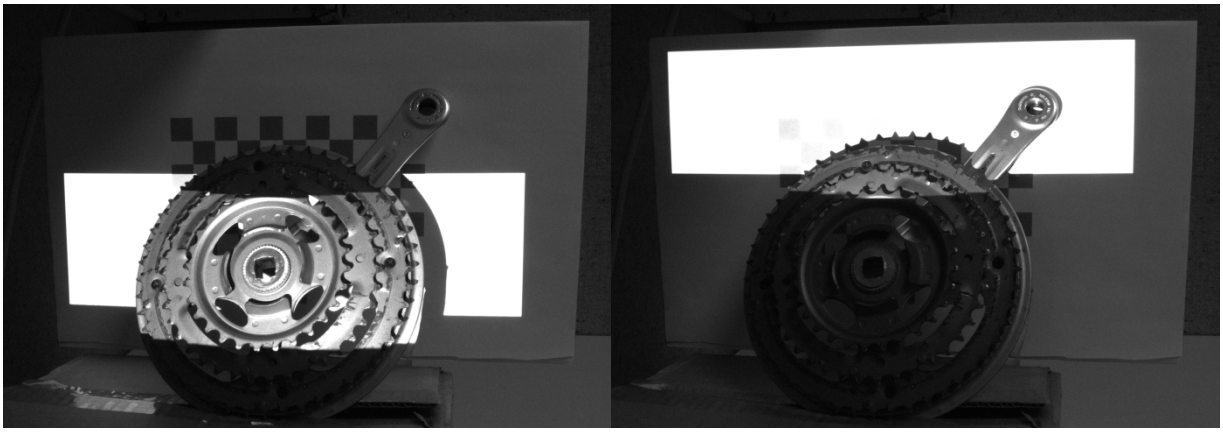

Figure 47 Non-inverted and inverted horizontal gray code pattern 2 capture

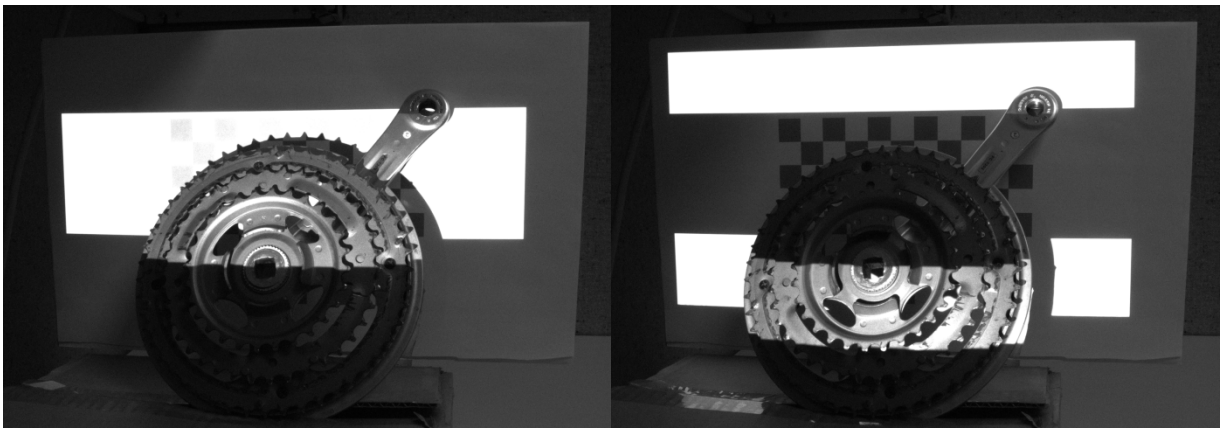

Figure 48 Non-inverted and inverted horizontal gray code pattern 3 capture

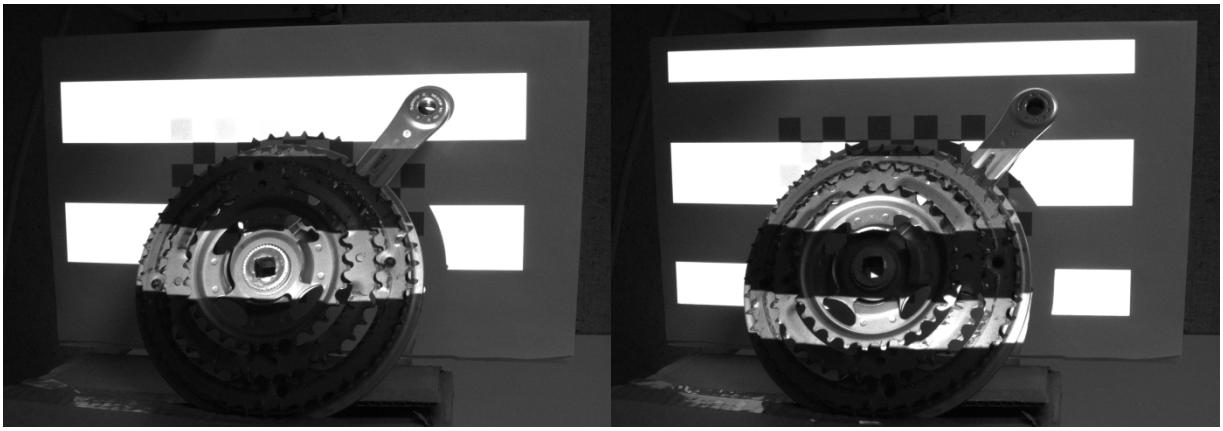

Figure 49 Non-inverted and inverted horizontal gray code pattern 4 capture

Figure 50 Non-inverted and inverted horizontal gray code pattern 5 capture

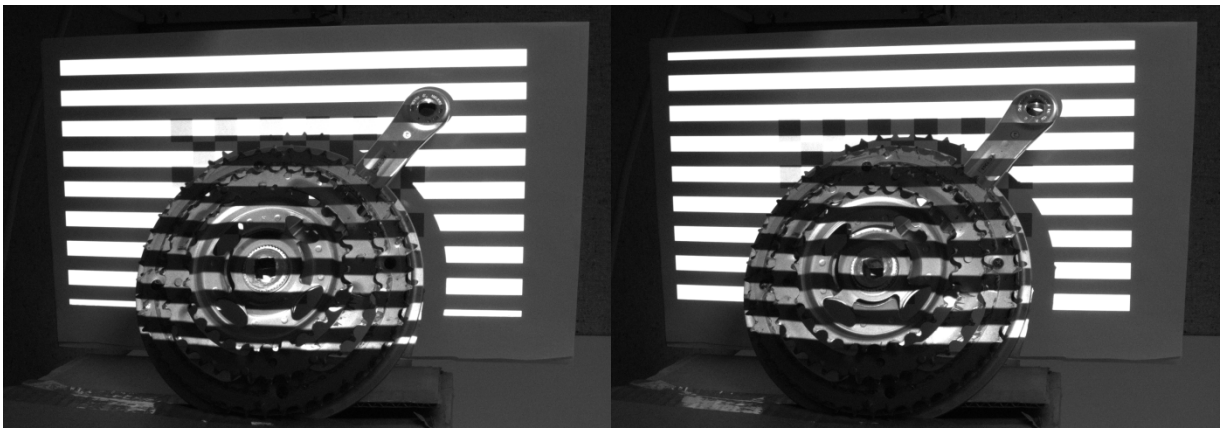

Figure 51 Non-inverted and inverted horizontal gray code pattern 6 capture

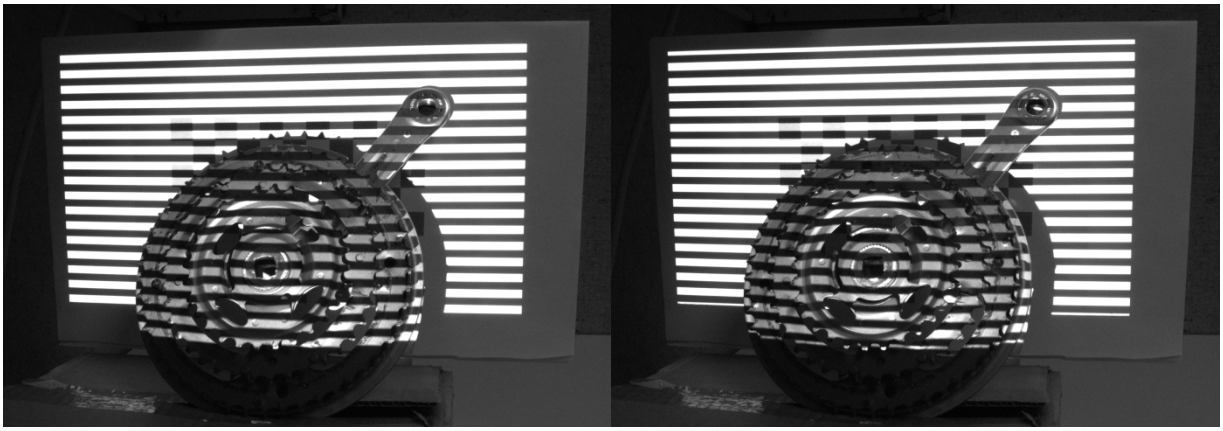

Figure 52 Non-inverted and inverted horizontal gray code pattern 7 capture

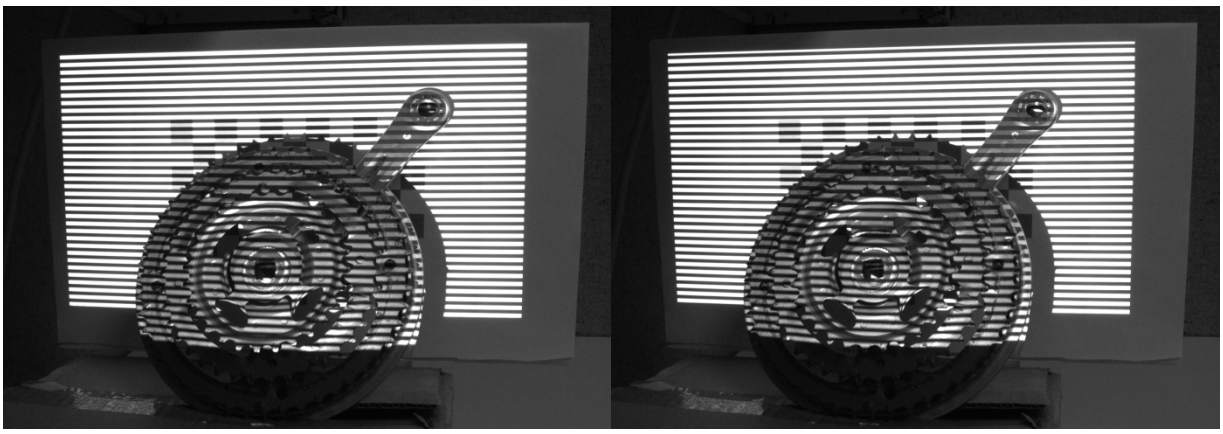

Figure 53 Non-inverted and inverted horizontal gray code pattern 8 capture

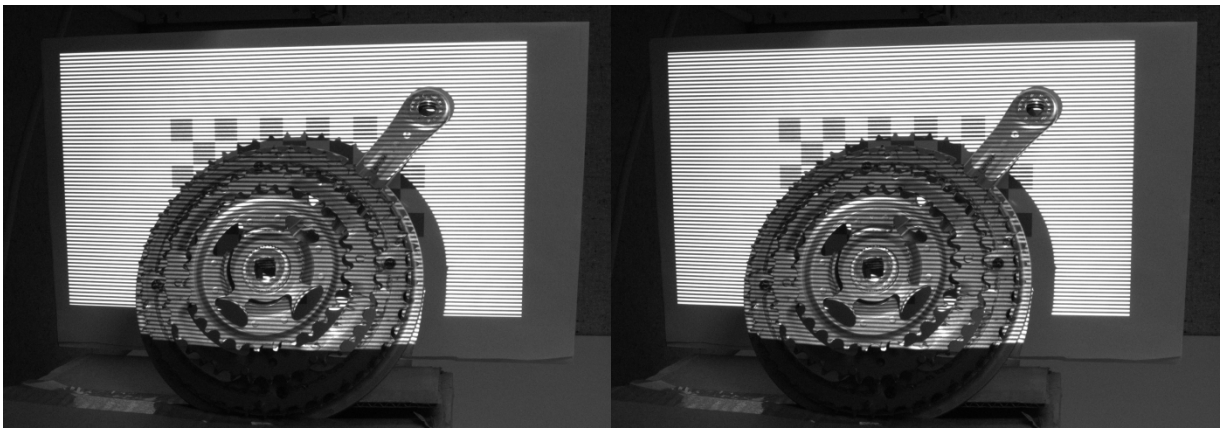

Figure 54 Non-inverted and inverted horizontal gray code pattern 9 capture

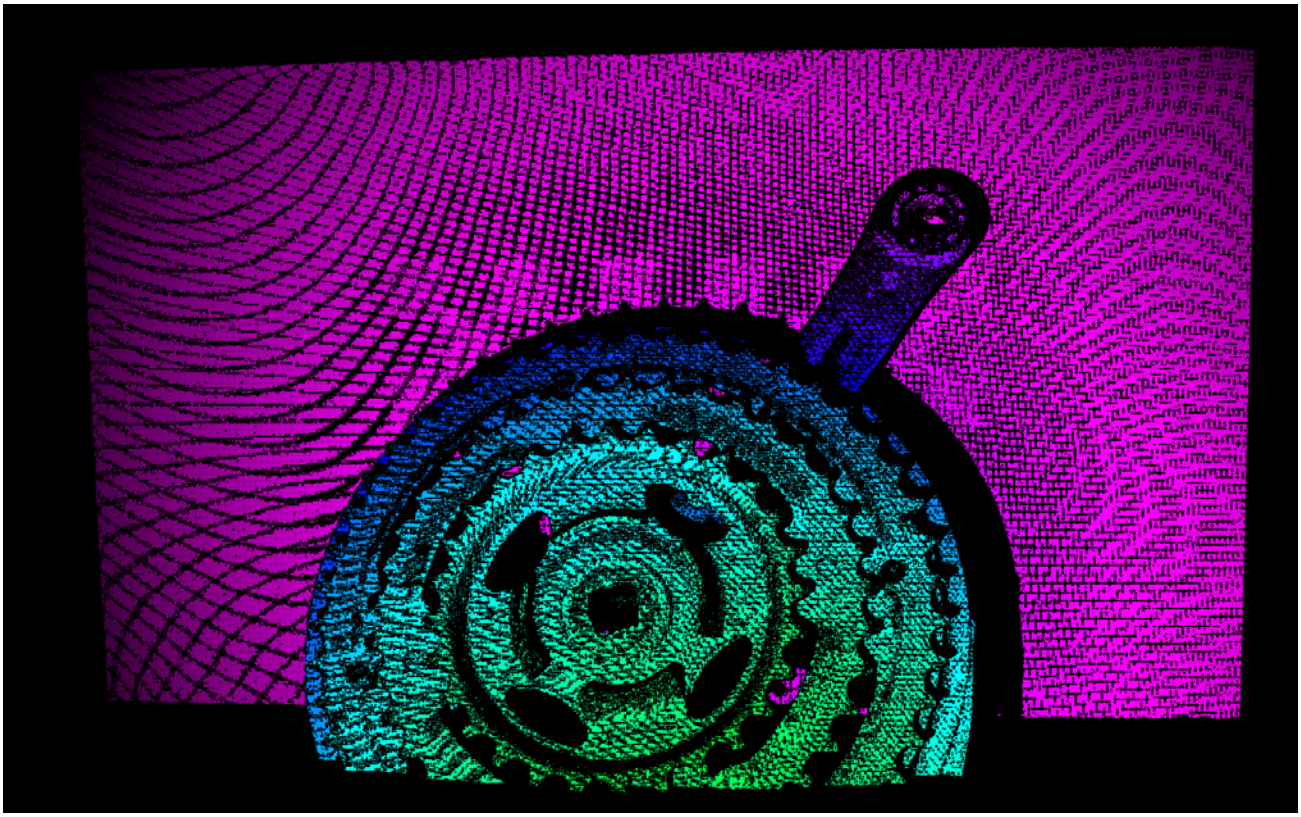

Figure 55 Point cloud color depth map

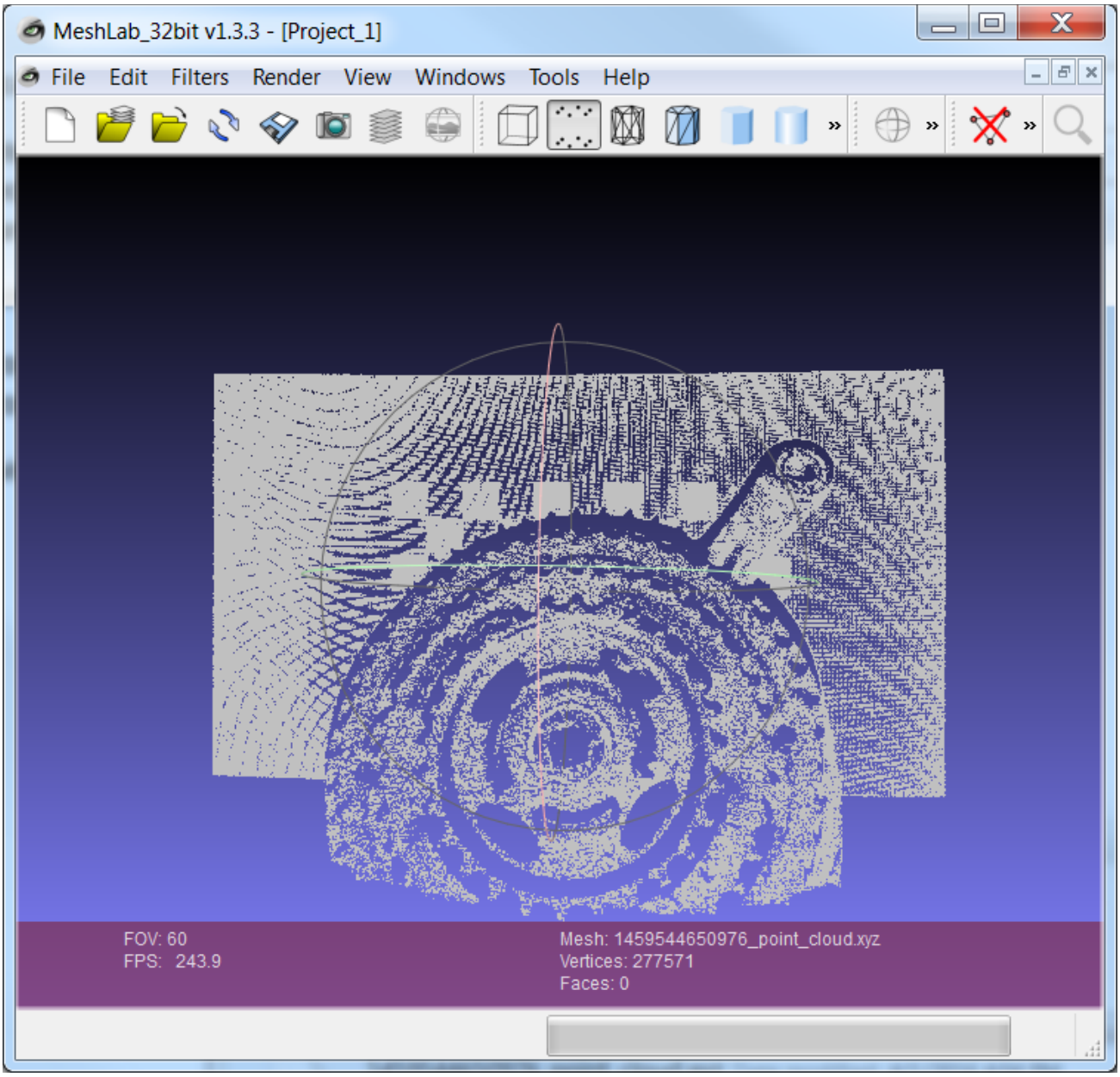

Figure 56 Front view of point cloud

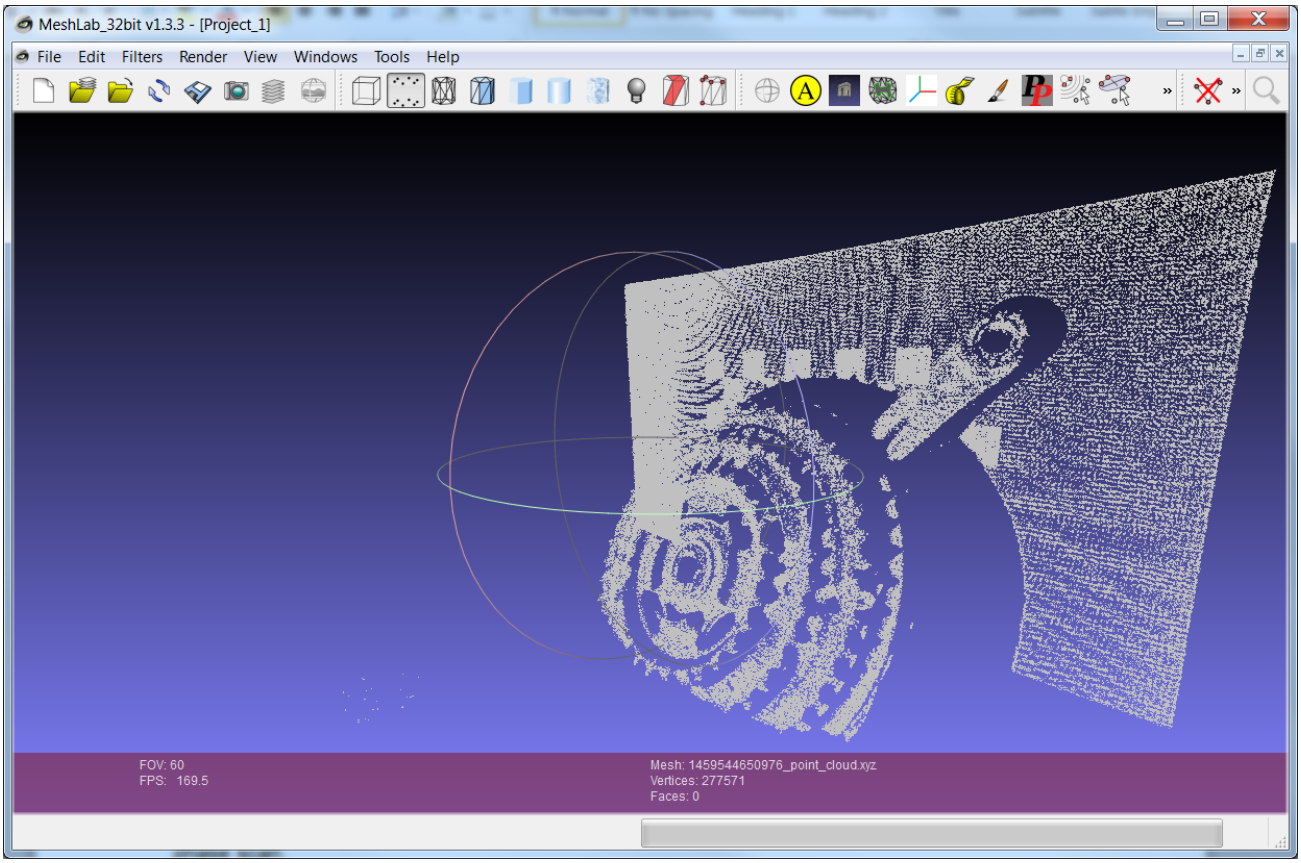

Figure 57 Isometric view of point cloud

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