Integrating 3D scanning into 3D printer

Ammar Hattab

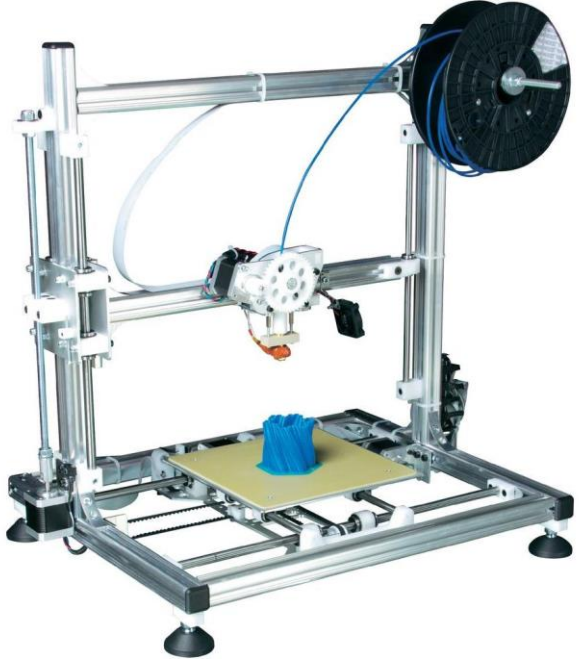
5/19/2016

Setup

Hardware

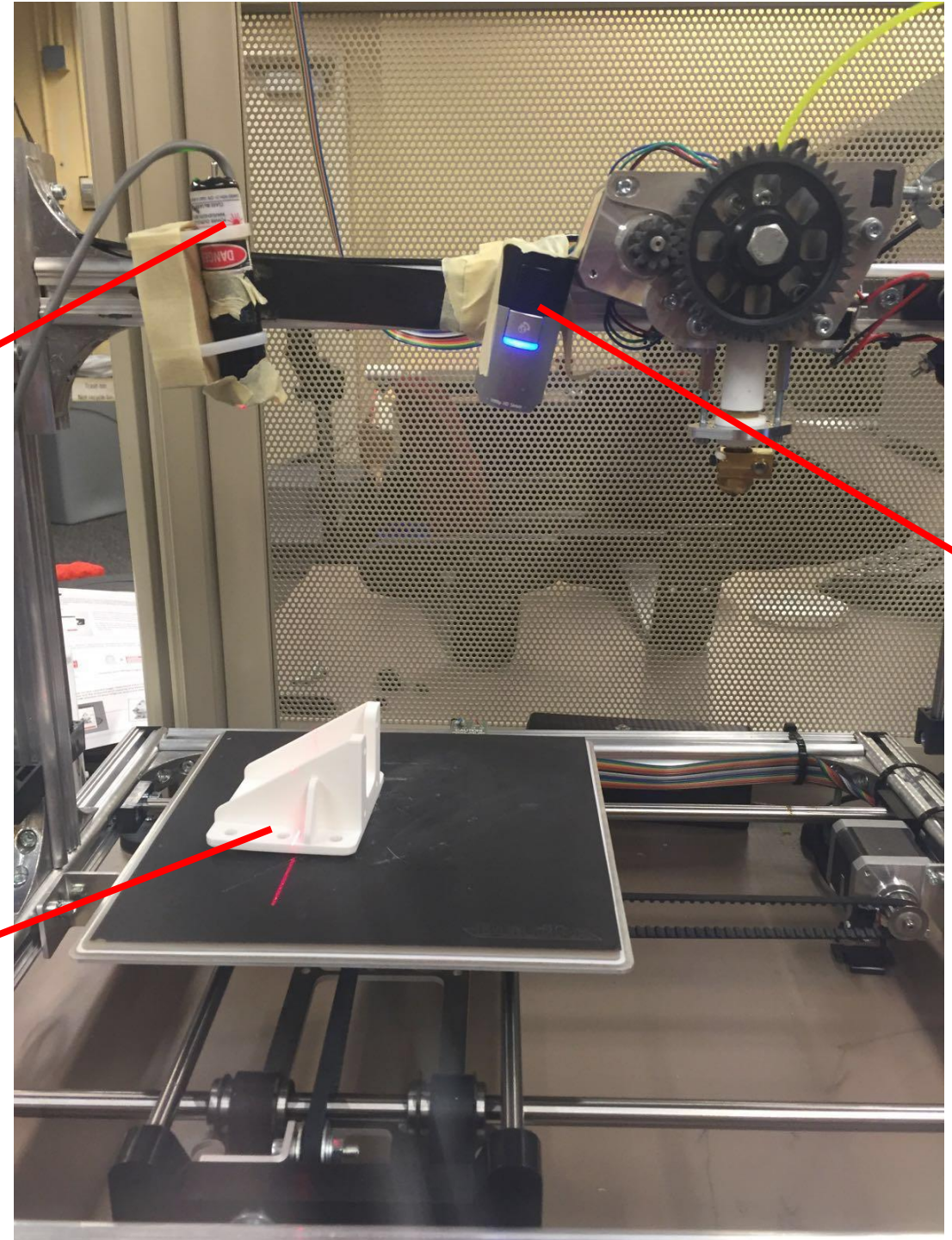
- 3D printer (K8200)

Build-It-Yourself 3D Printer Kit



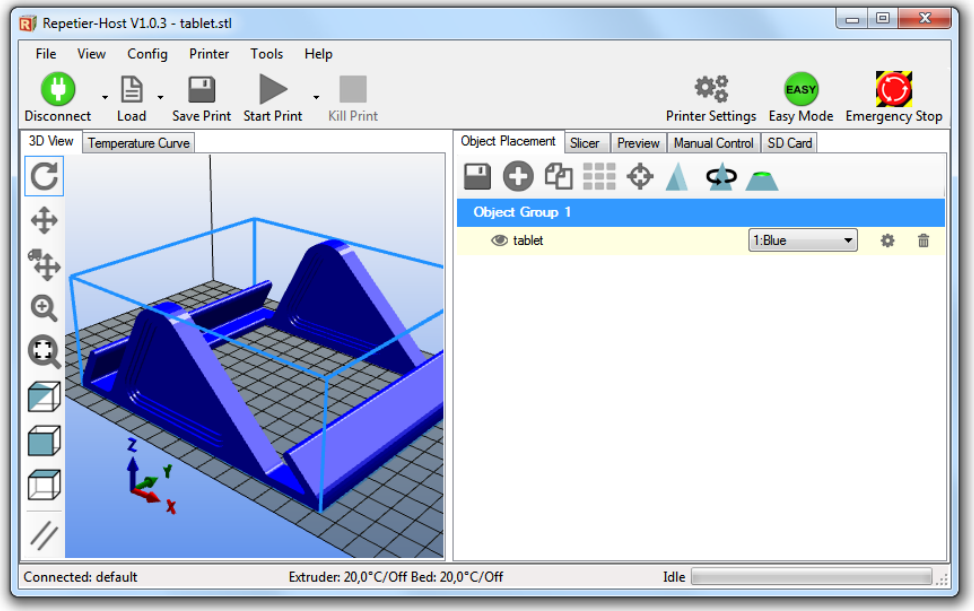
- USB camera (Microsoft LifeCam HD)

- Line laser

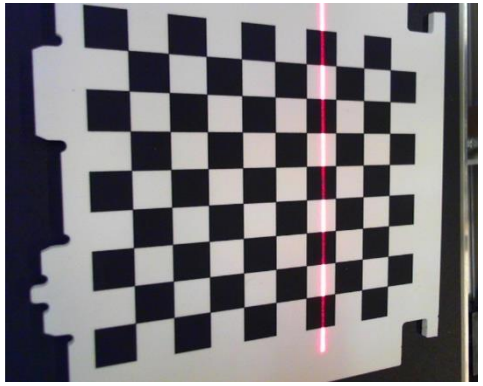

Line laser
USB Camera
Object to be scanned

Software

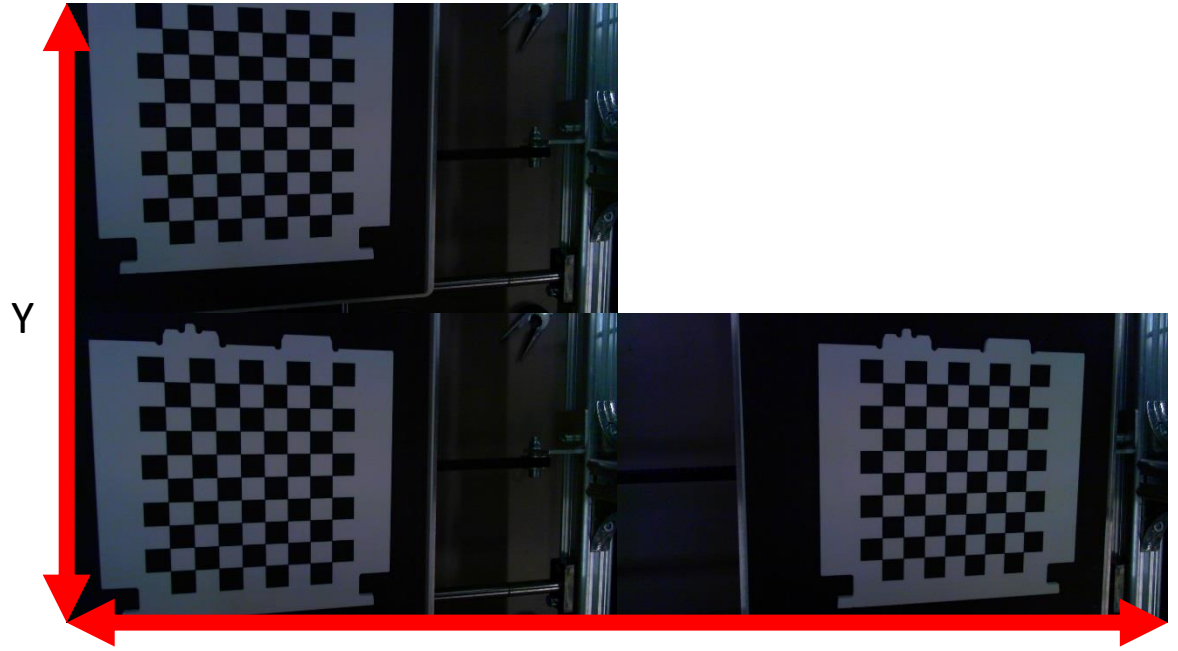
- Open source **Reptier-host** 3D printing software
- Modified to support:
  - Camera Capture
  - X, Y movement that follows a specific toolpath for scanning
  - After each step, stop and capture an image from the camera.



Steps

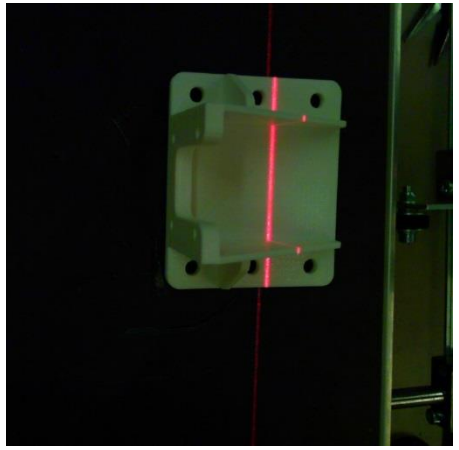


Camera and Laser plane calibration



Movement Calibration

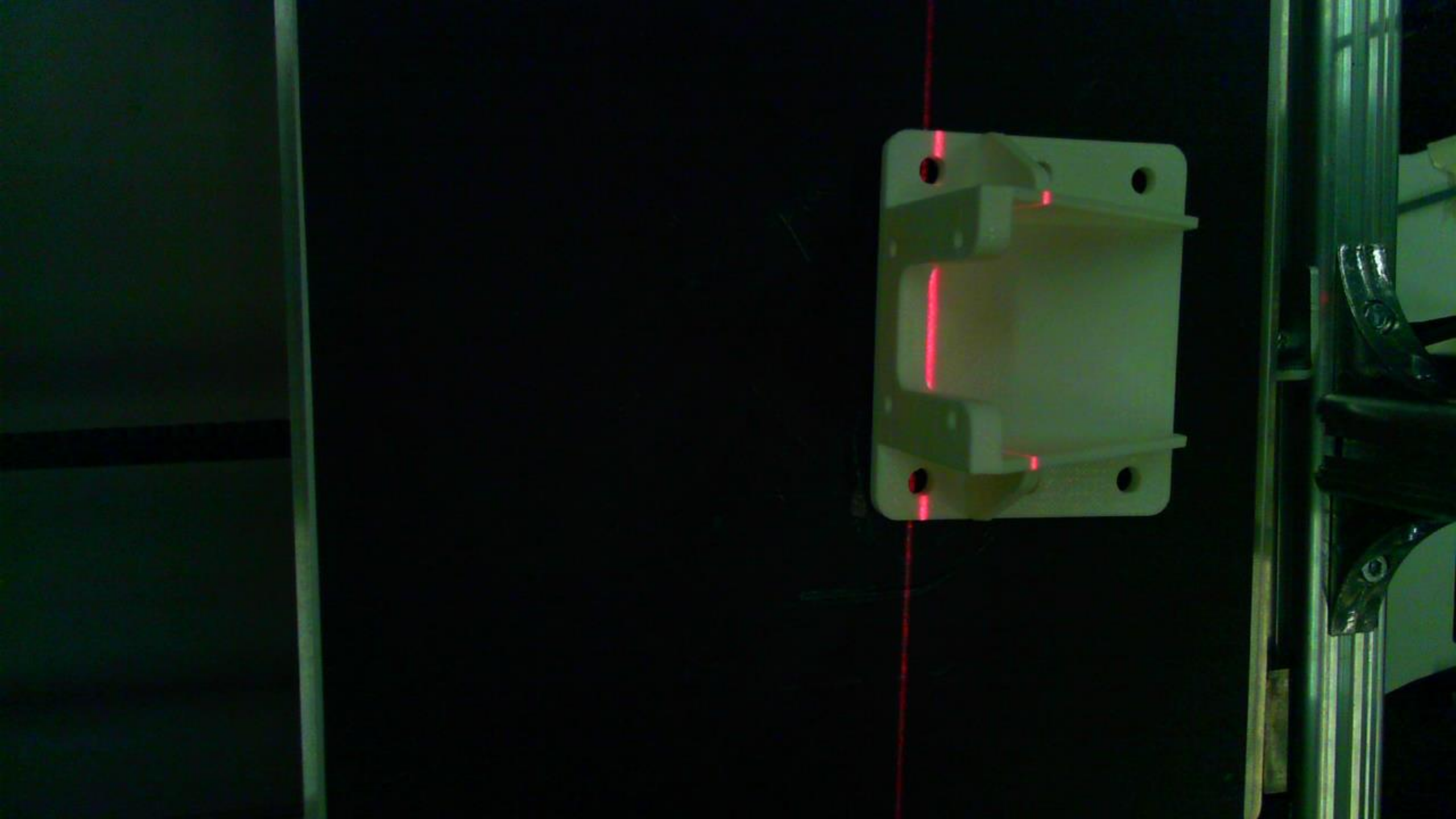
Camera Parameters
Laser Plane

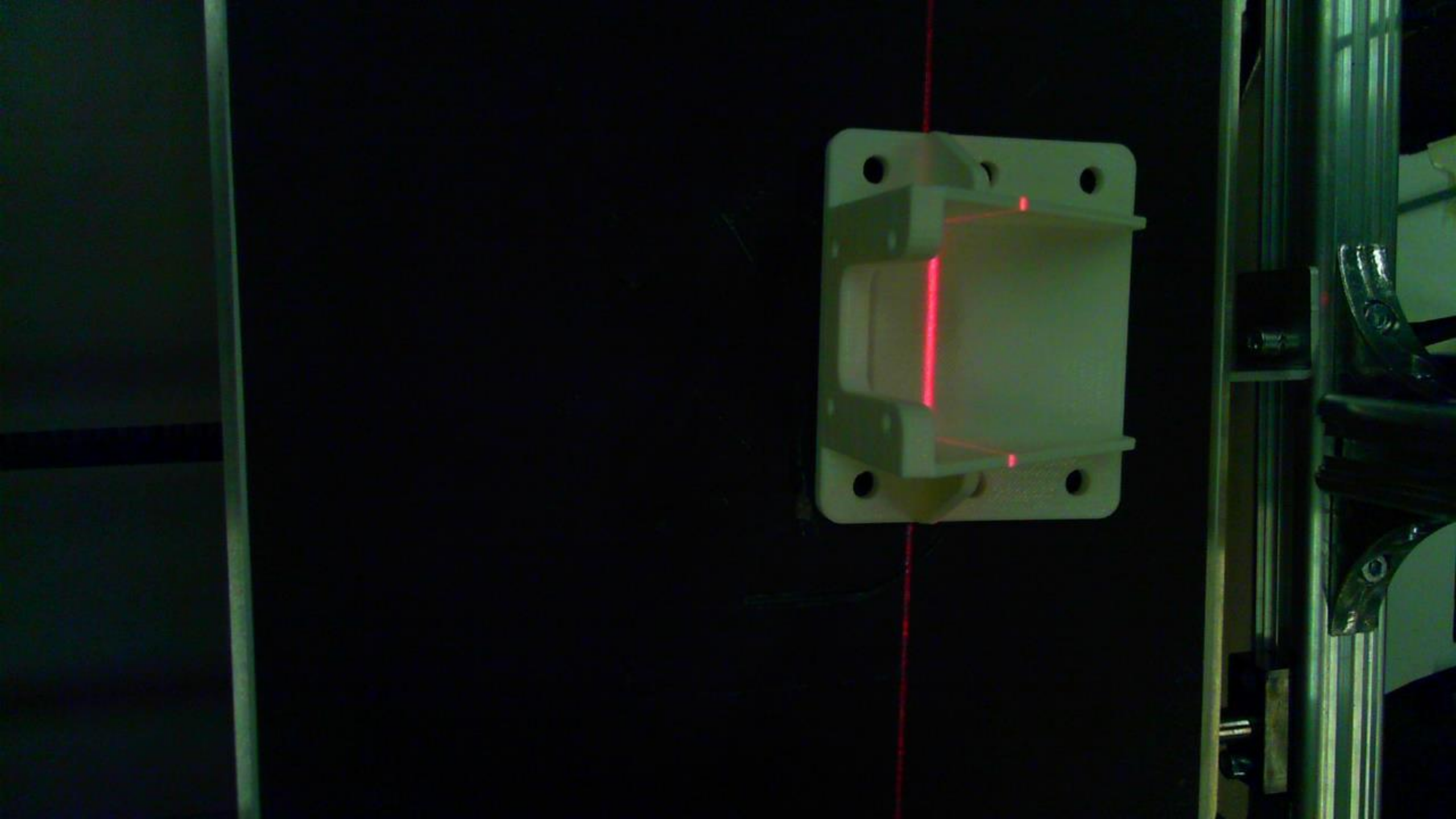


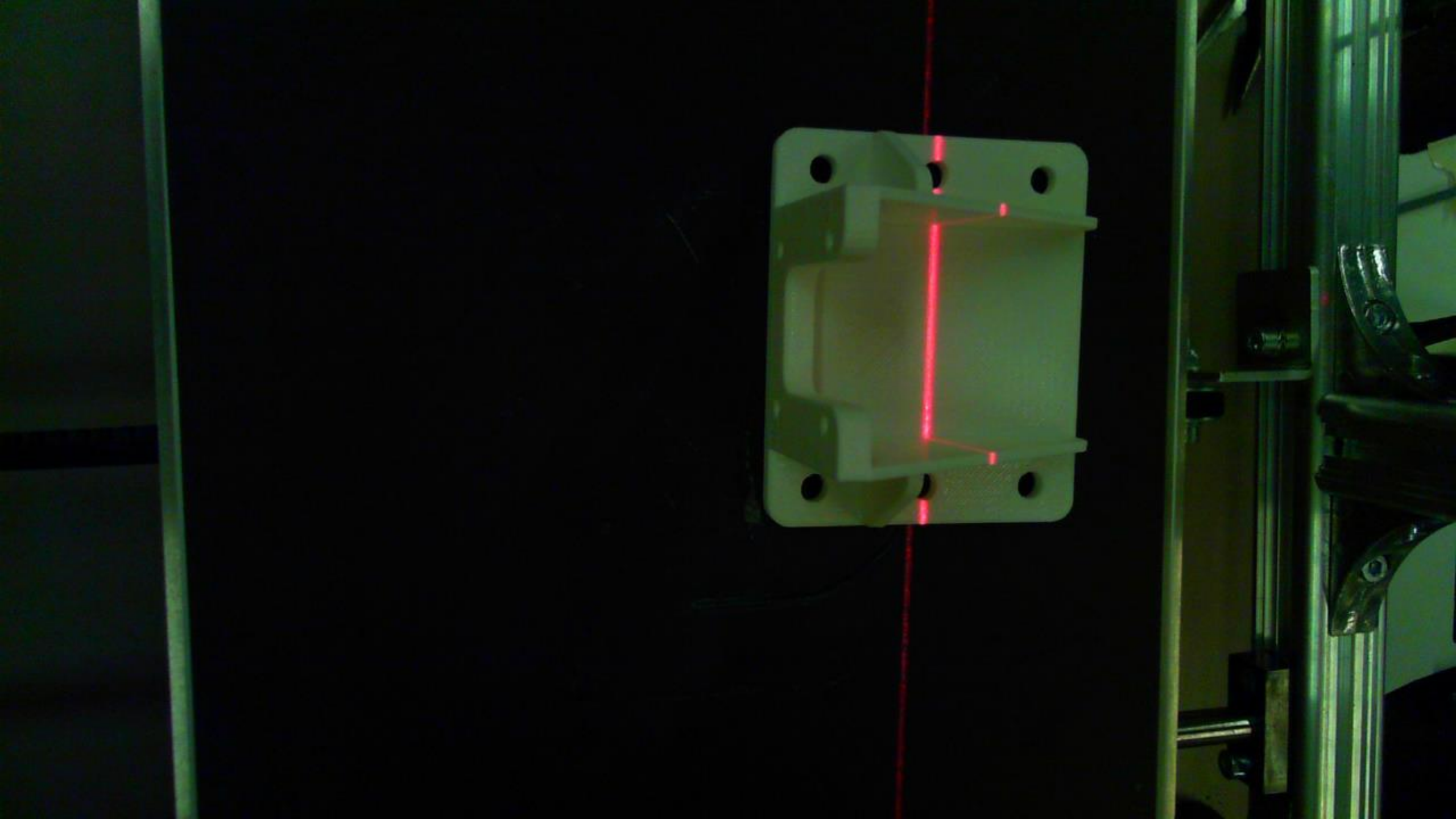
X, Y axes
Printer bed plane

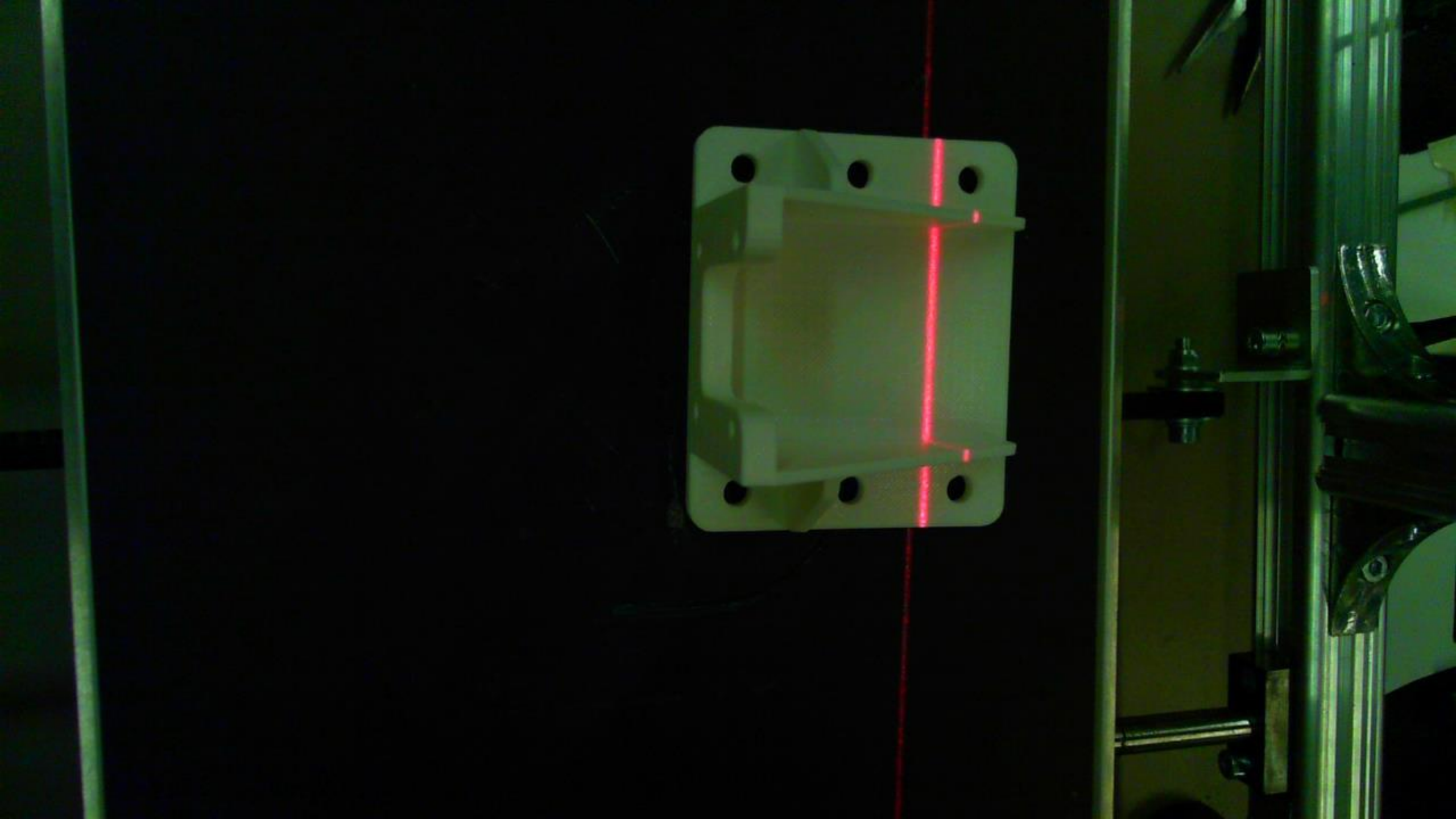
Object Scanning

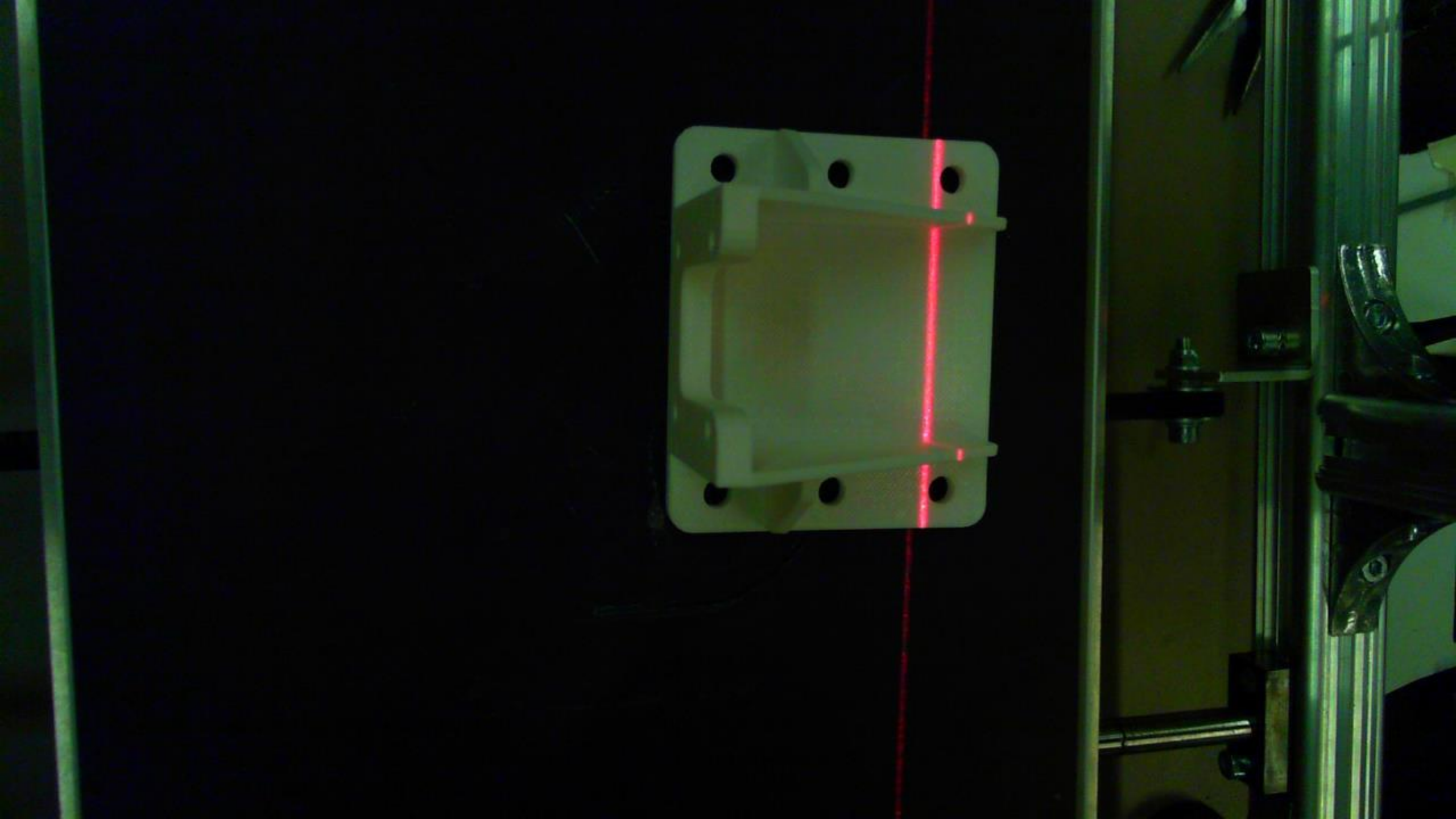
Previously…

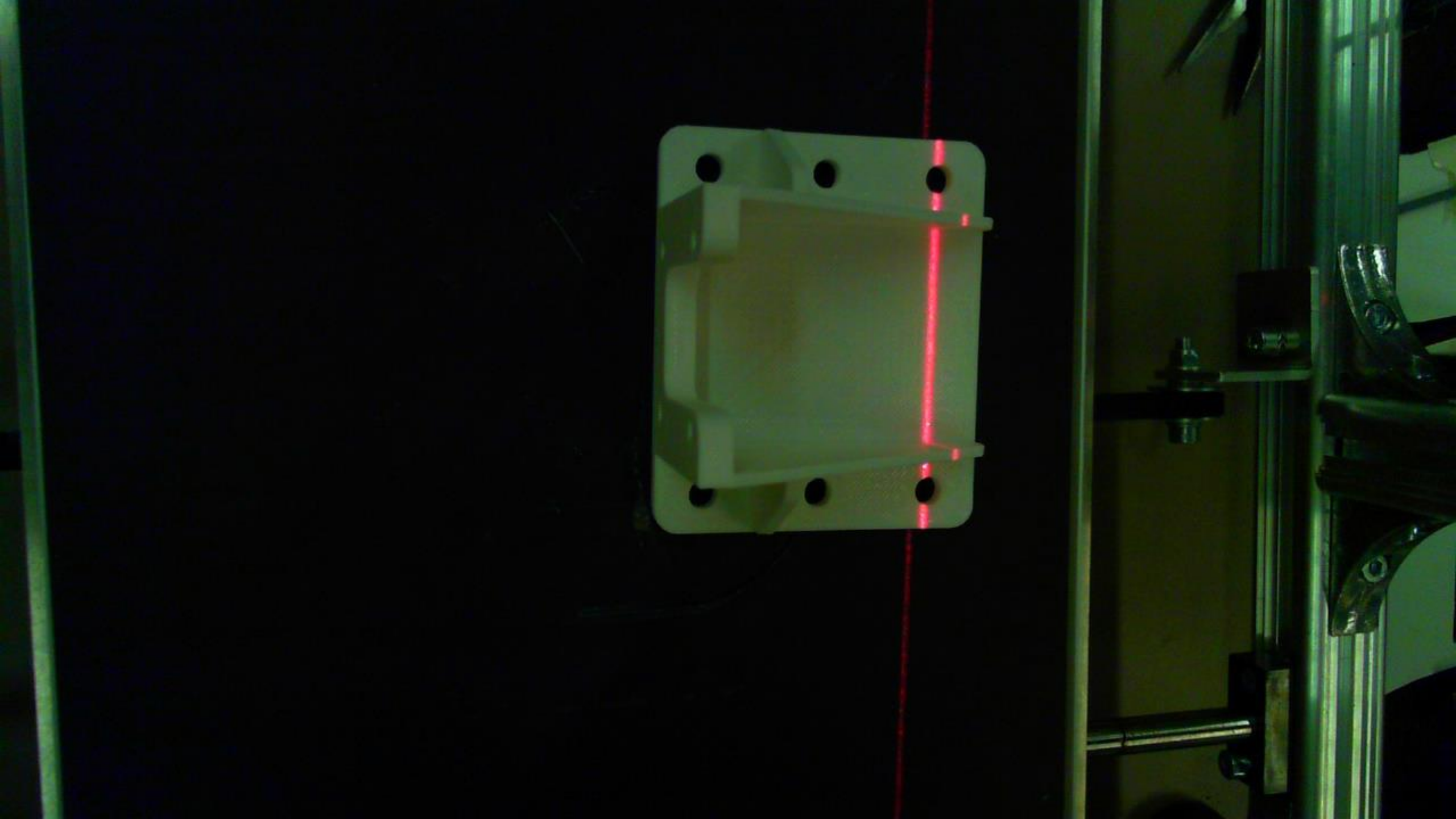






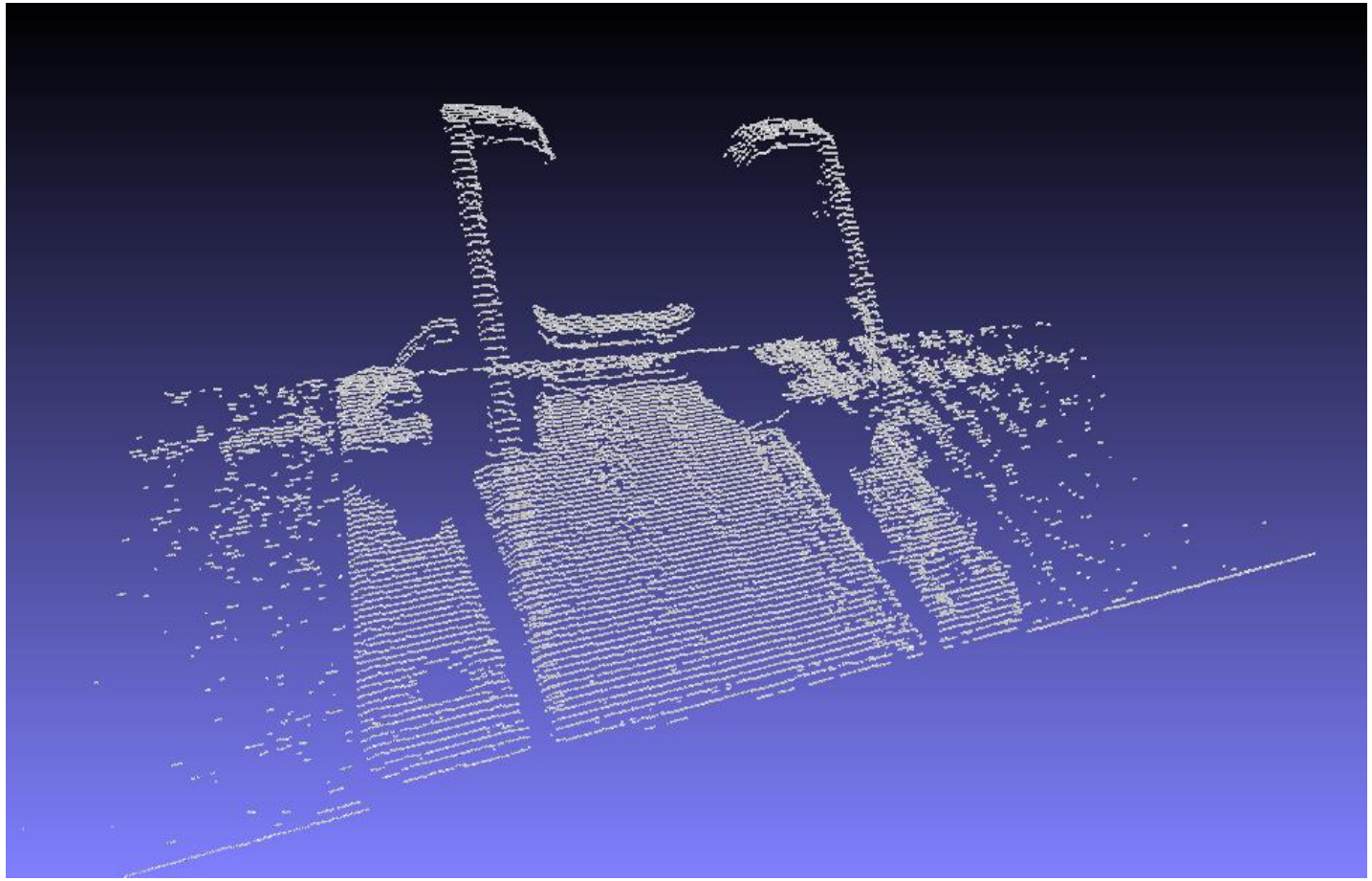




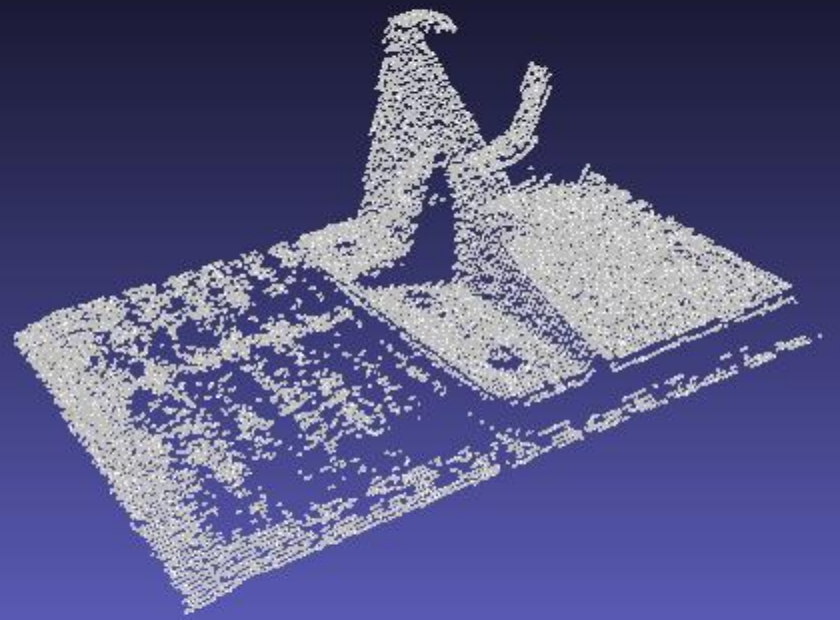


First Result

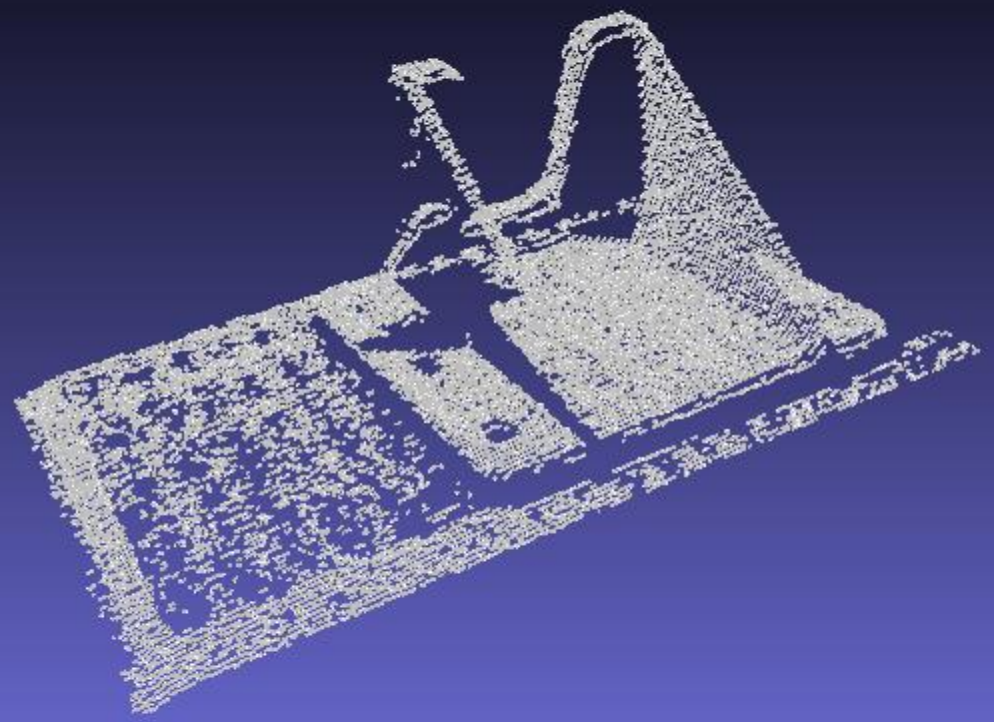
- **80 Images**
- **1 mm movement in X**
- **Y = 7 cm**



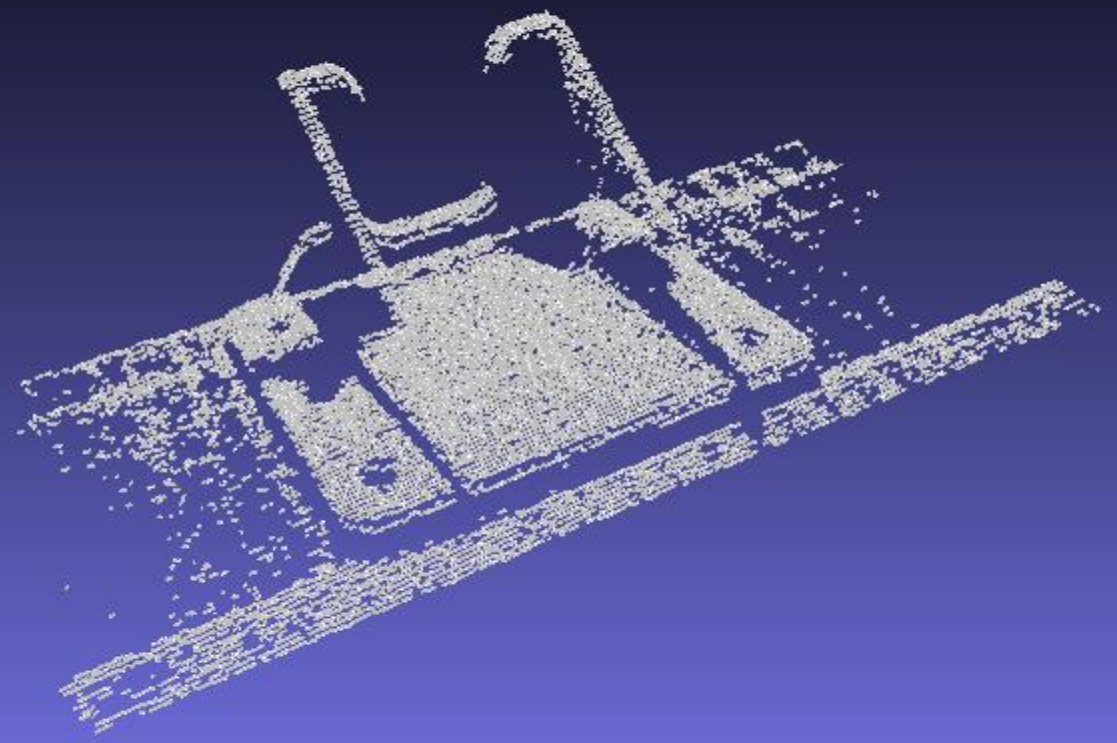
- 80 Images
- 1 mm movement in X
- Y = 0 cm



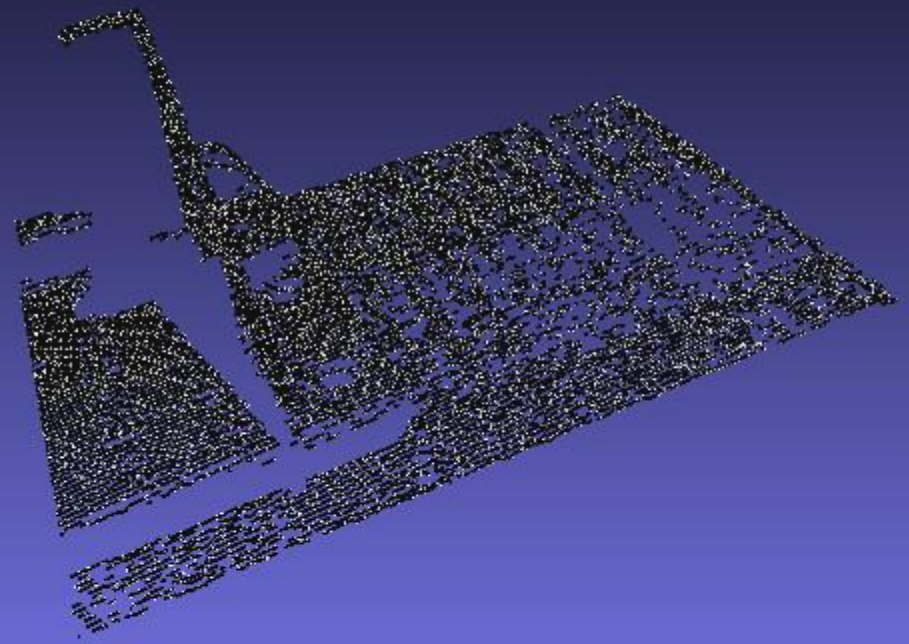
- 80 Images
- 1 mm movement in X
- Y = 3 cm

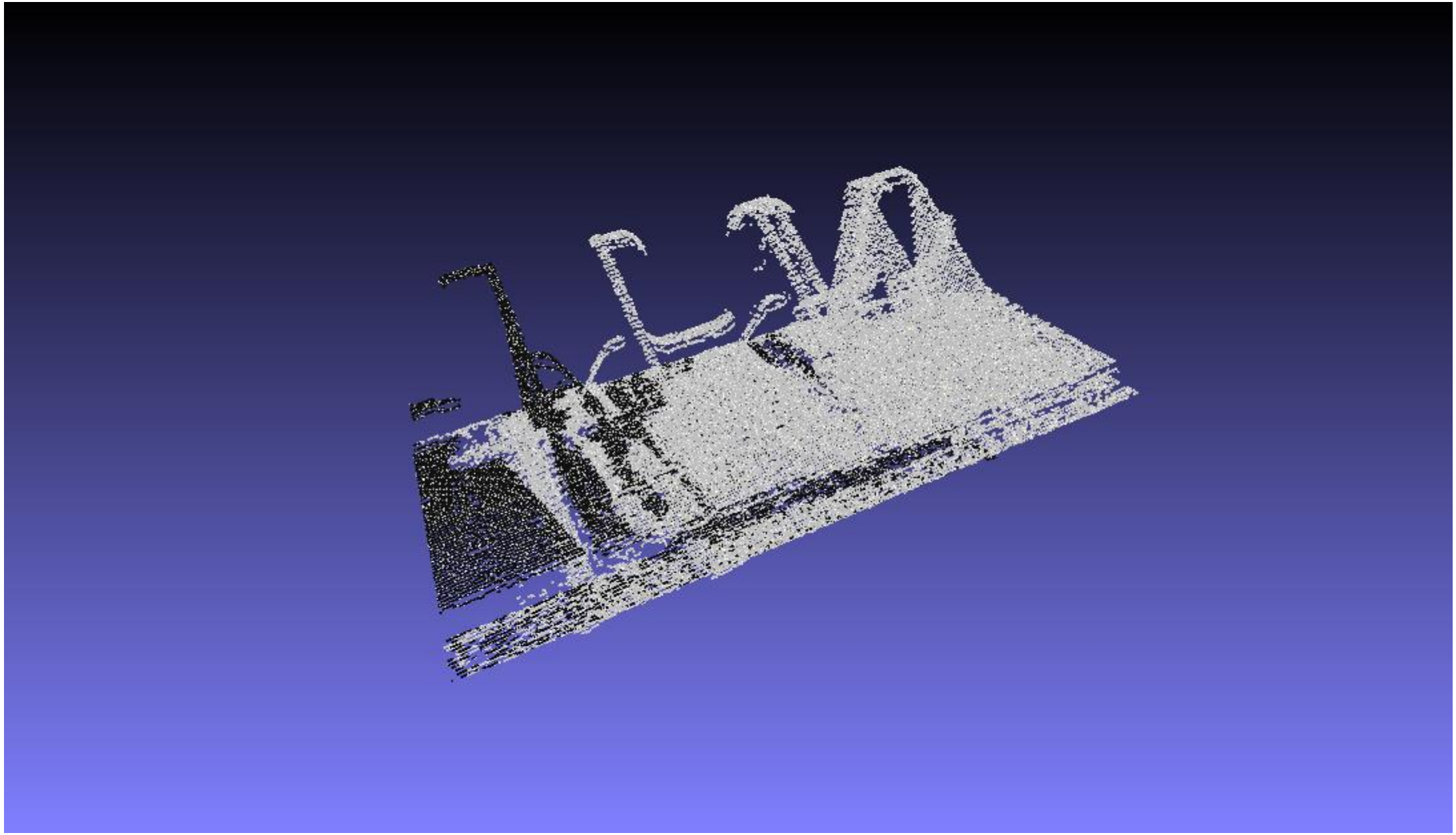


- 80 Images
- 1 mm movement in X
- Y = 7 cm

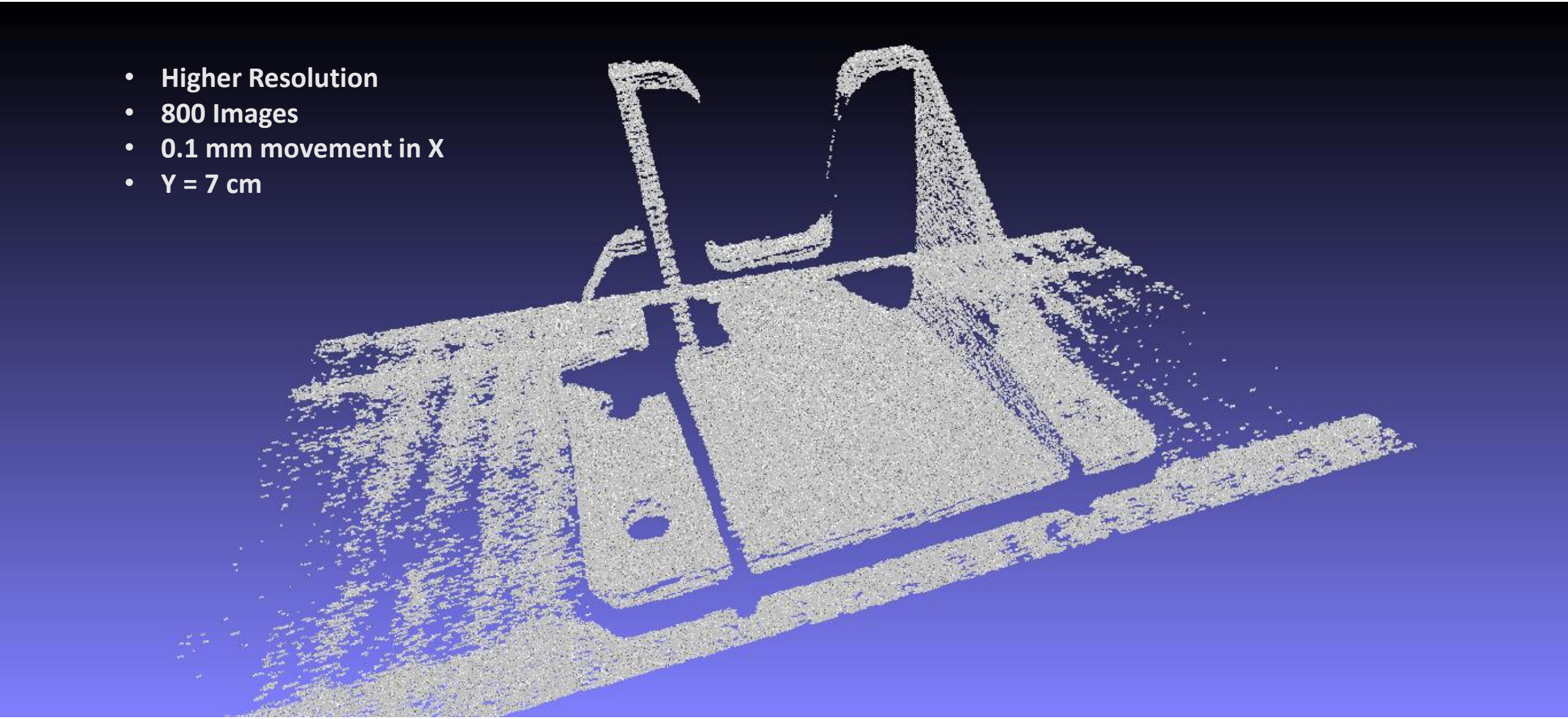


- 80 Images
- 1 mm movement in X
- Y = 10 cm

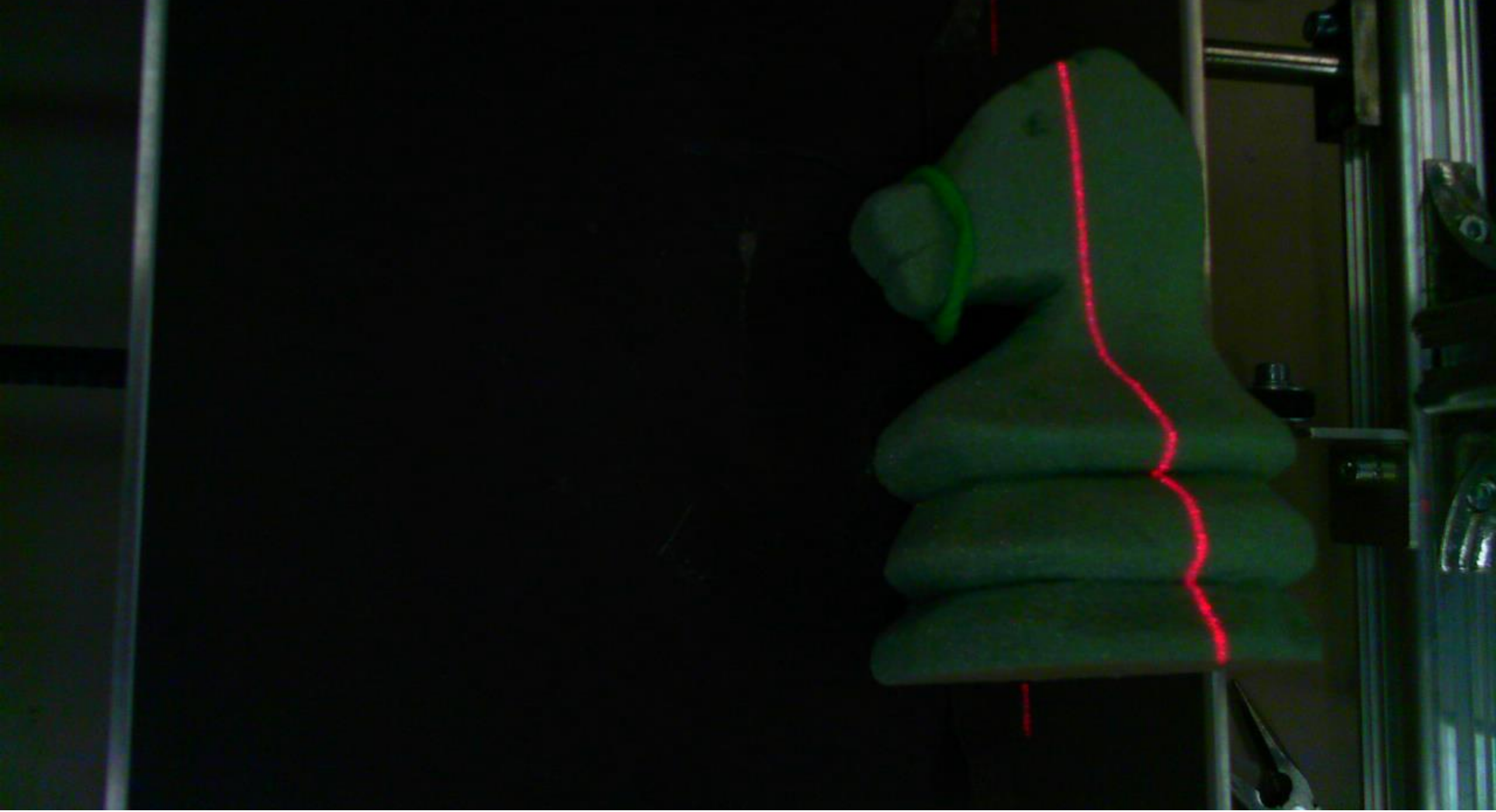




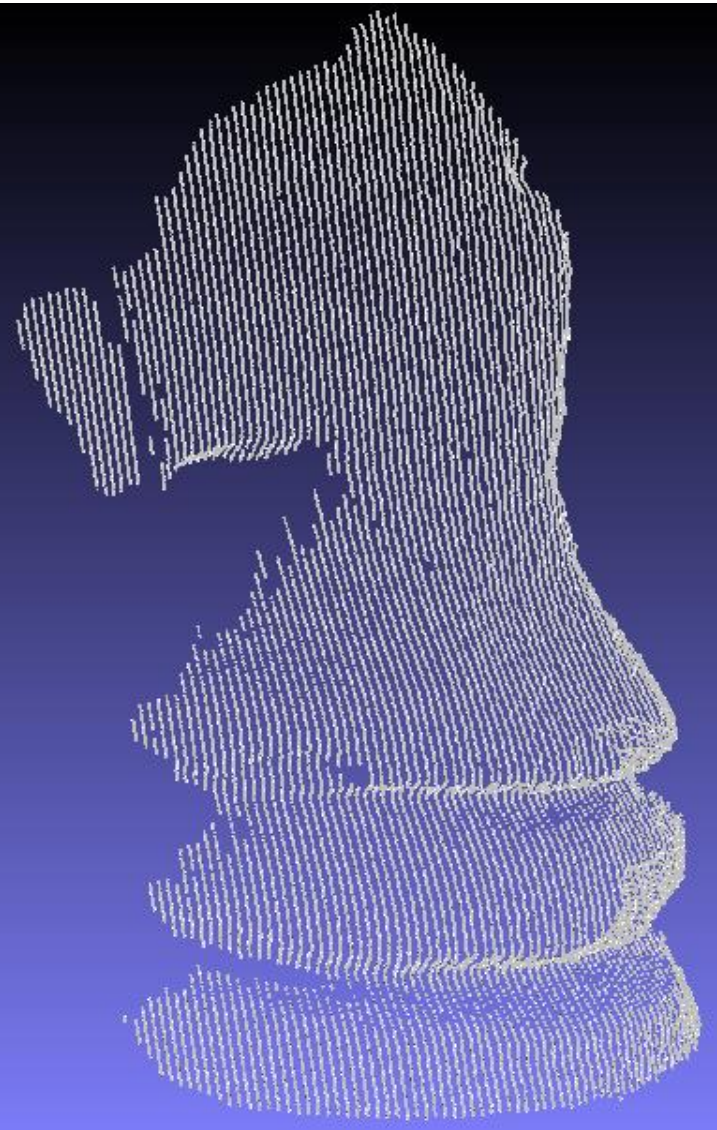
- Higher Resolution
- 800 Images
- 0.1 mm movement in X
- Y = 7 cm

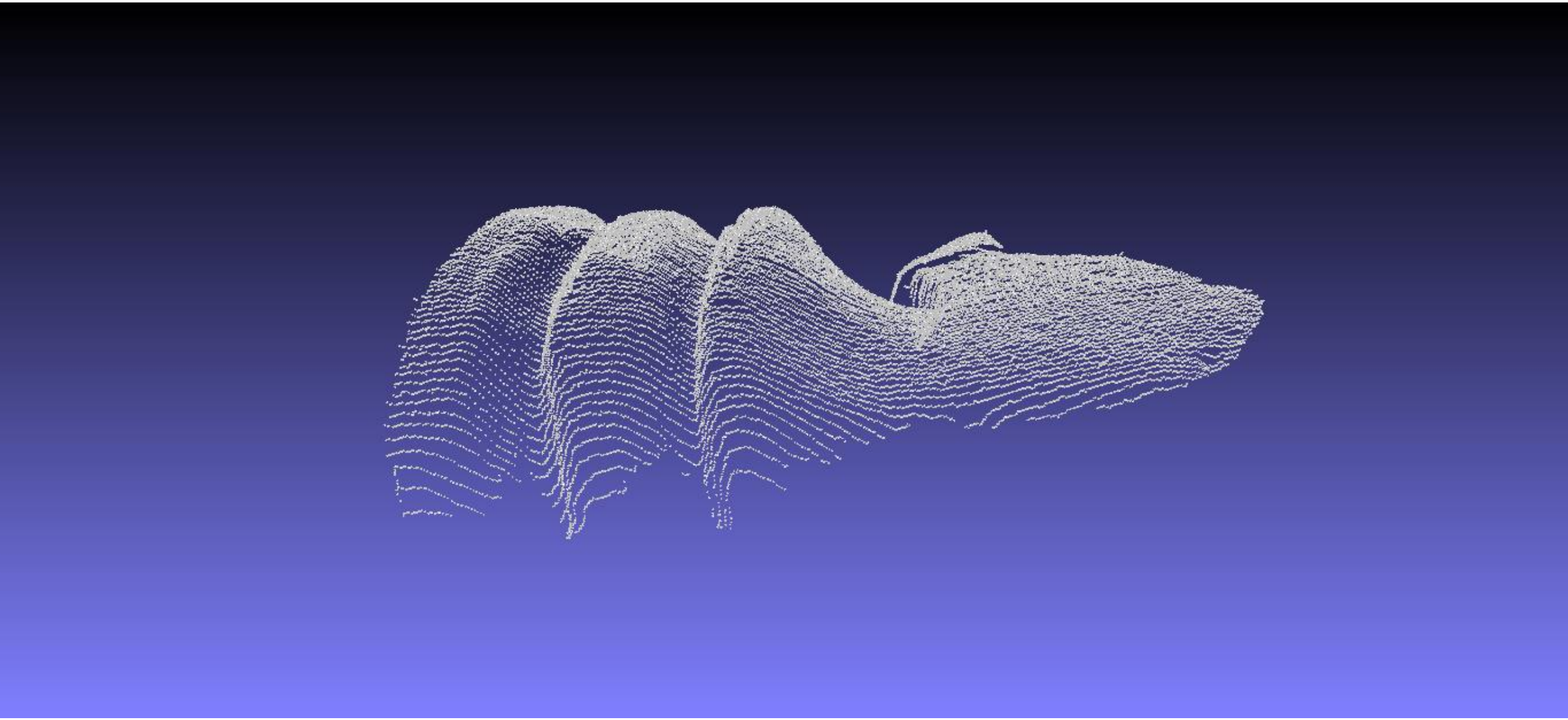


Scan more objects

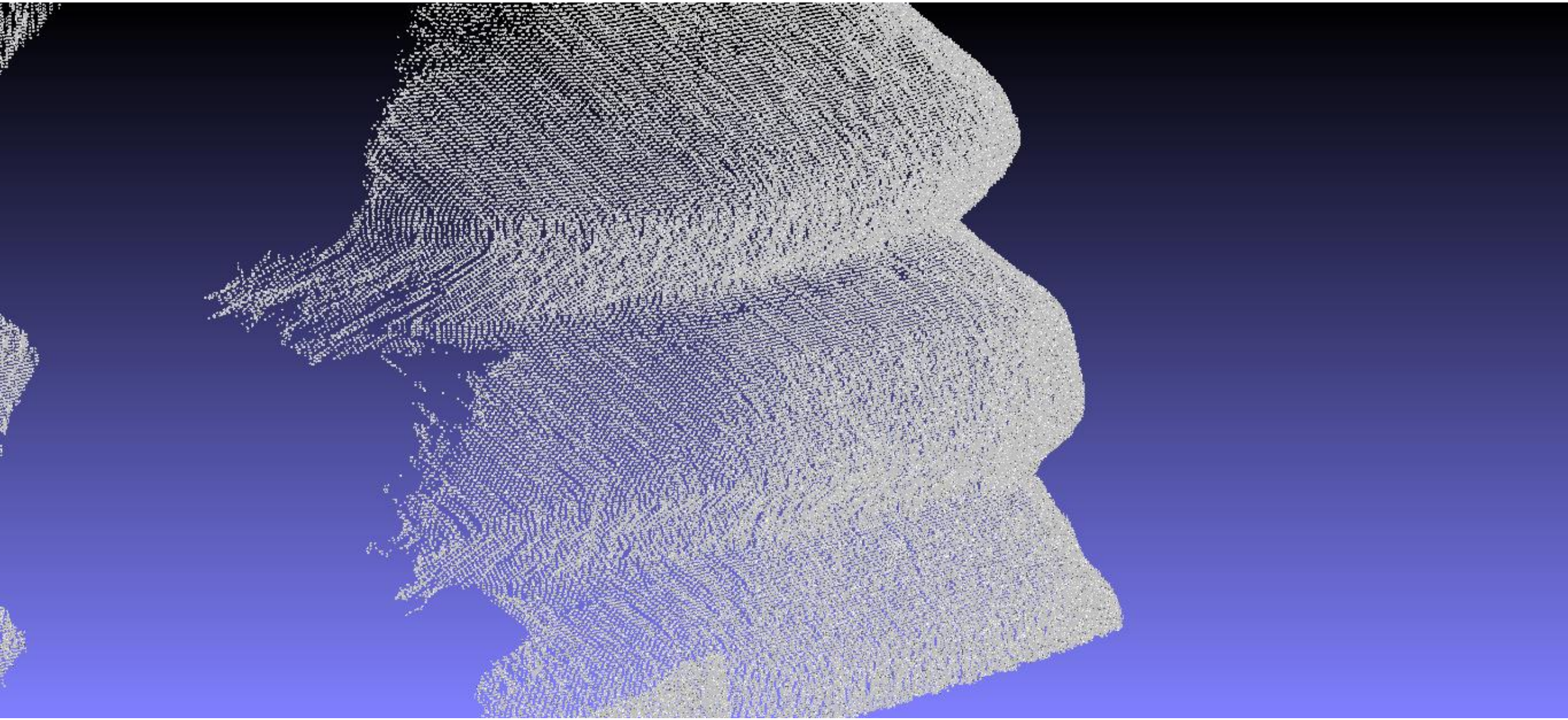


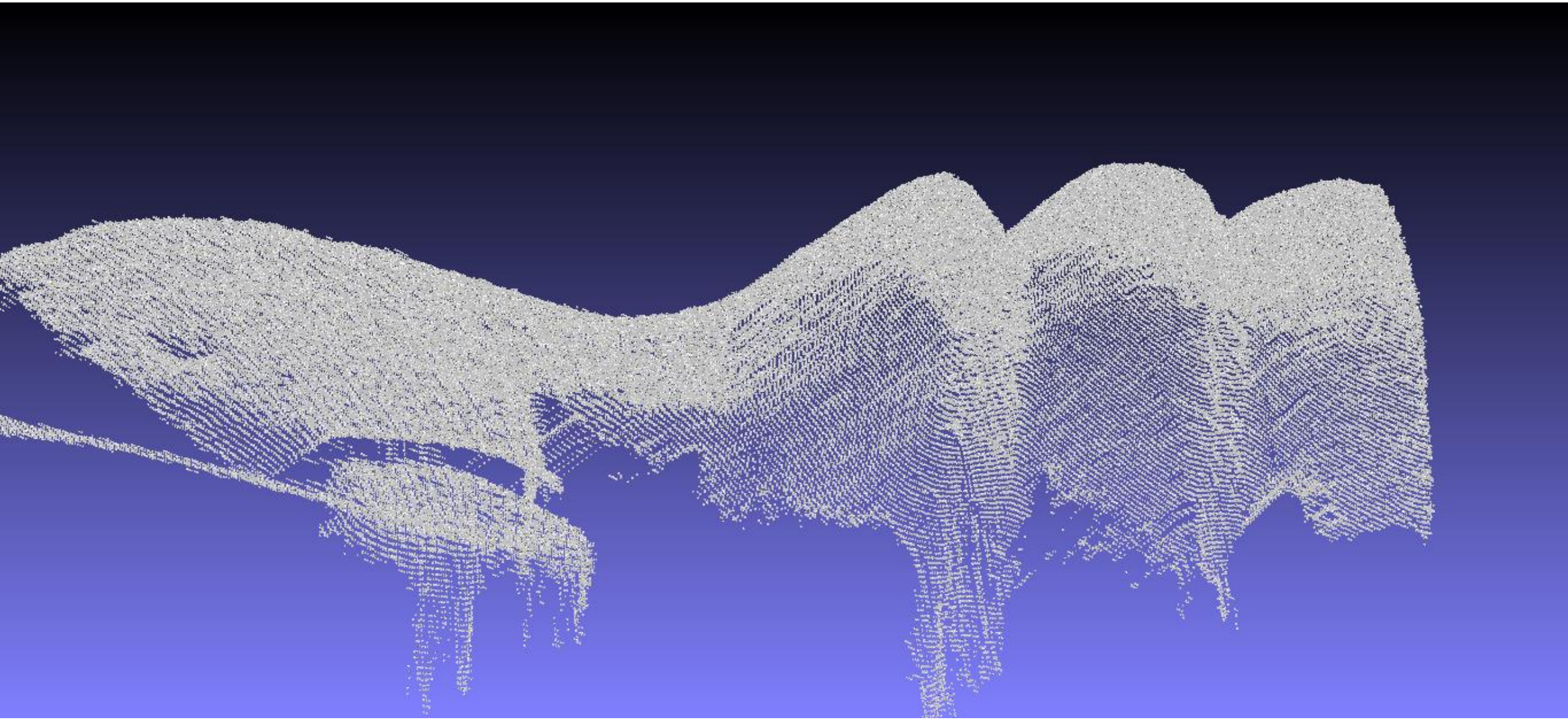
- 80 Images
- 1 mm movement in X



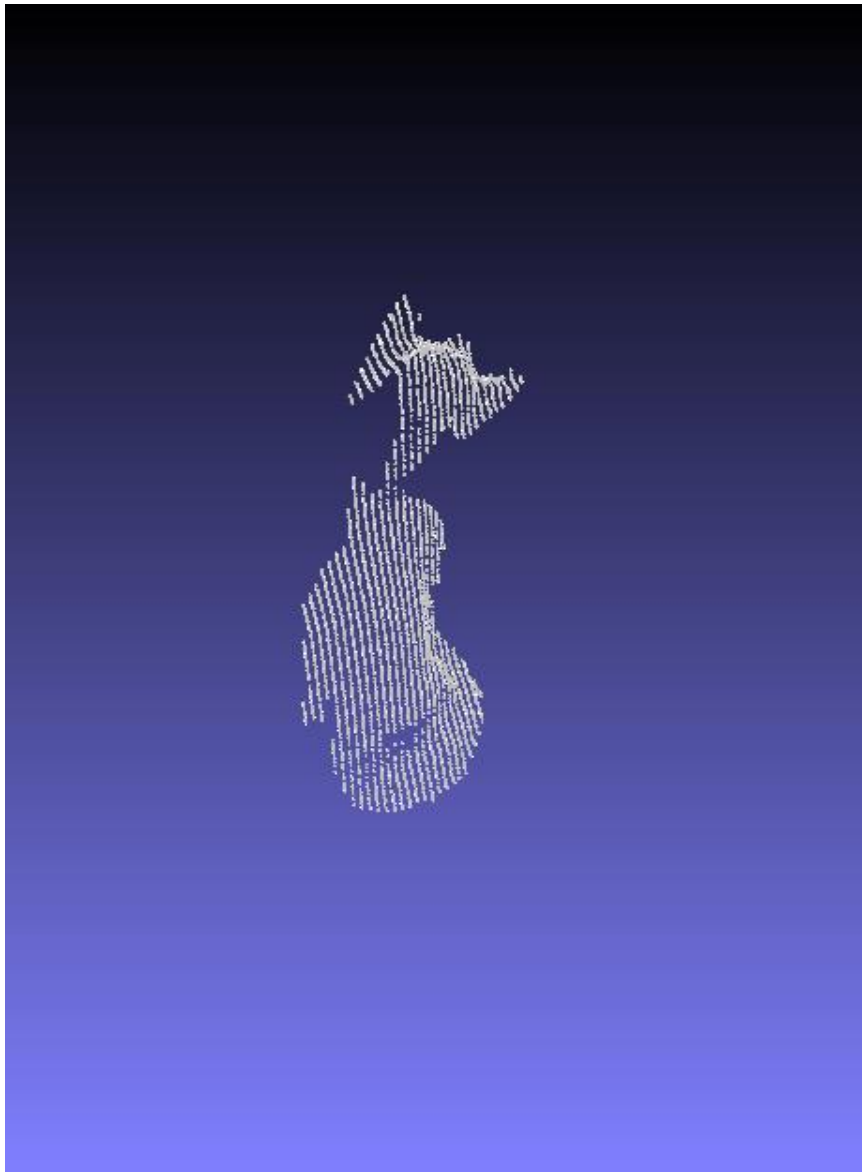


- 800 Images
- 0.1 mm movement in X





- 80 Images
- 1 mm movement in X



- 80 Images
- 1 mm movement in X

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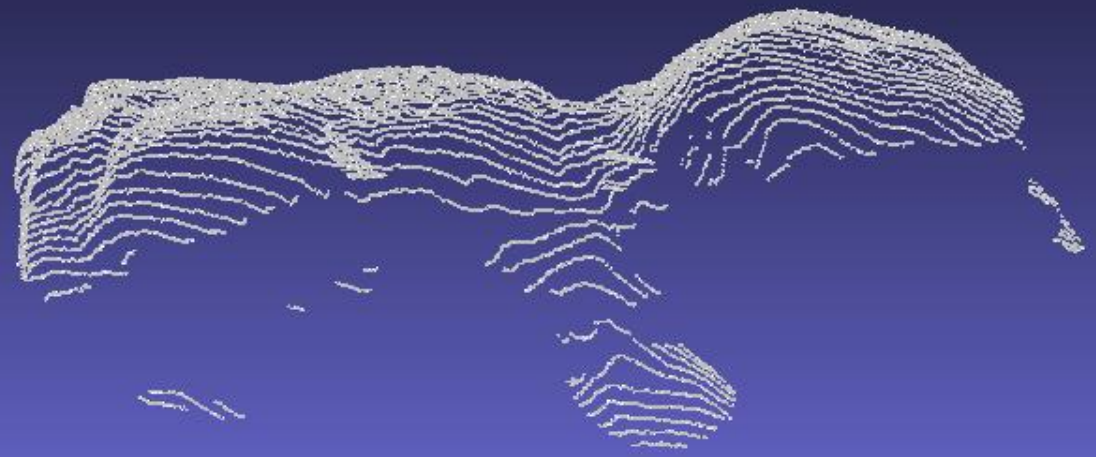
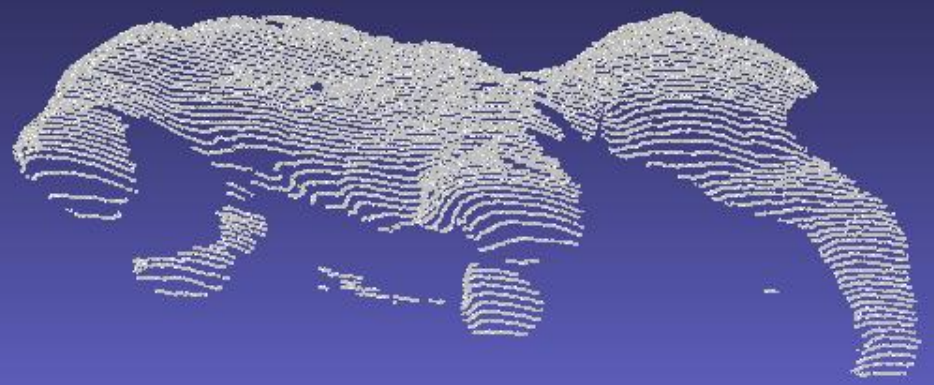
- 1 mm movement in X



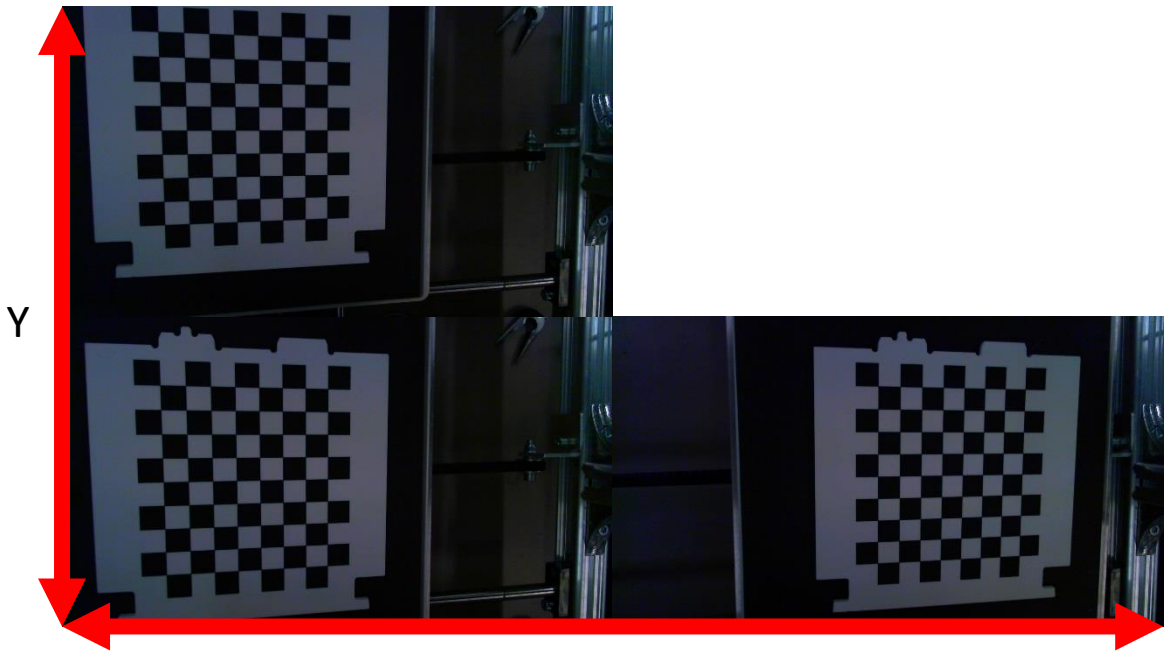
- 80 Images
- 1 mm movement in X



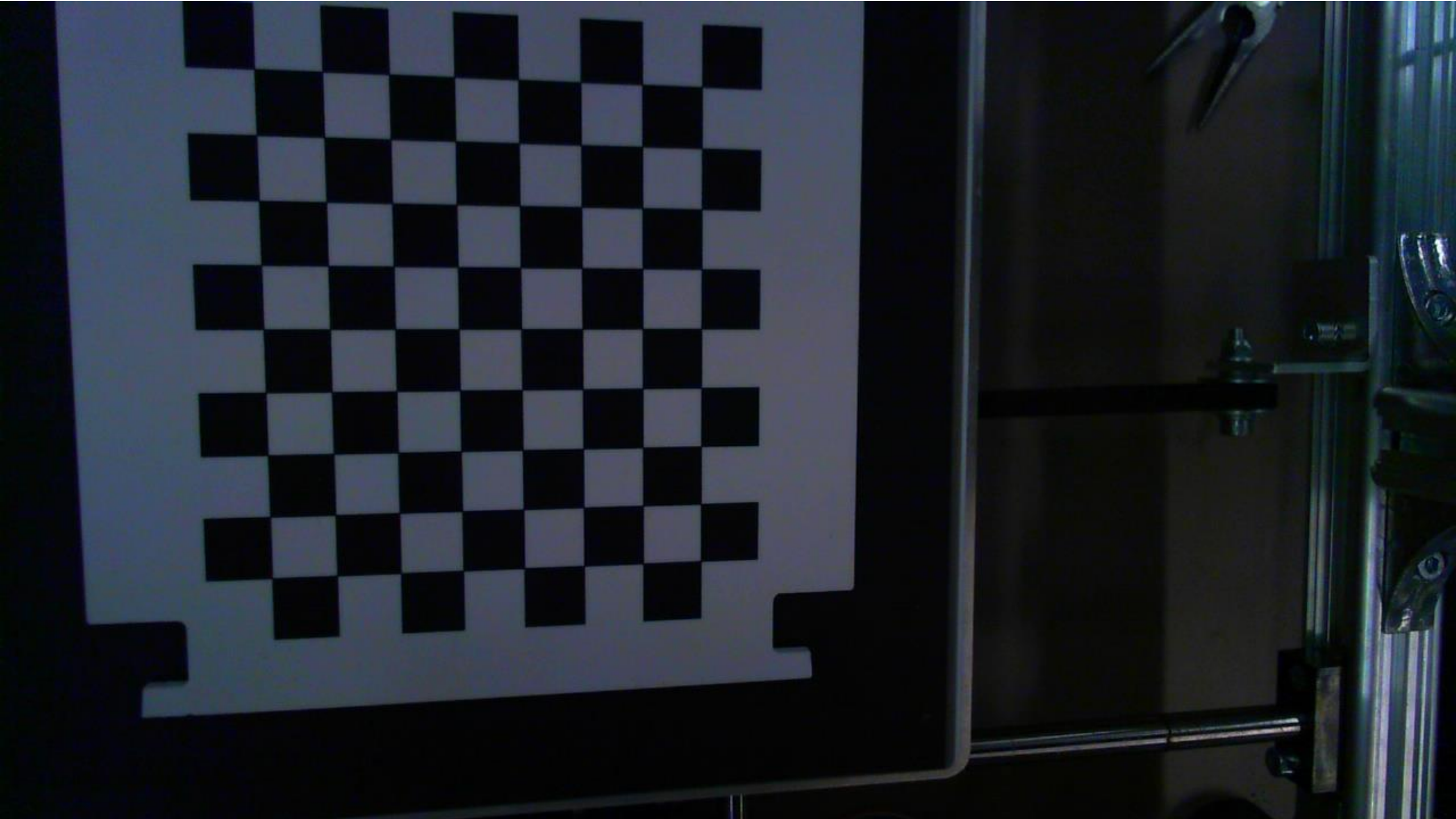
Movement Calibration

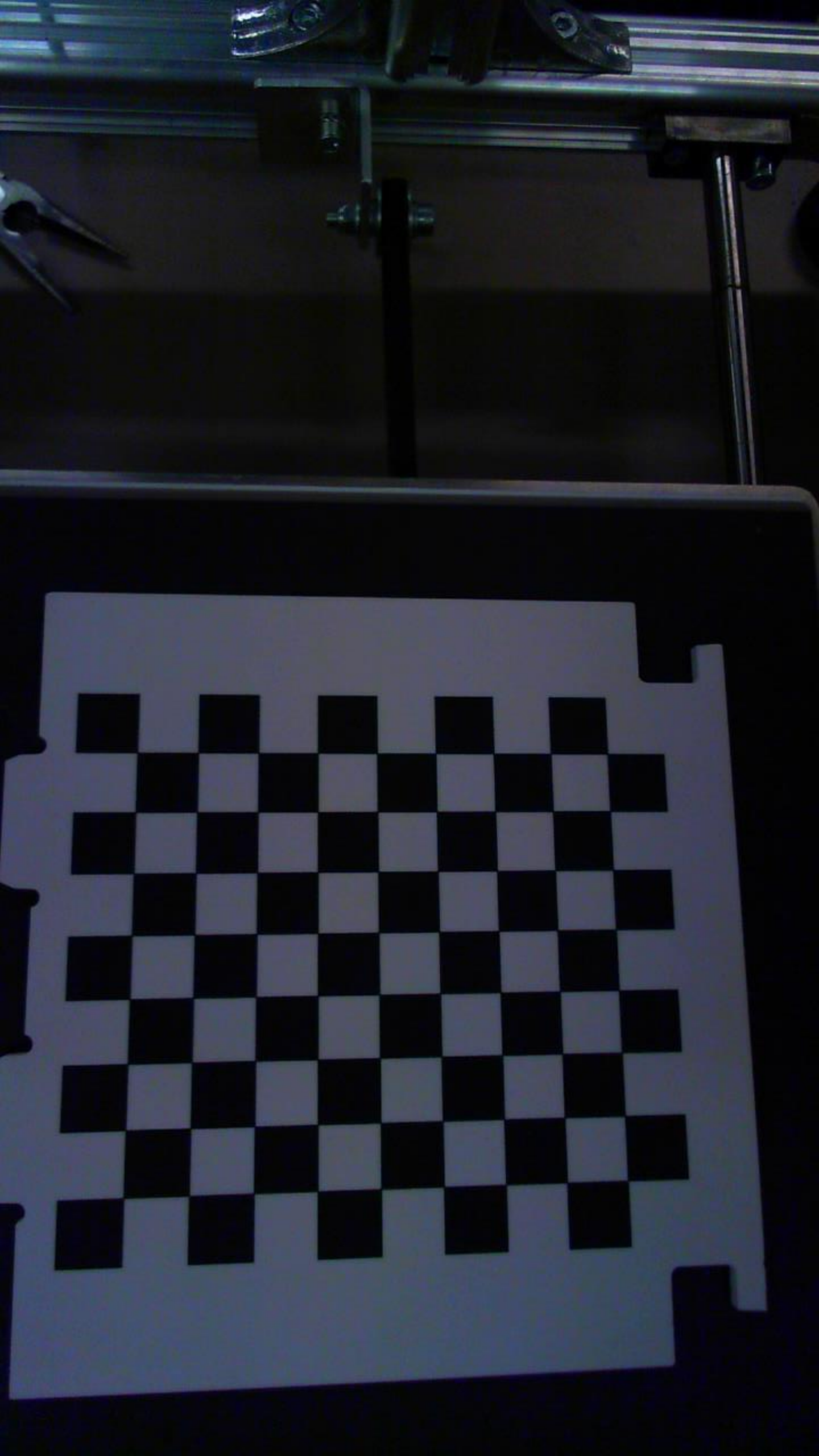
Movement Calibration

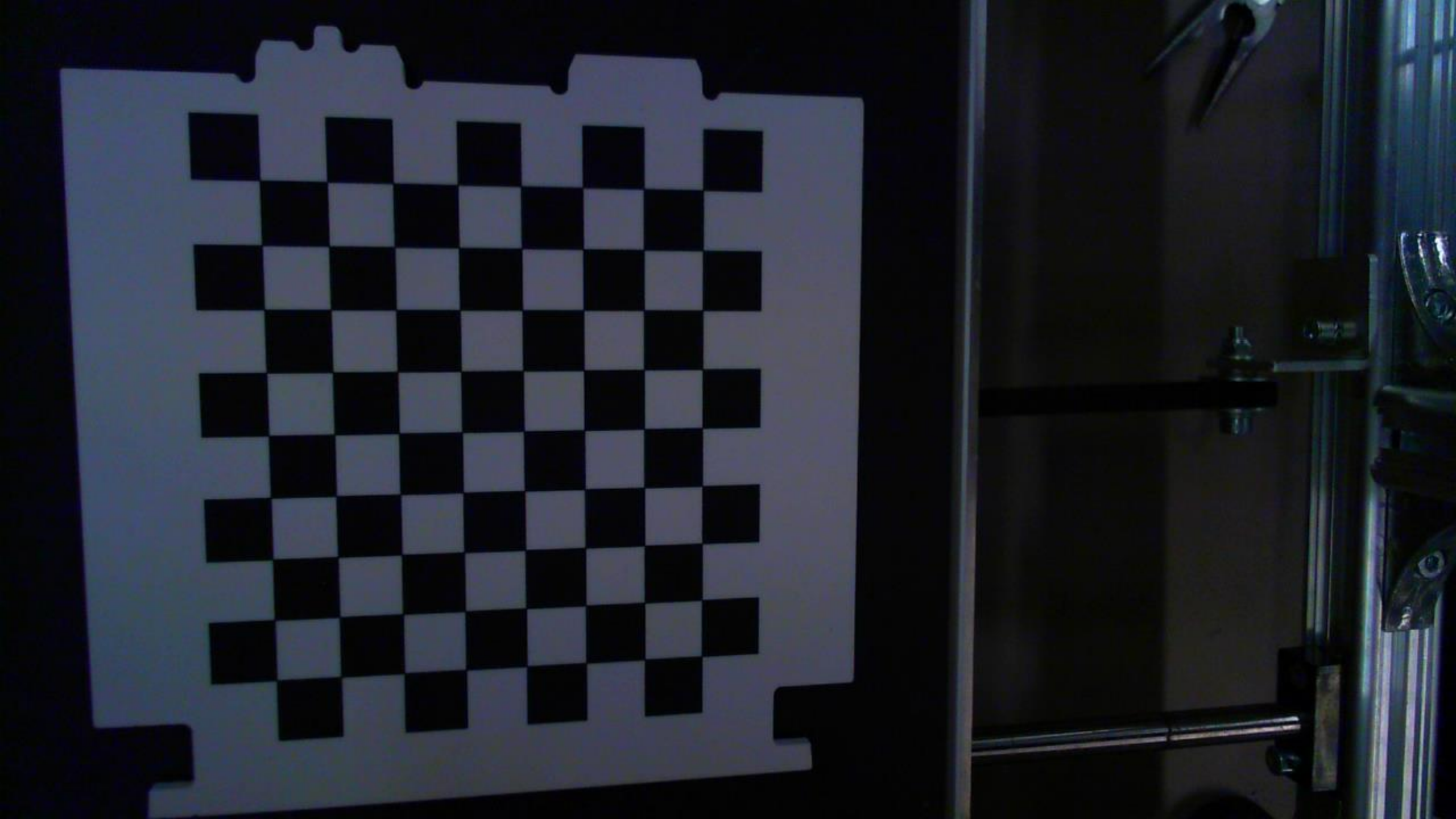
- Use the checkerboard corners to estimate the movement X and Y axes.

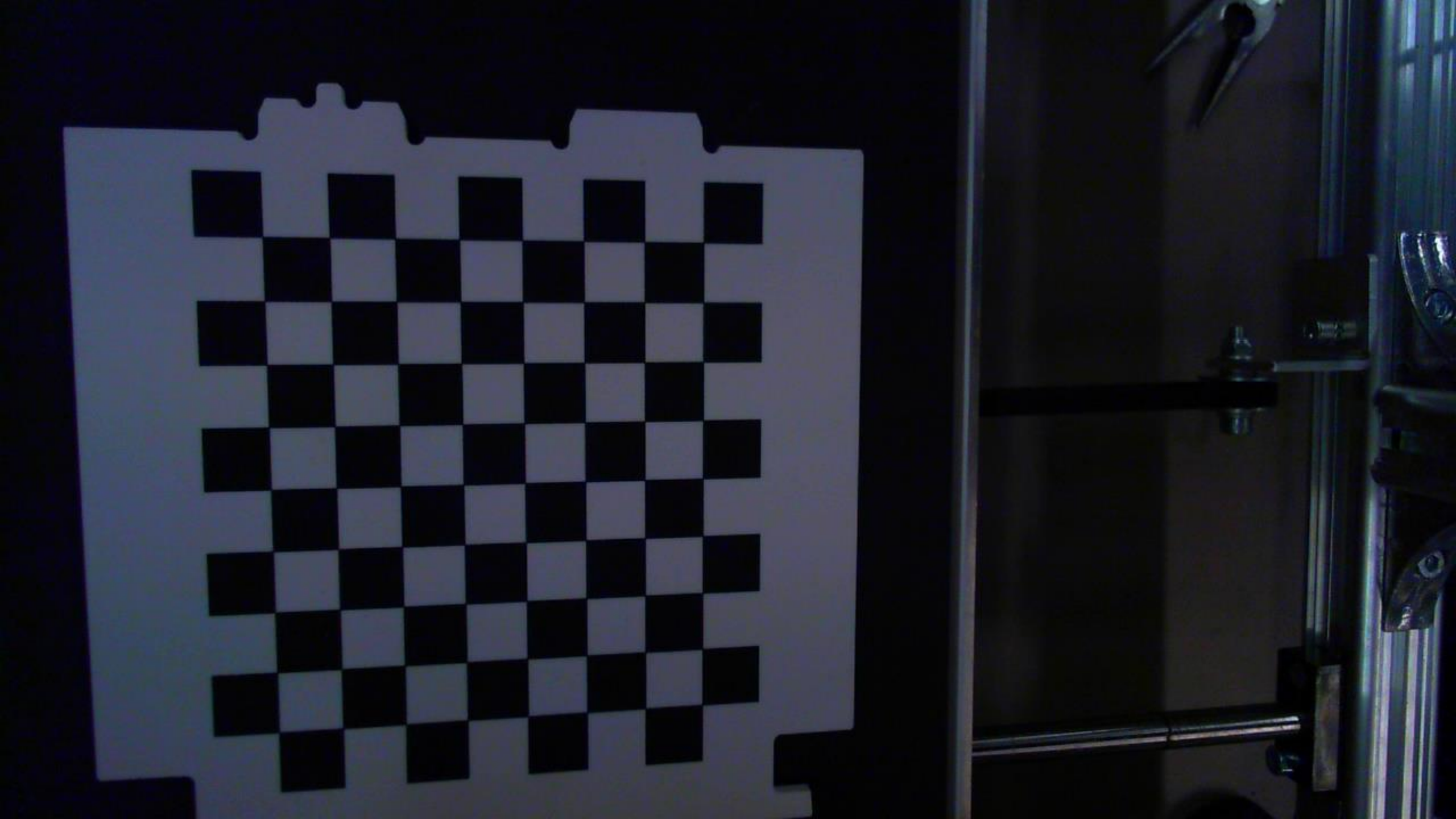


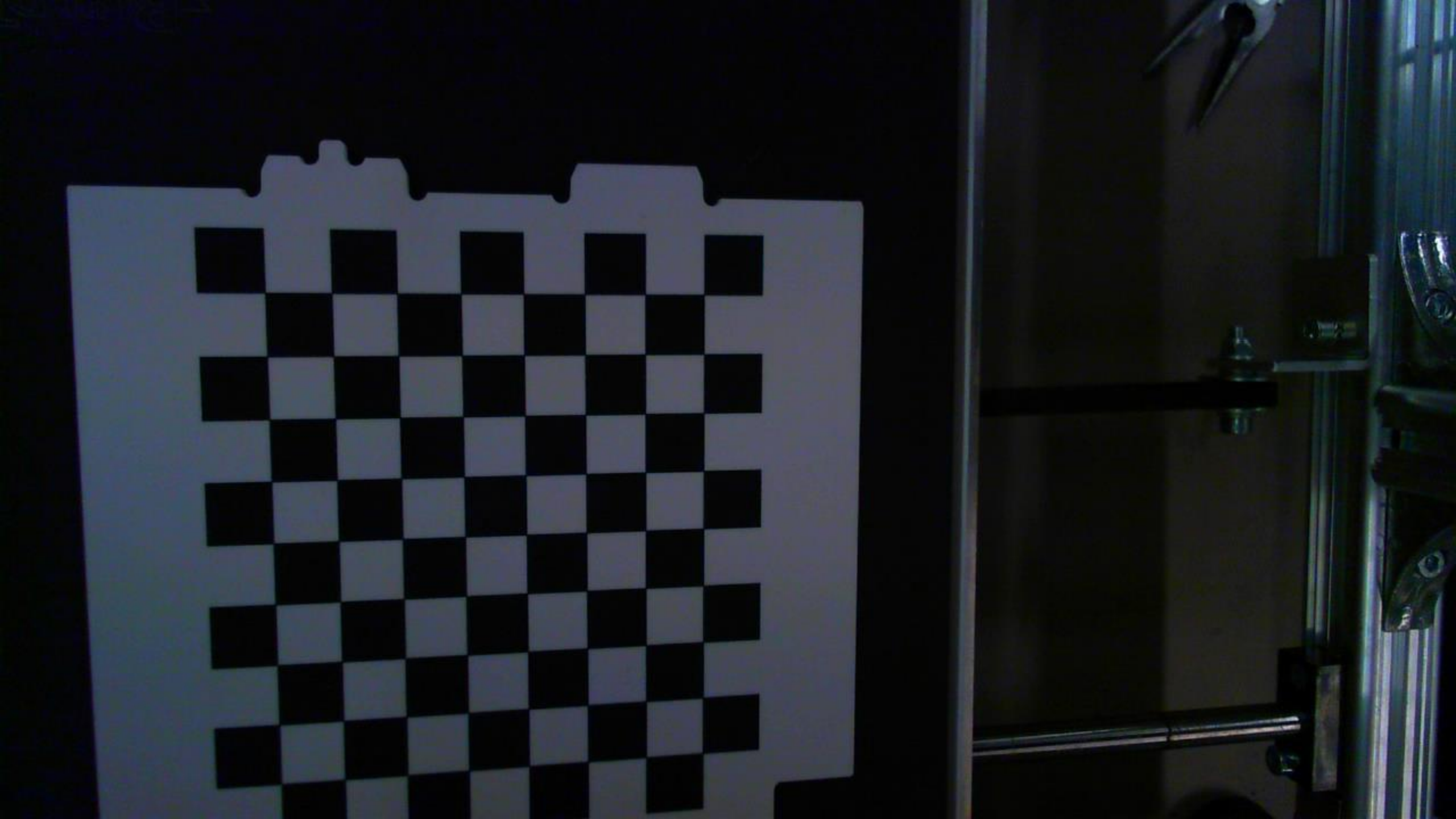
Movement Calibration

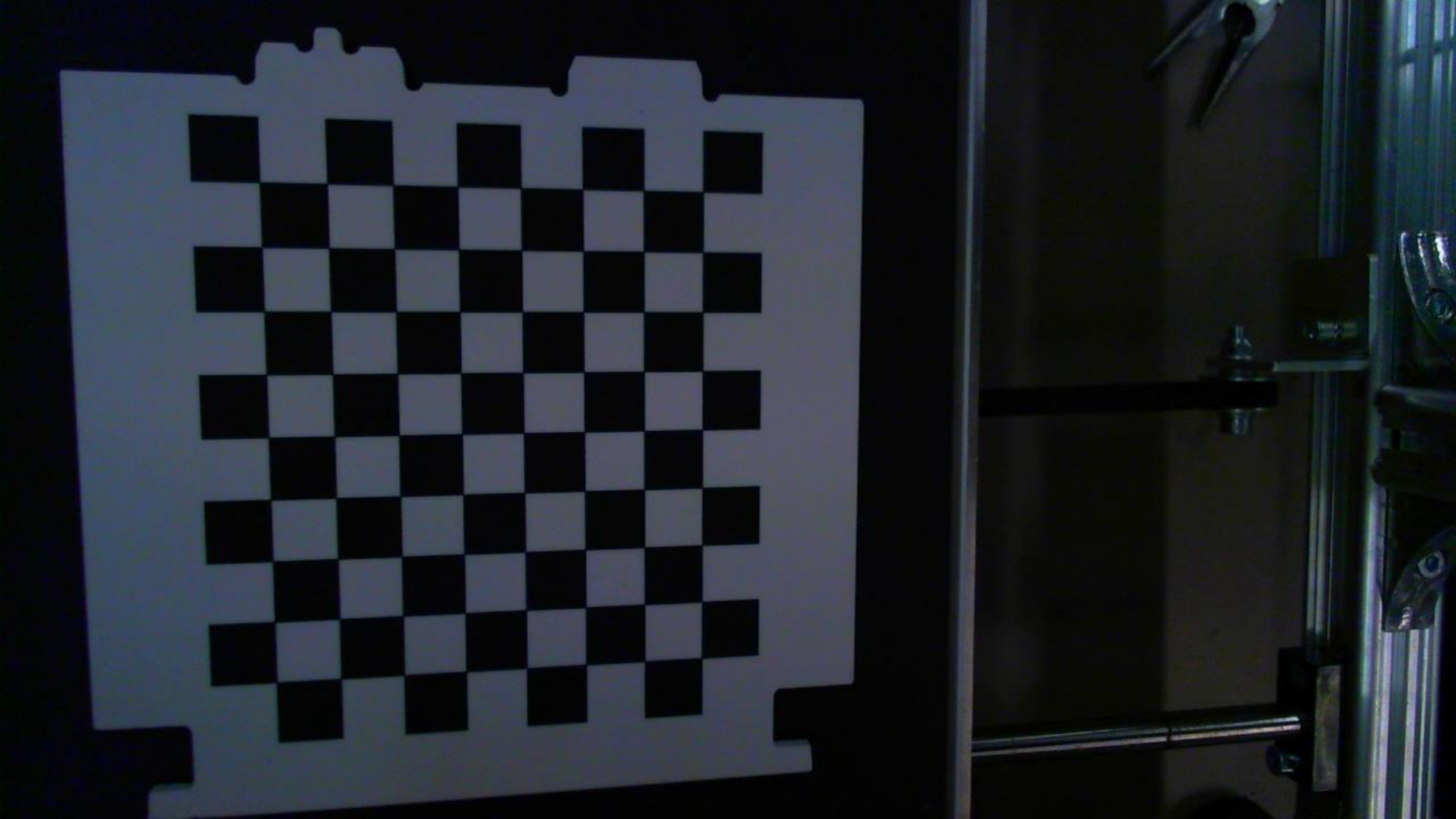


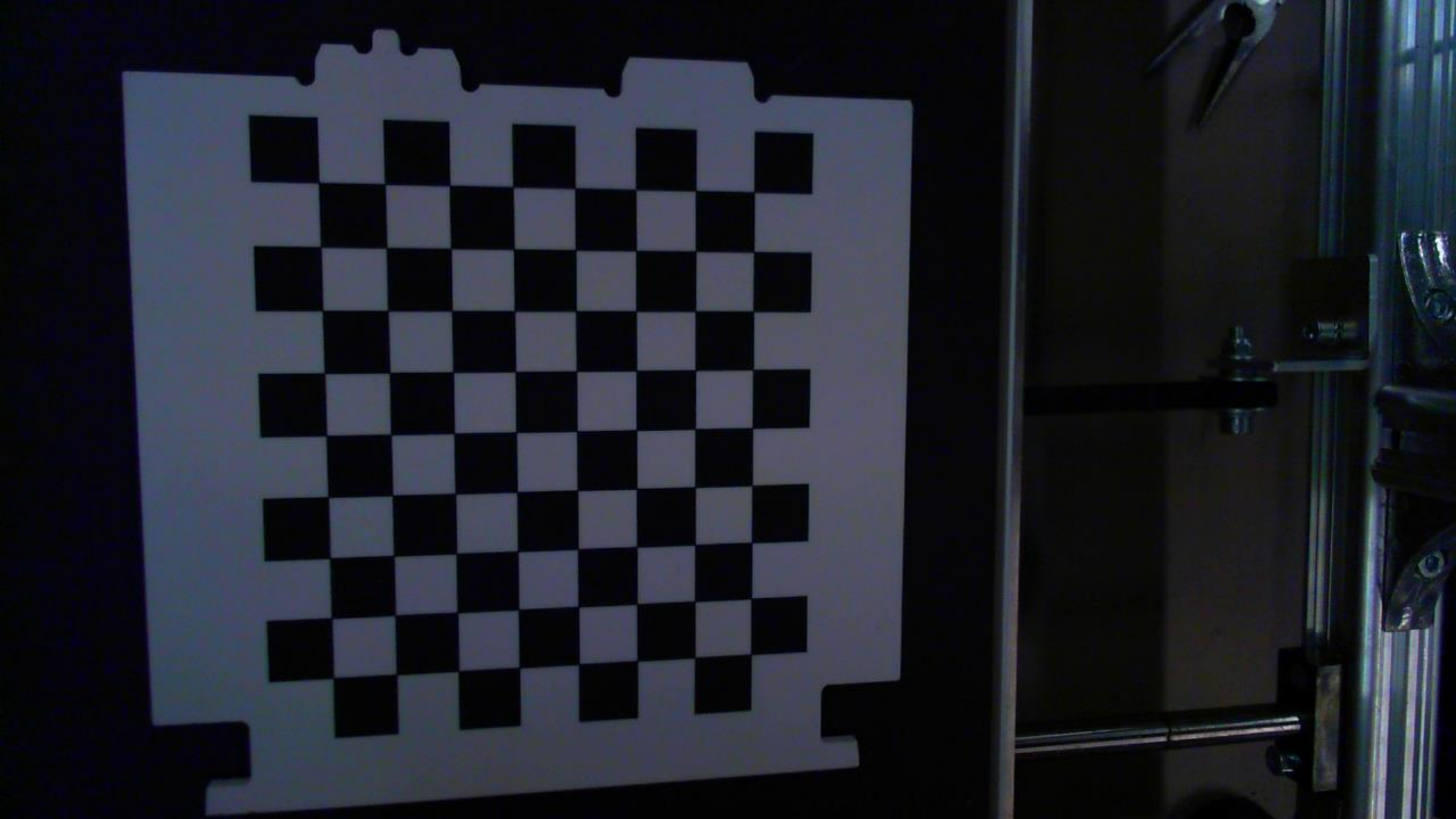


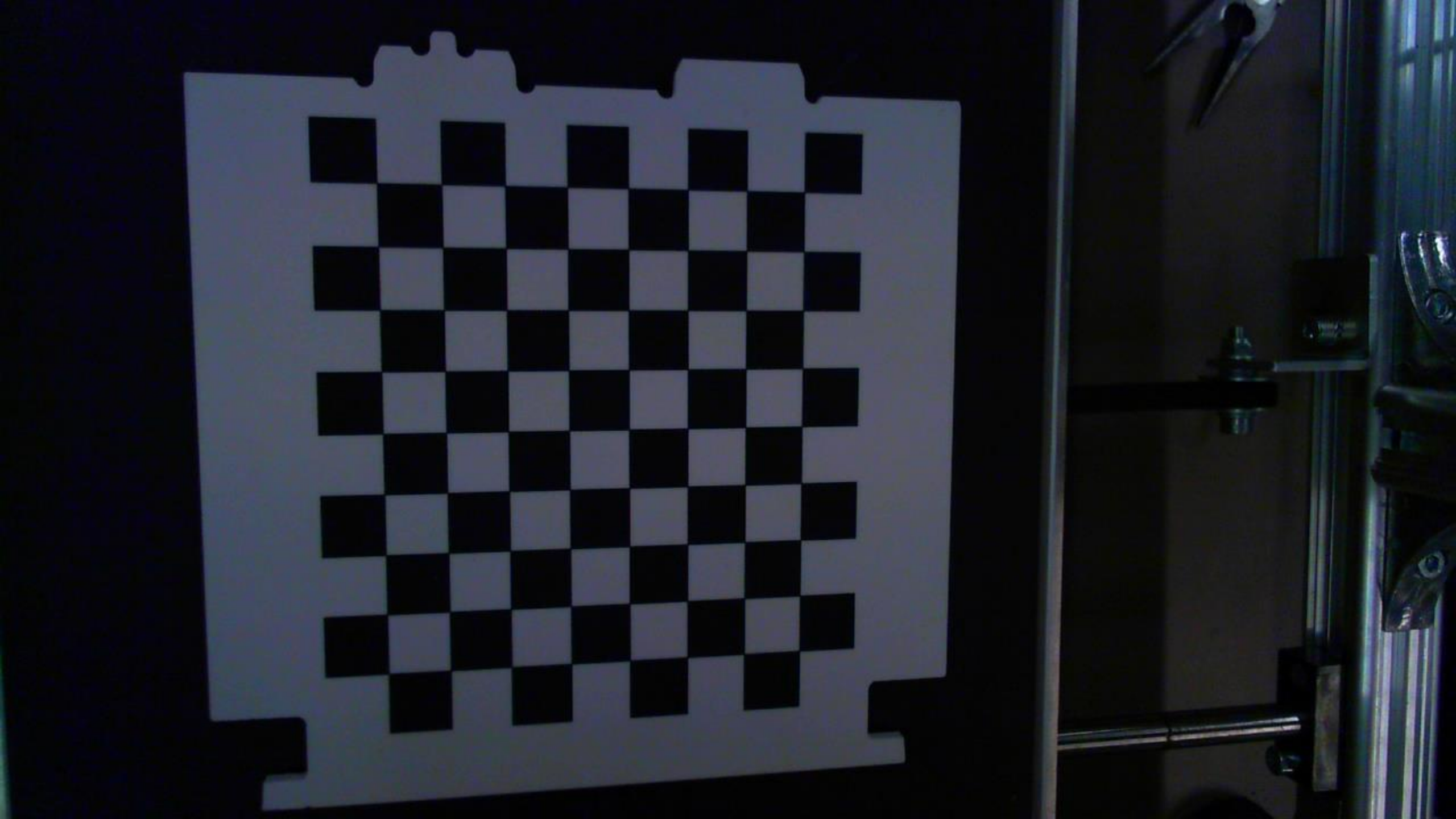


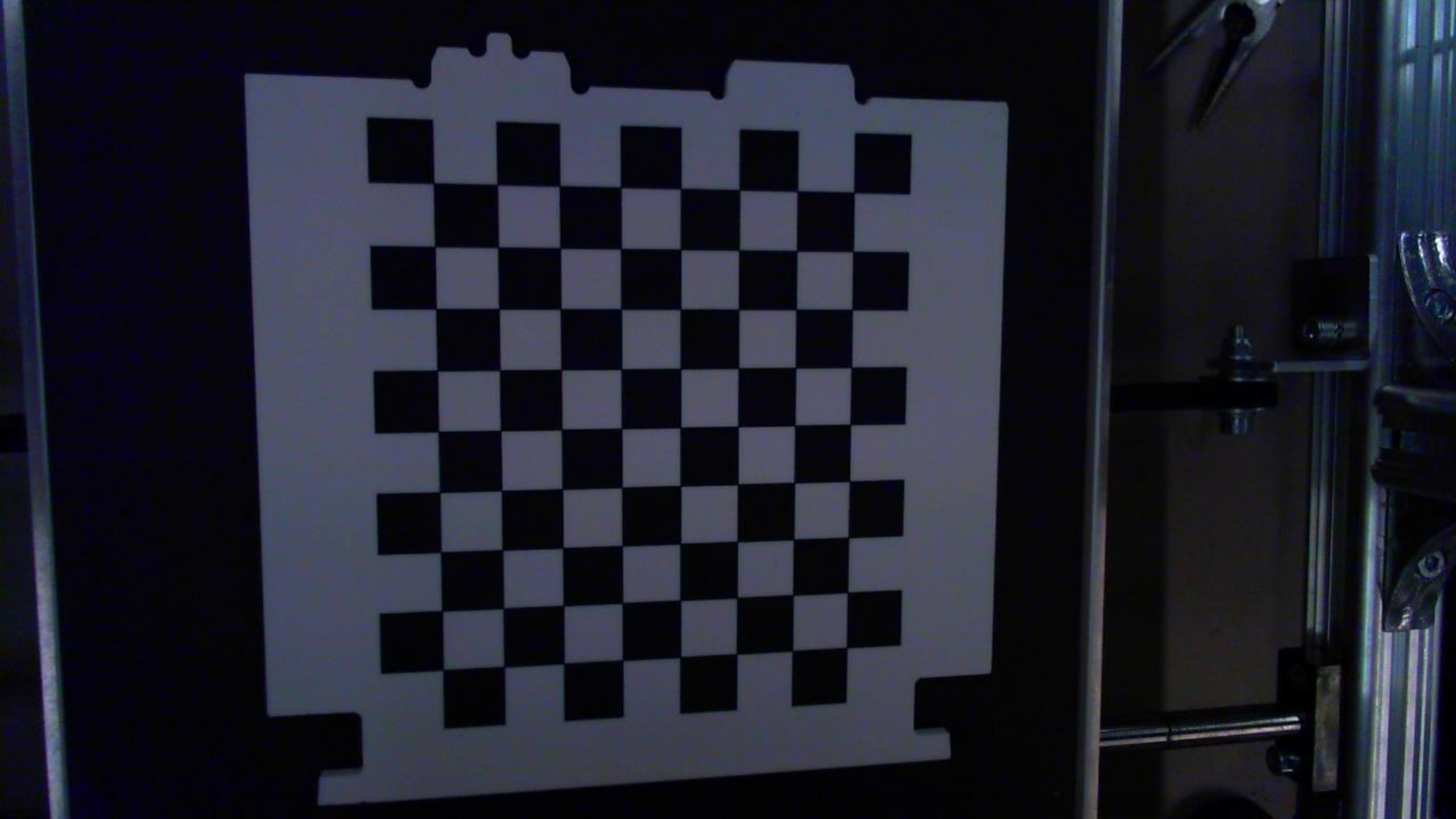


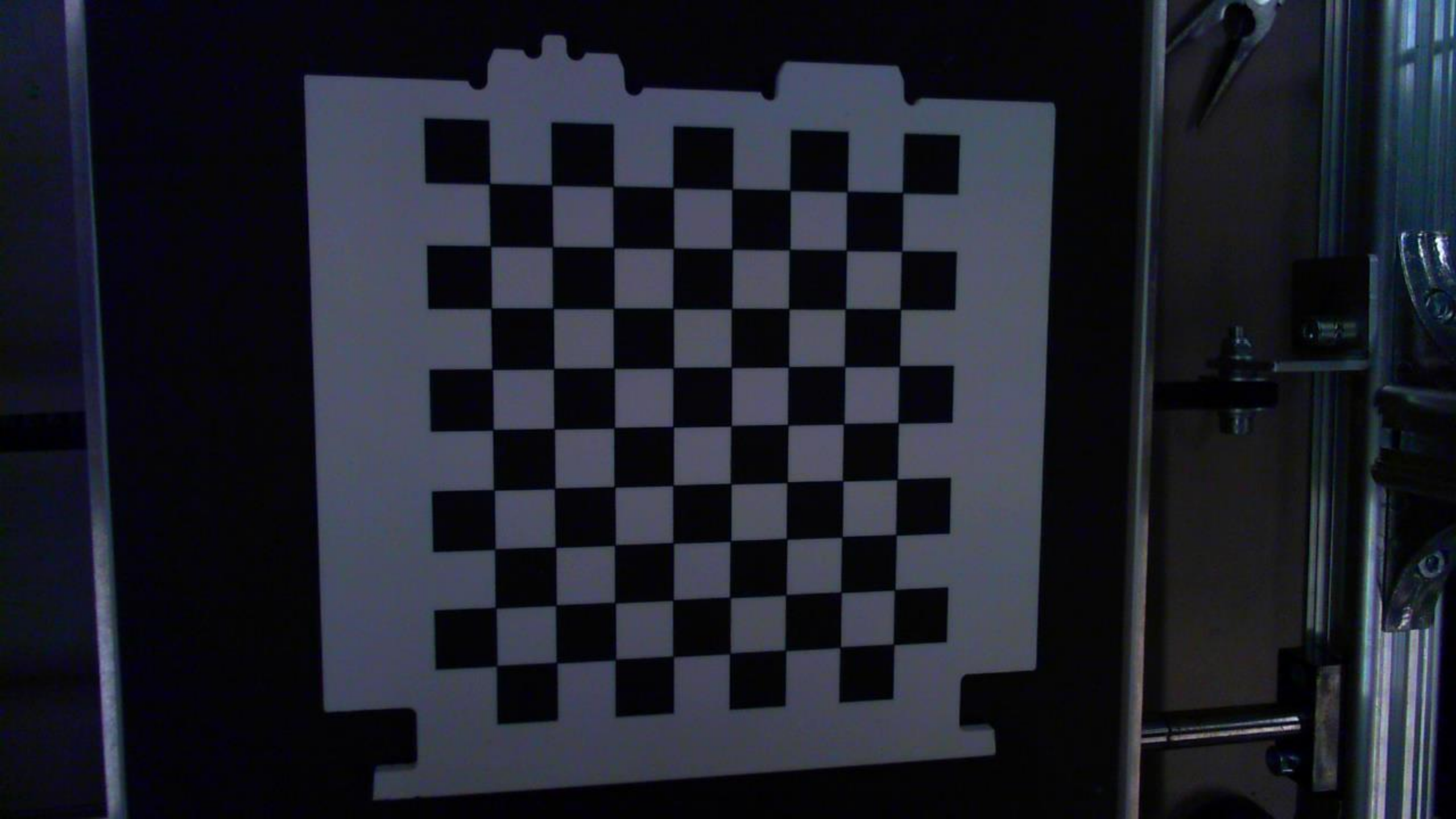


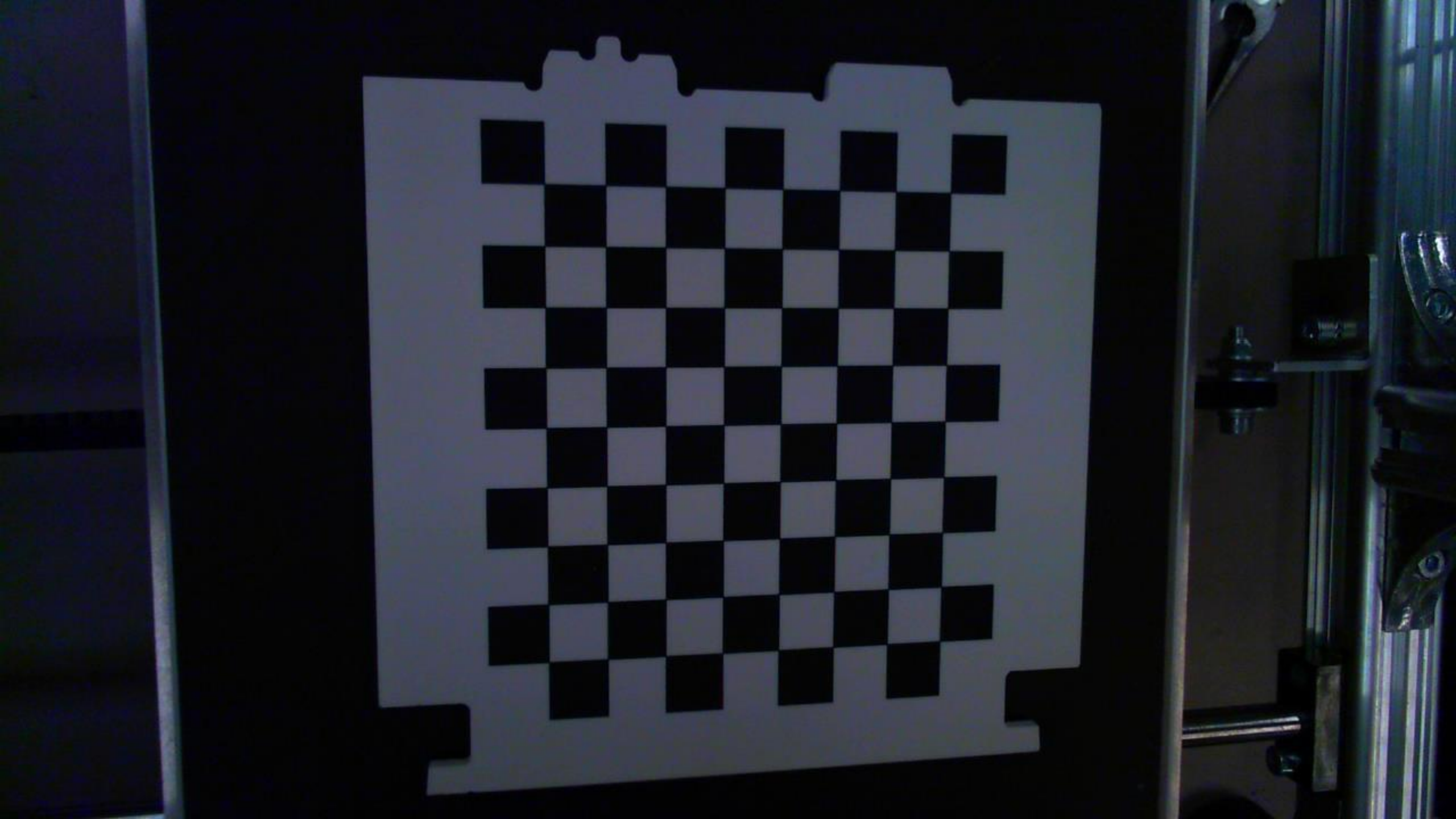


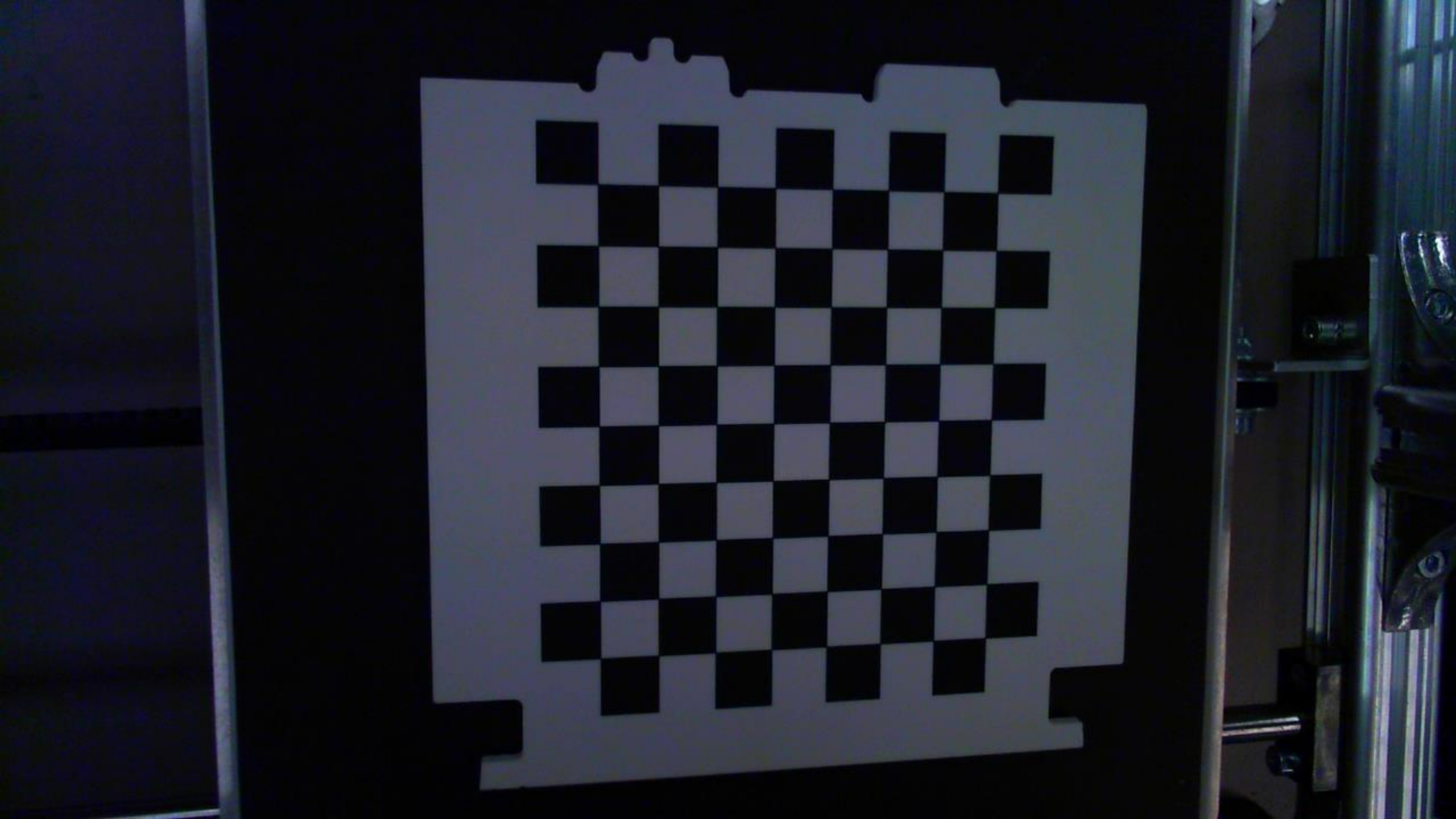


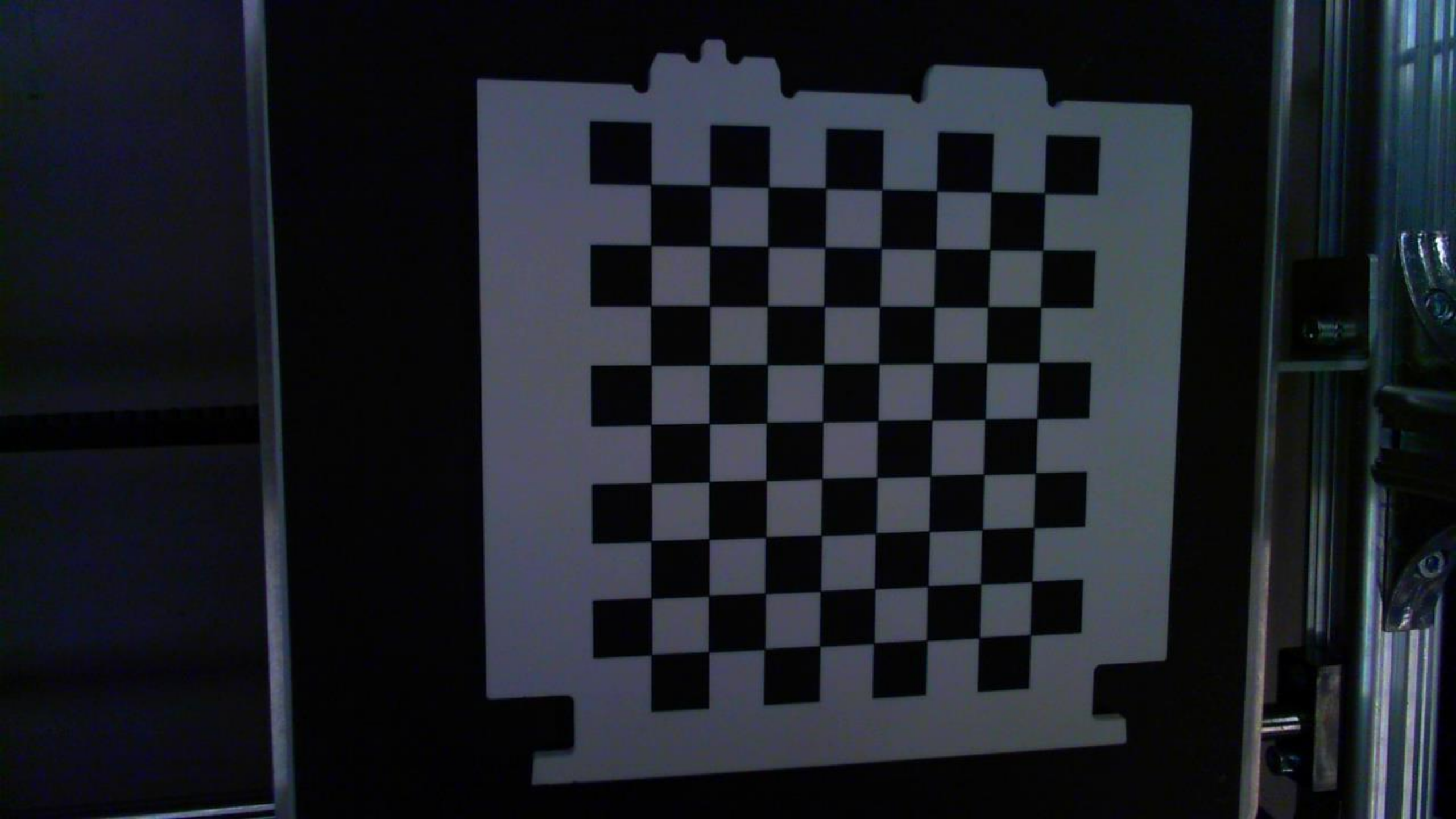


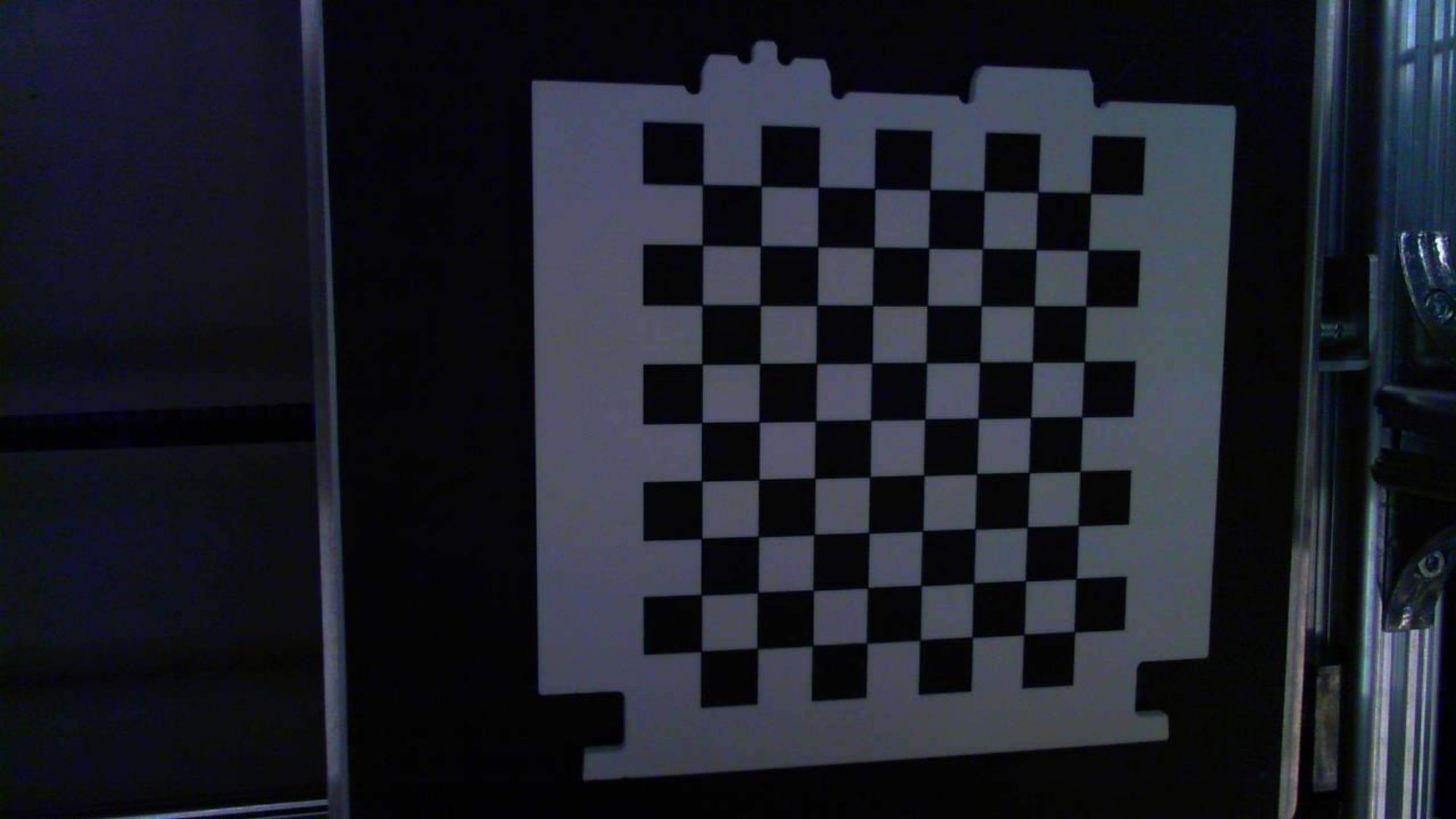






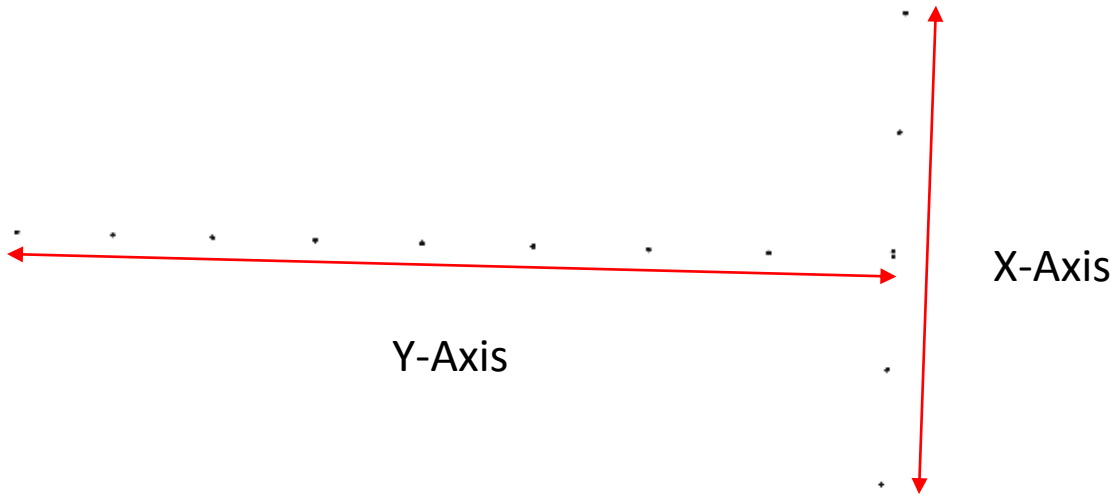




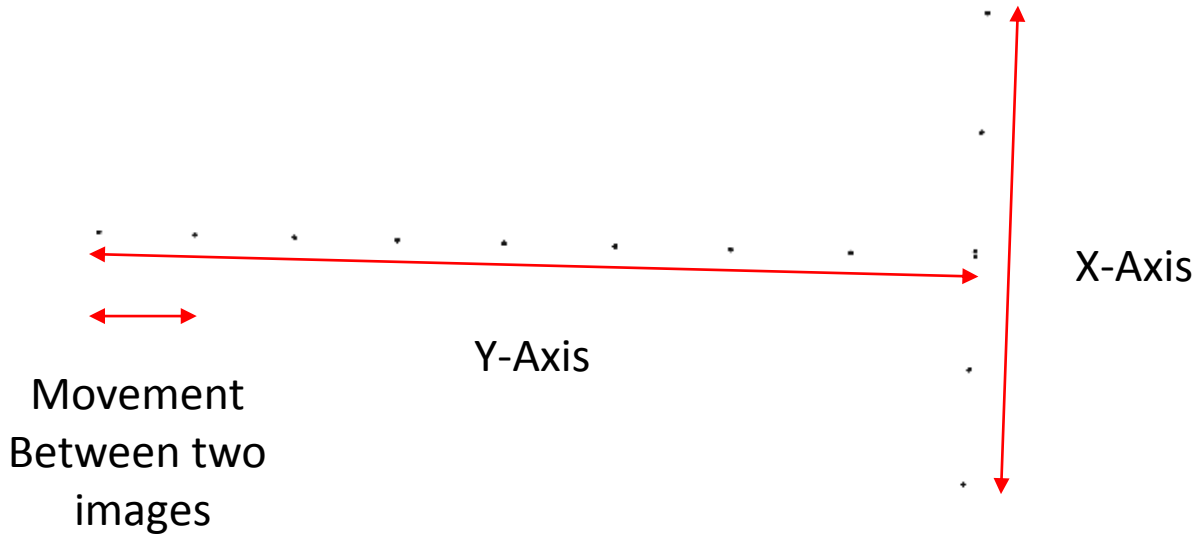


One Checkerboard Corner Movement

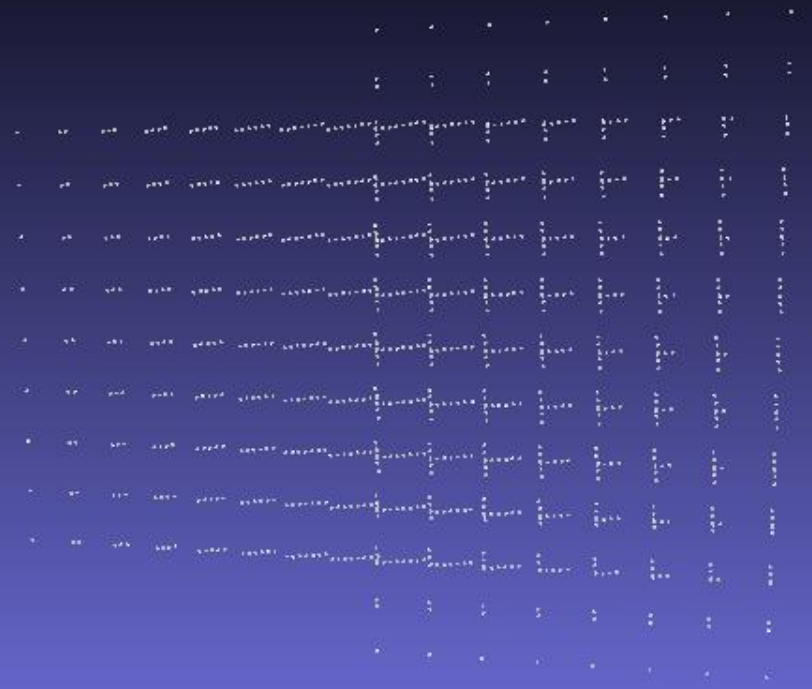
One Checkerboard Corner Movement



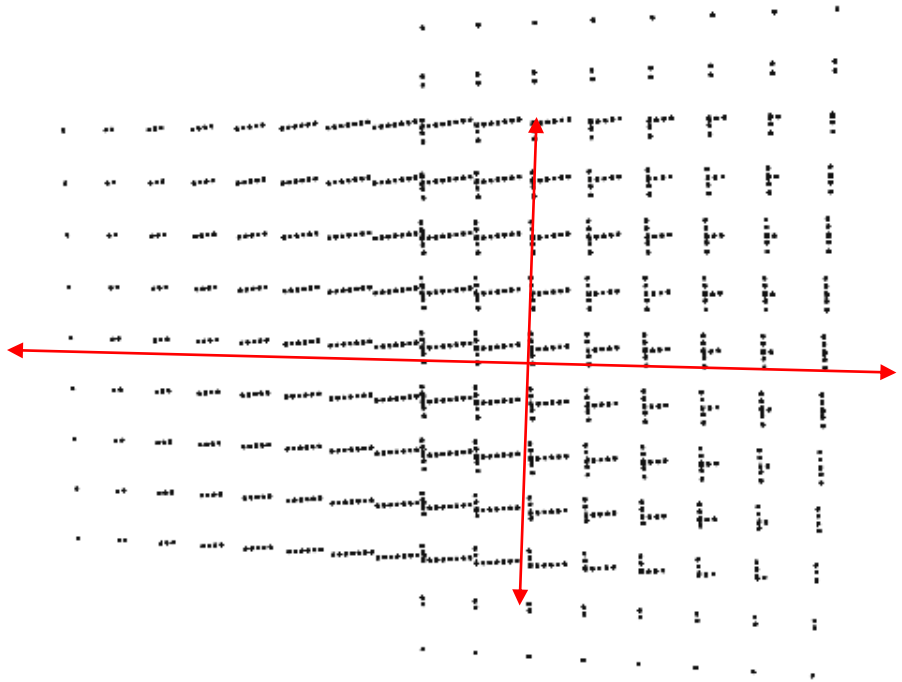
One Checkerboard Corner Movement



All Checkerboard Corners Movement



All Checkerboard Corners Movement



Y-Axis

Average difference vector

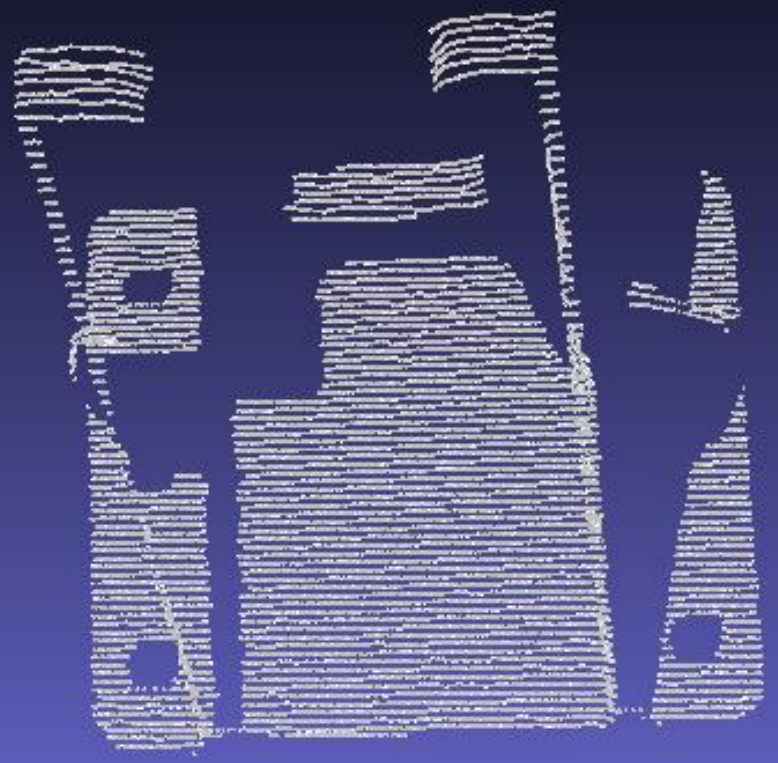
X-Axis

Average difference vector

Y = 11 cm

Y-Axis

Y = 11 cm **Y = 7 cm**



Y-Axis

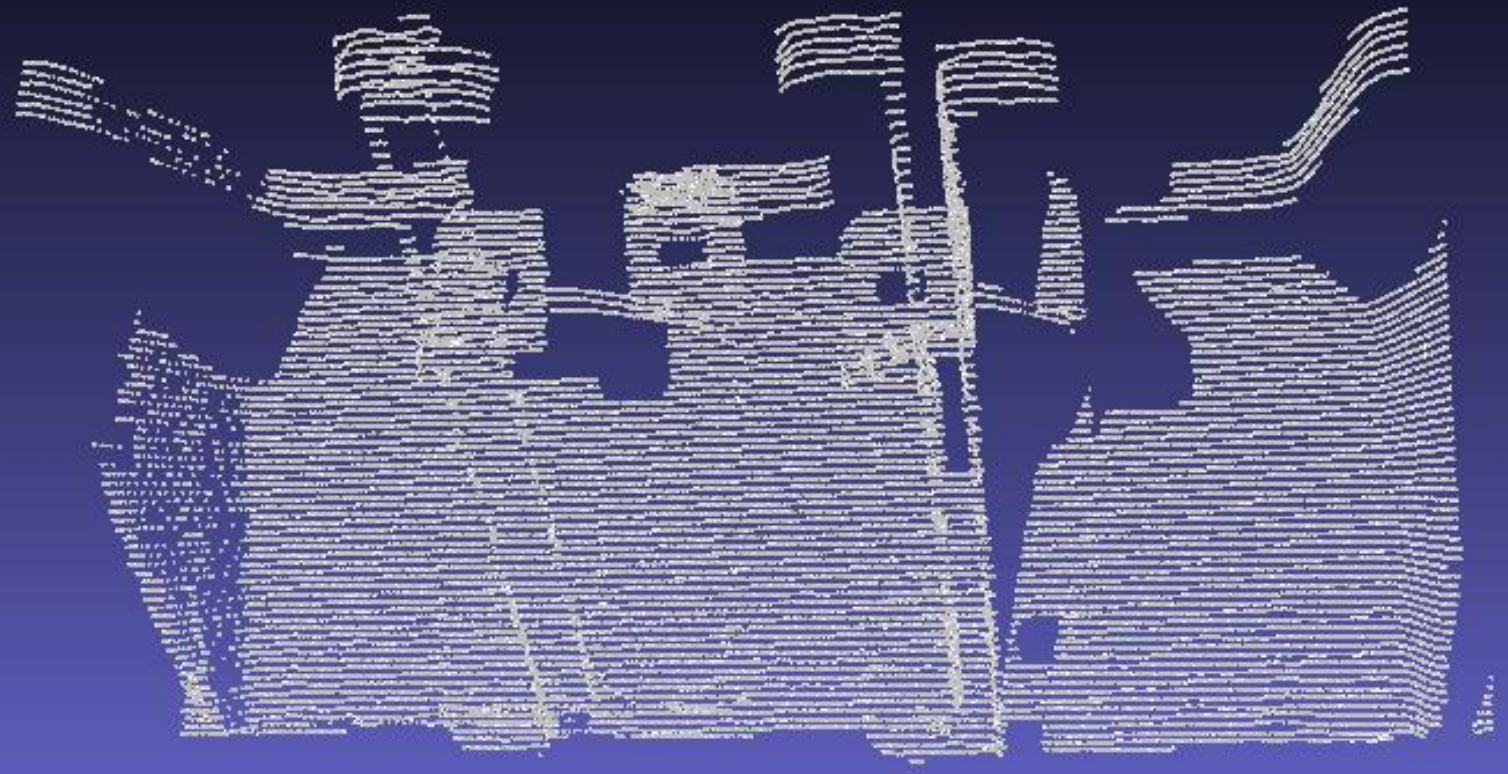
Y = 11 cm

Y = 7 cm

Y = 2 cm

Y-Axis

Y = 11 cm **Y = 7 cm** **Y = 2 cm**



Y-Axis

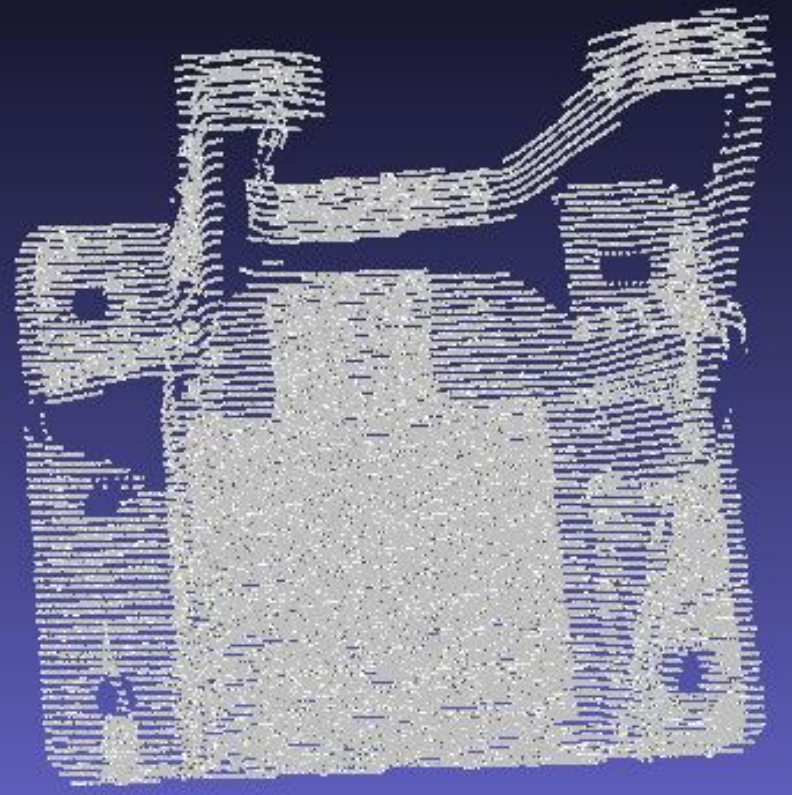
Move them along Y axis to zero

Y = 11 cm

Y = 7 cm

Y = 2 cm

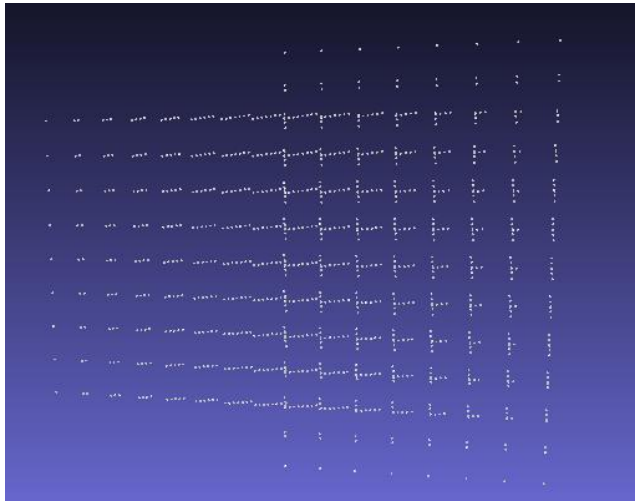
Y = 0 cm



Y-Axis

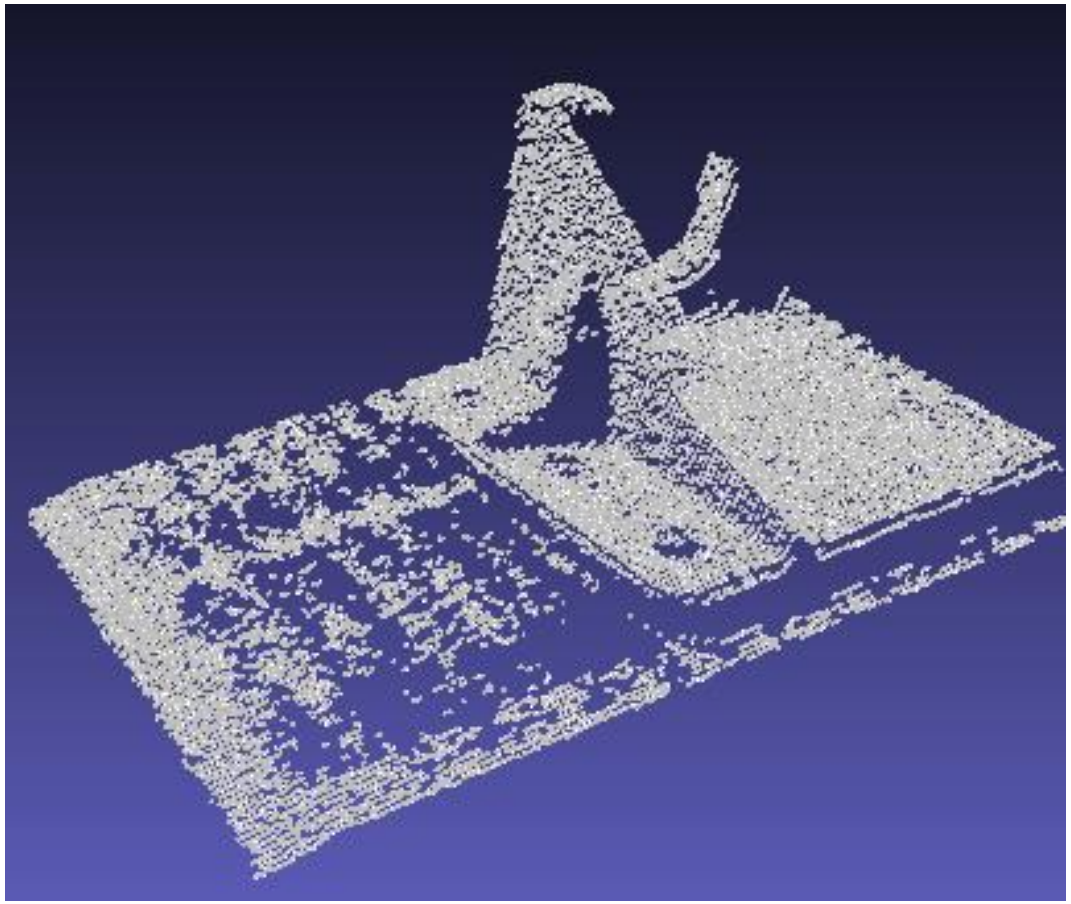
Clipping out of range noise

- Use the checkerboard corners movement to estimate the **printer bed plane**.



- Calculate the distance between each output 3d point and the printer bed plane.
- Remove any result point that’s on or below the bed (distance <0.1)
- Remove any result point with distance higher than the object height (distance > h).

Clipping out of range noise

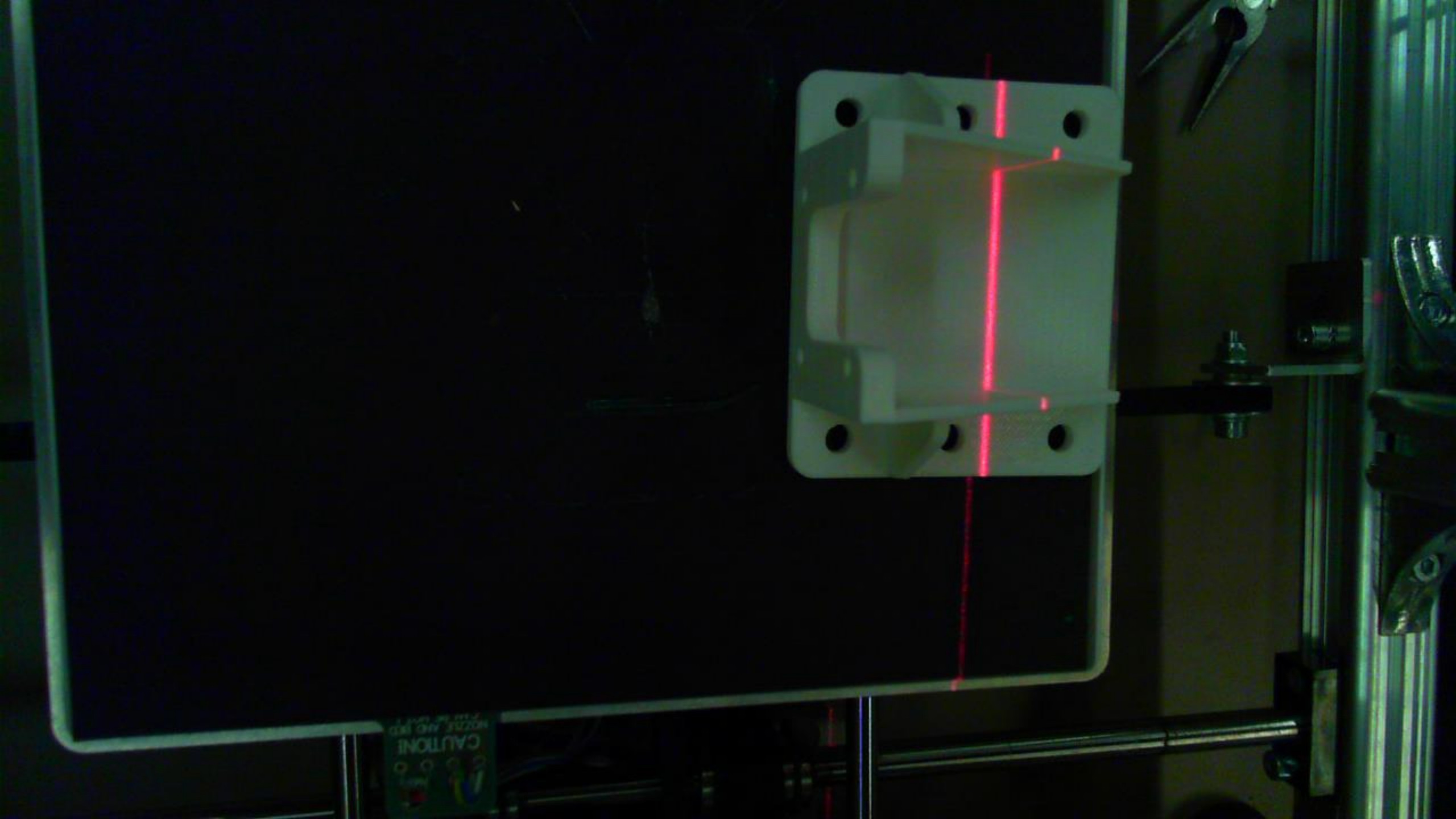


Cleaner result

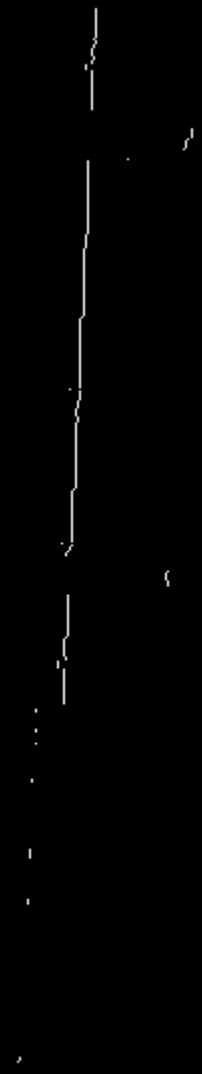
Laser Detection

Laser Detection Problem

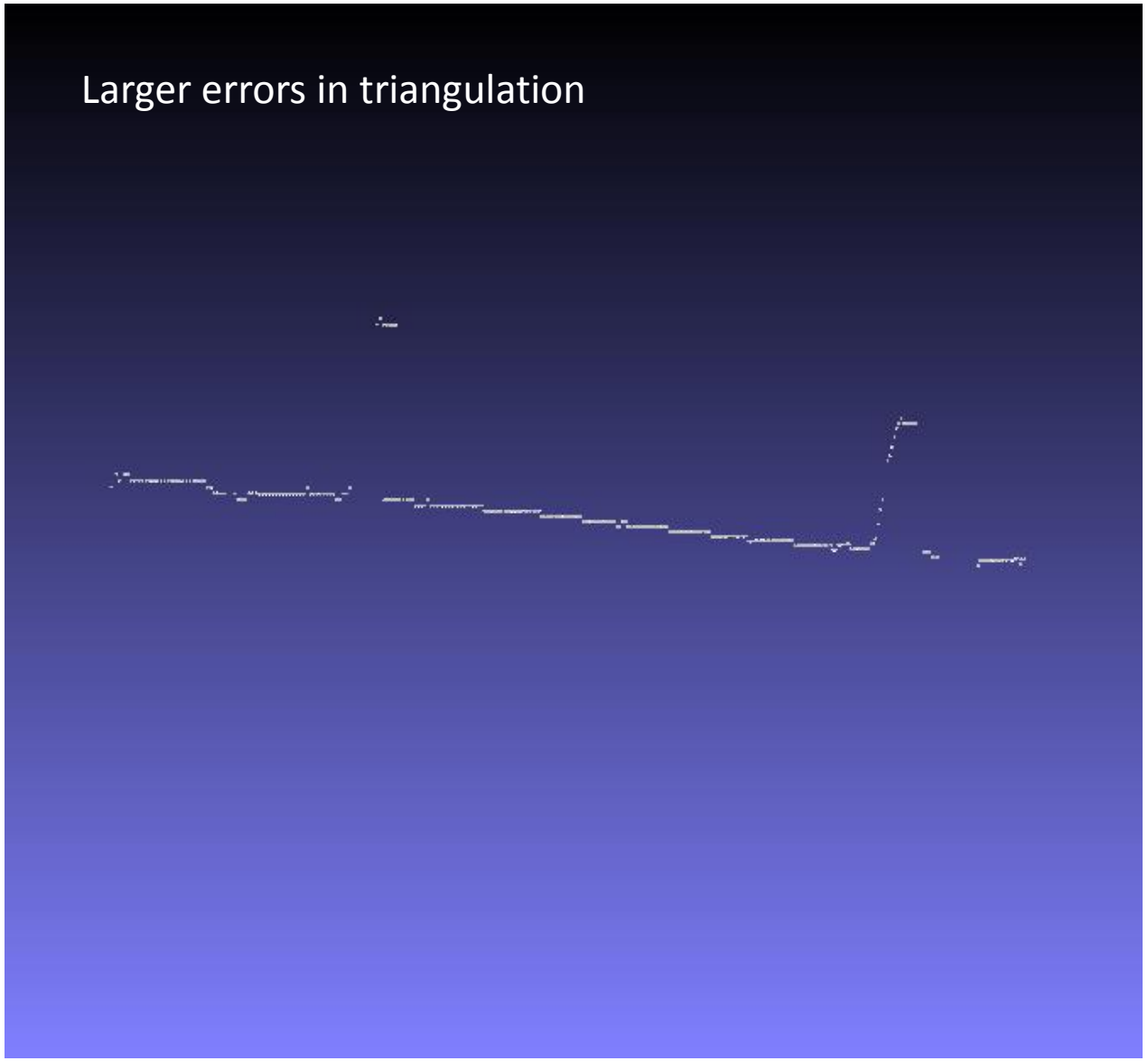
- Result depends a lot on a **good laser detection**.
- But the laser light depends a lot on the object color and **image brightness**.


CAUTION!

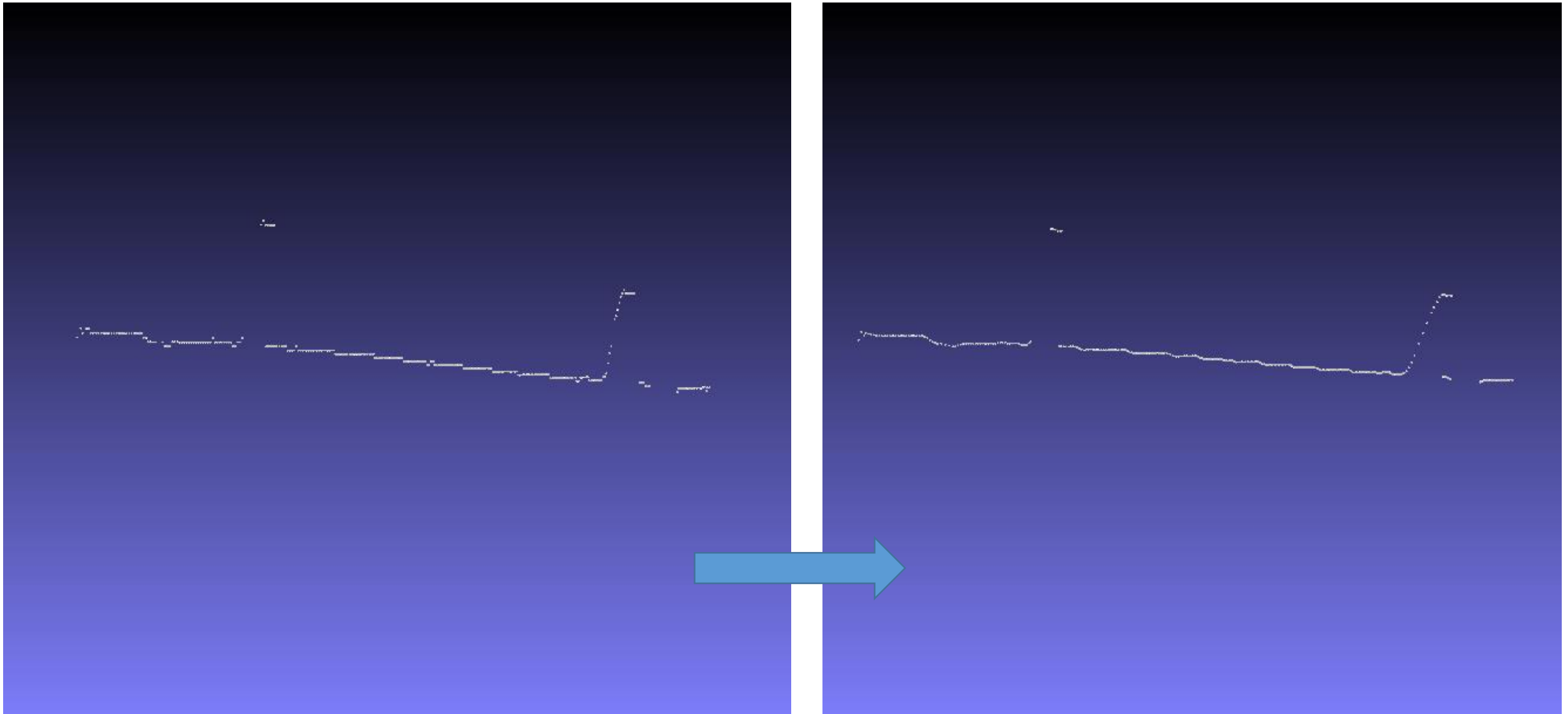
Detecting the maximum



Larger errors in triangulation



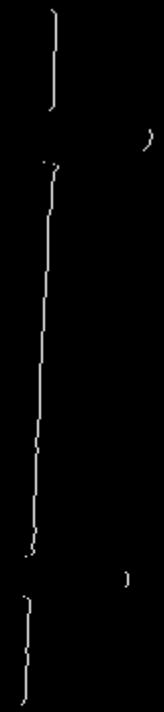
Smoothing in 3D (each line independently)



The **Middle Point**

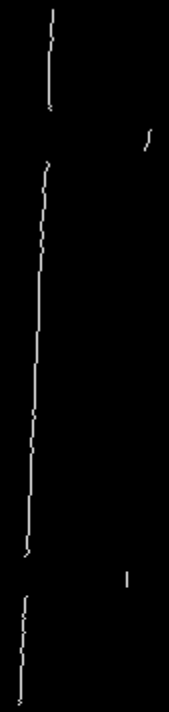
Instead of the maximum, I tried to find the **middle point**
Of the laser strip along each row.

Right

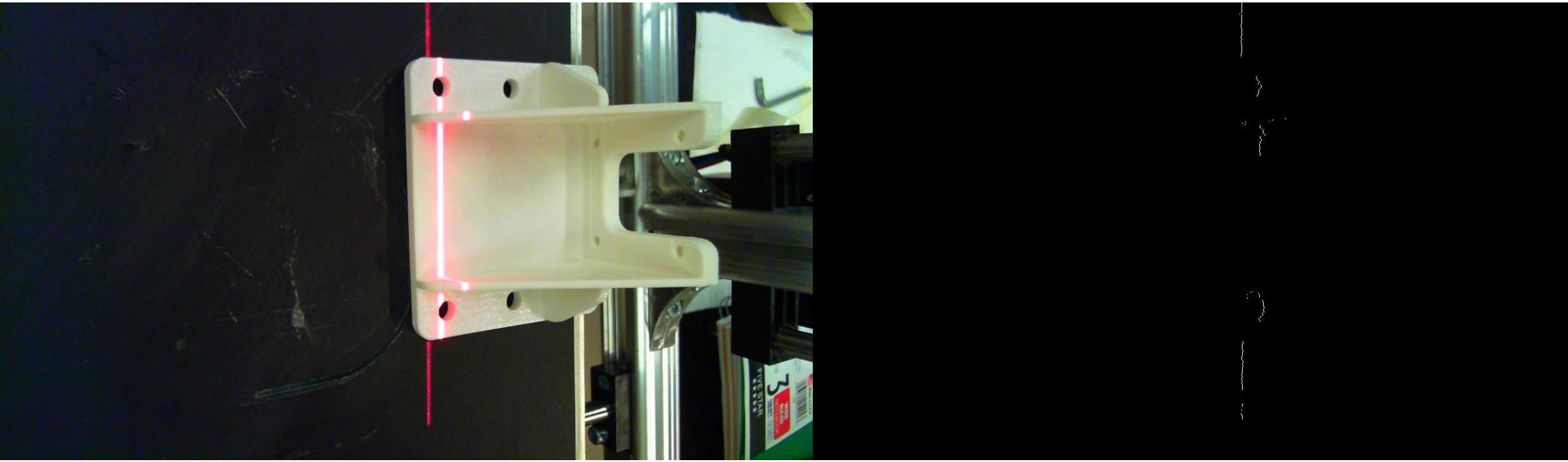


Left

Middle

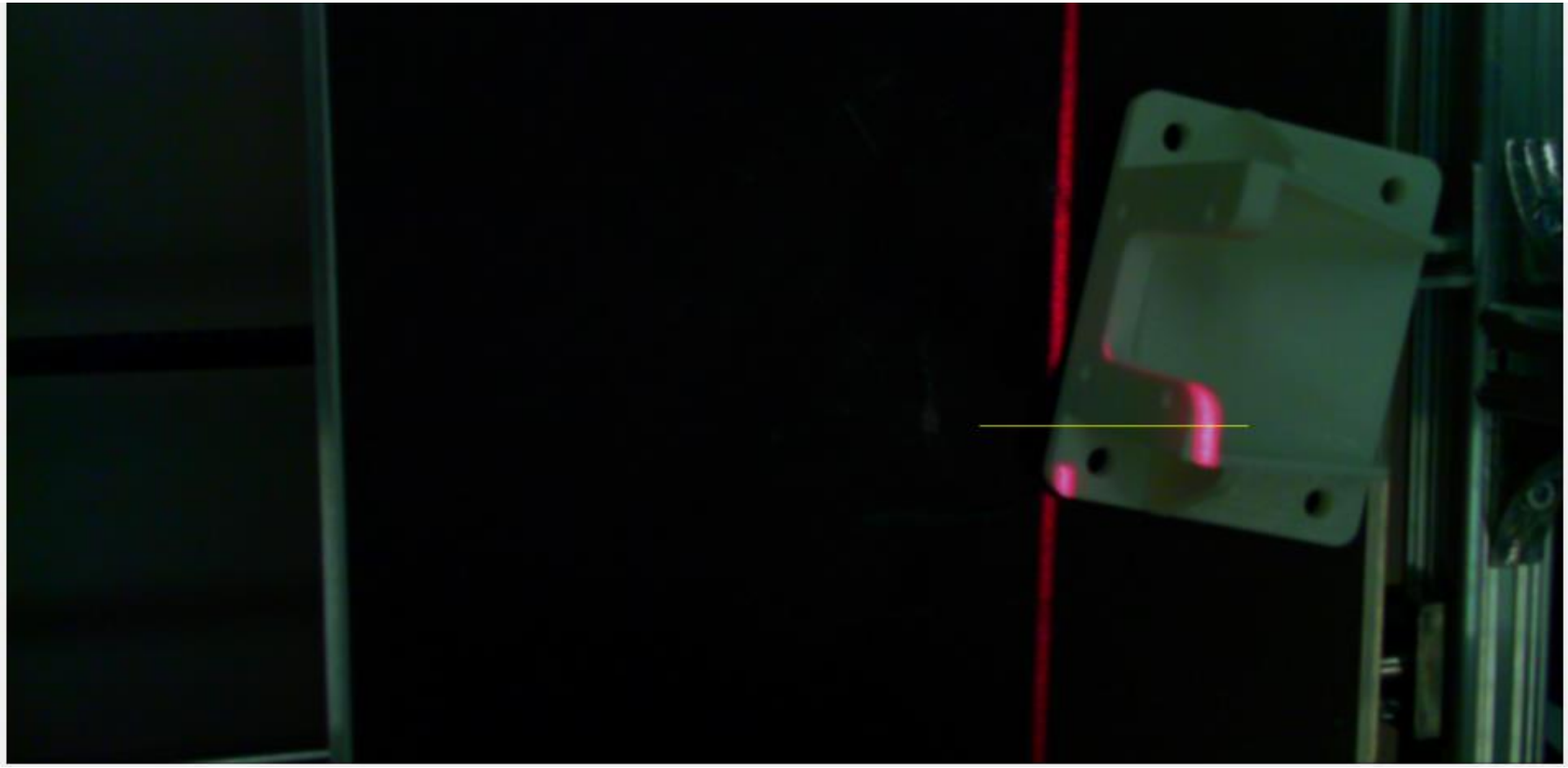


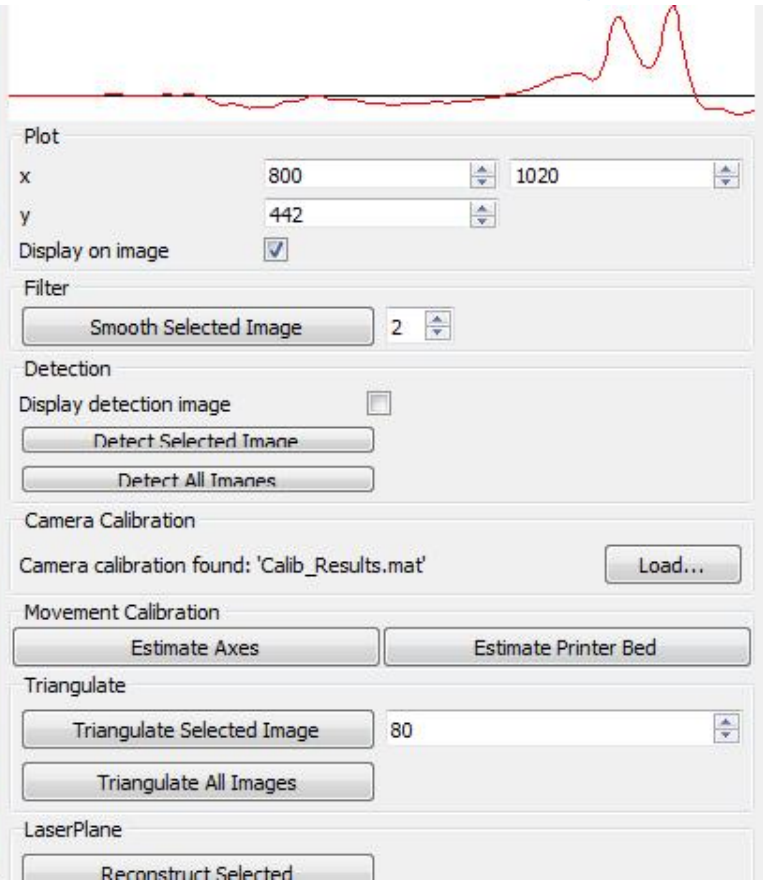
Saturation Problem: Too white!



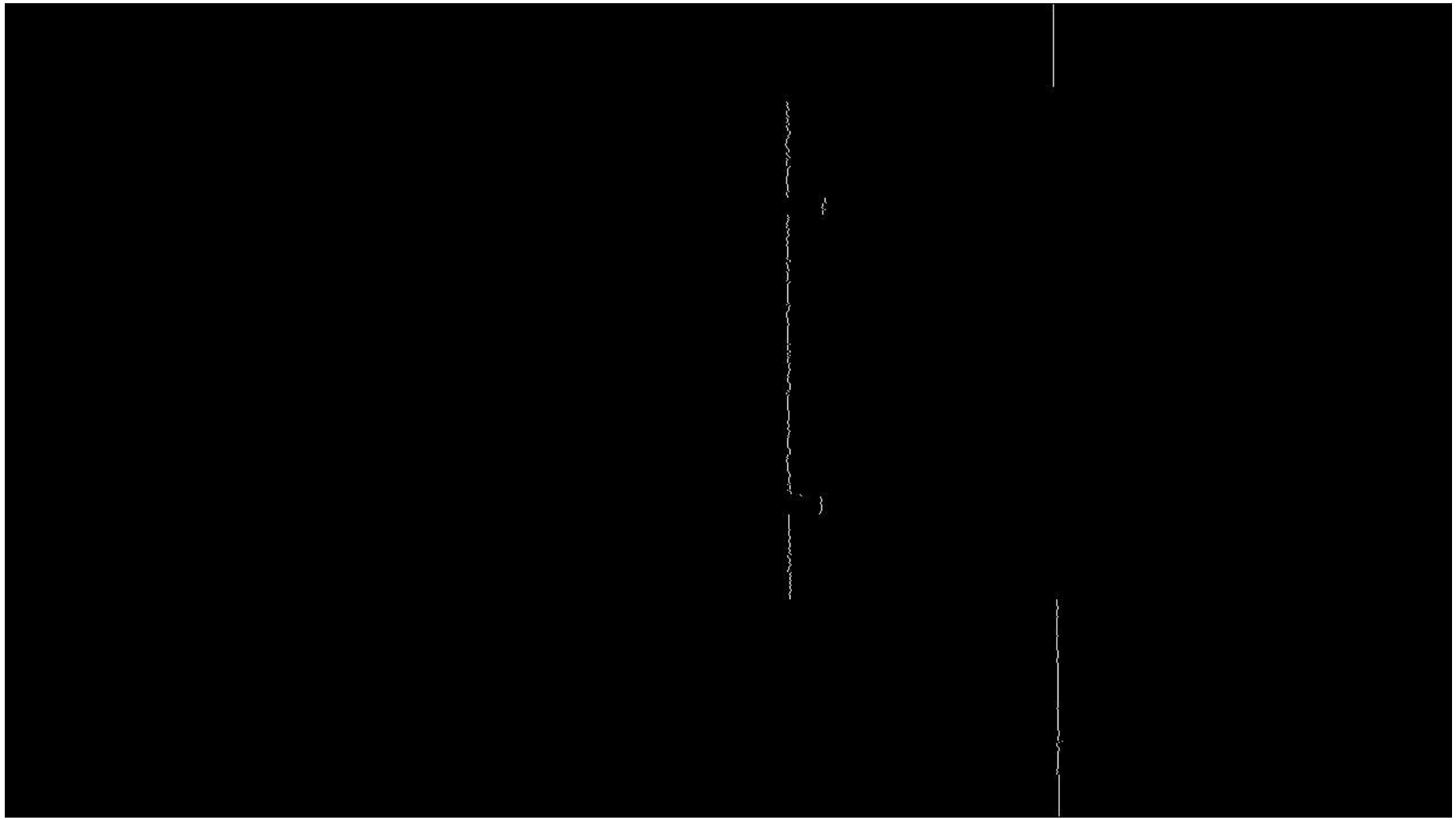
Saturation Problem

Two peaks !!

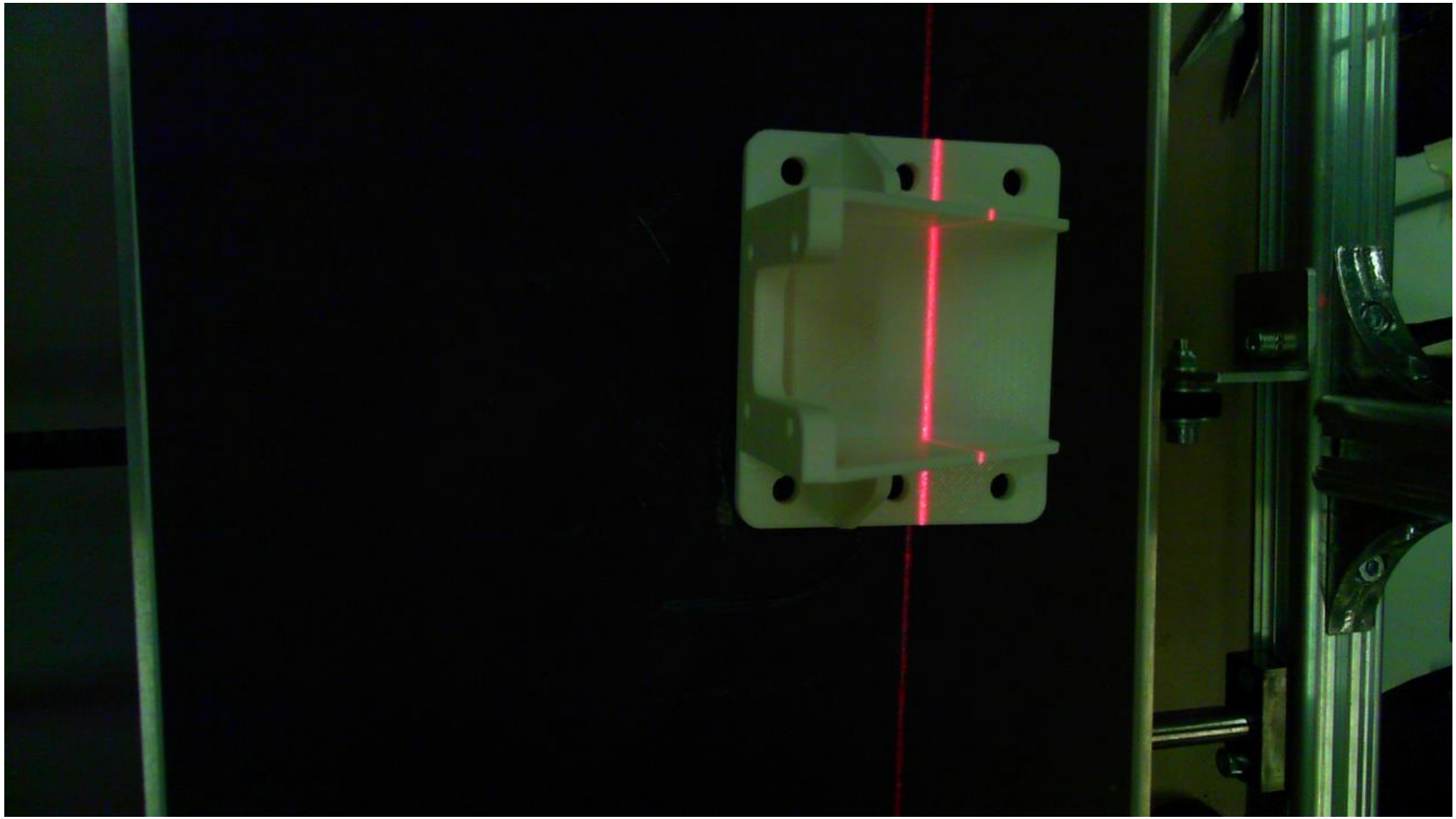




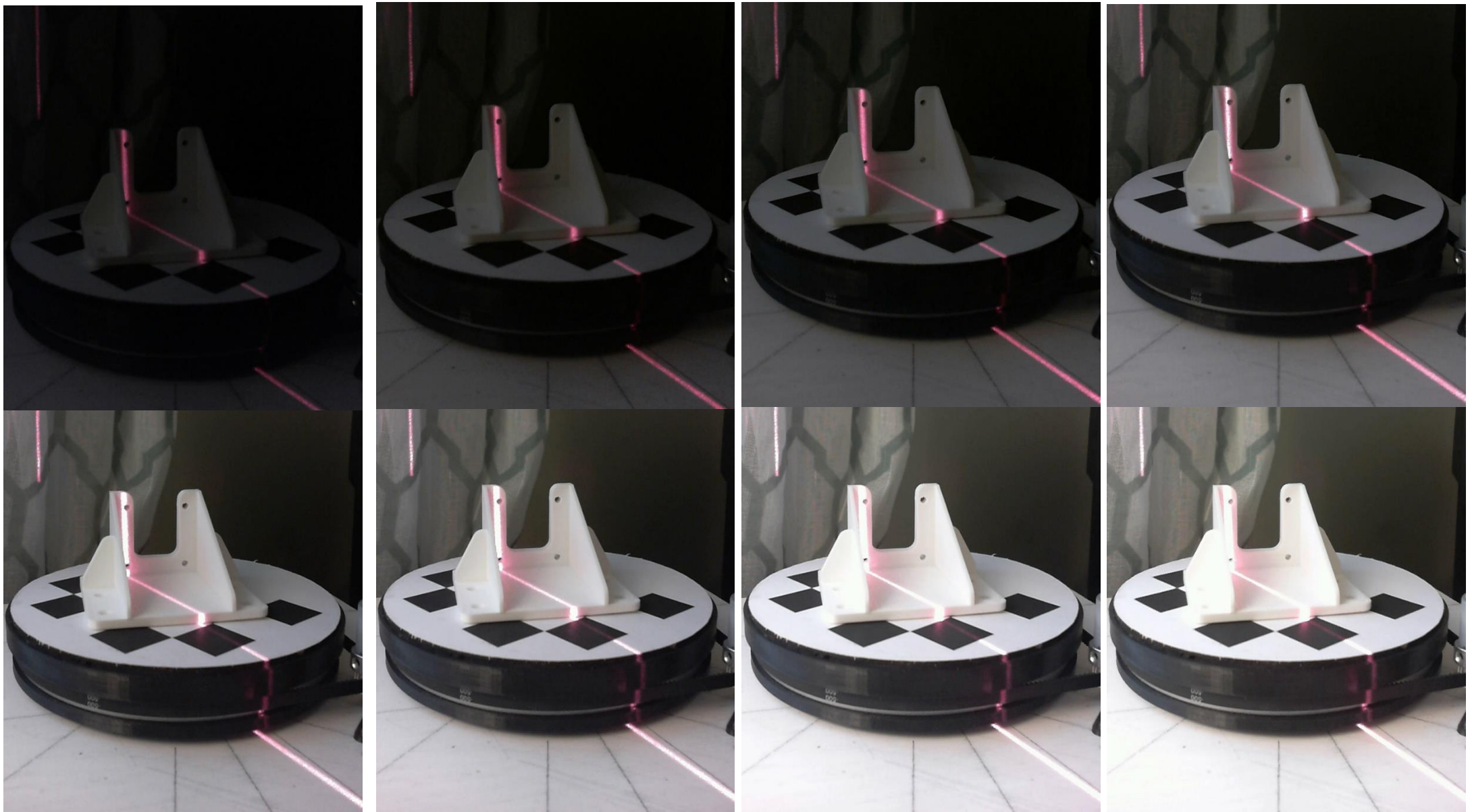
Solution 1: Detect White



Solution 2: Darker Images



Solution 3: Capture Multiple Exposures



Solution 3: Capture Multiple Exposures

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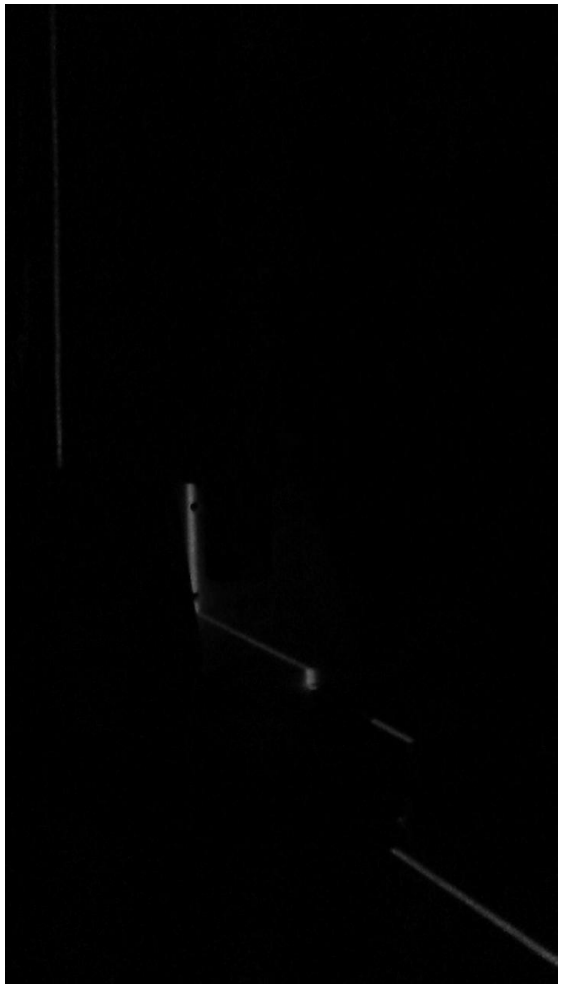
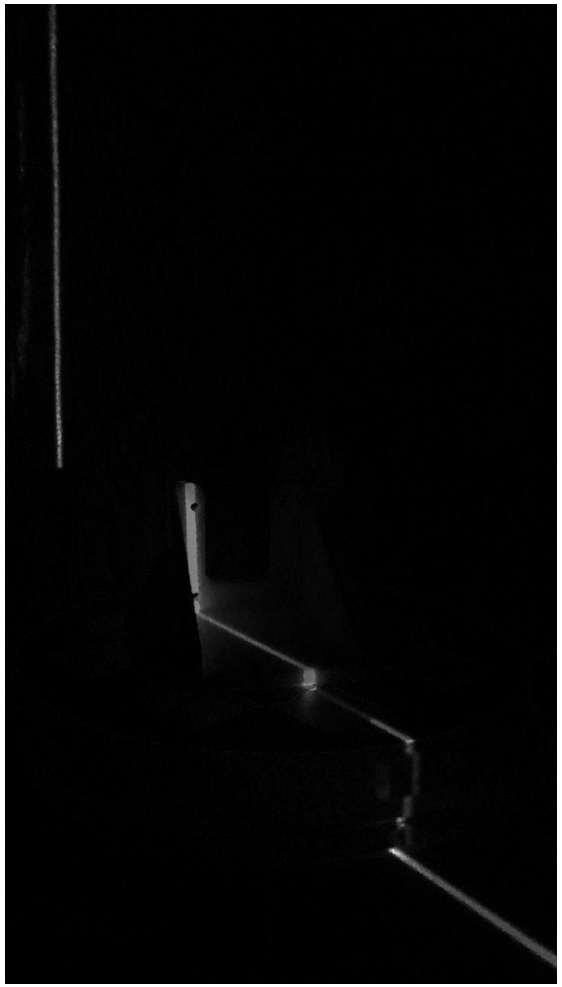
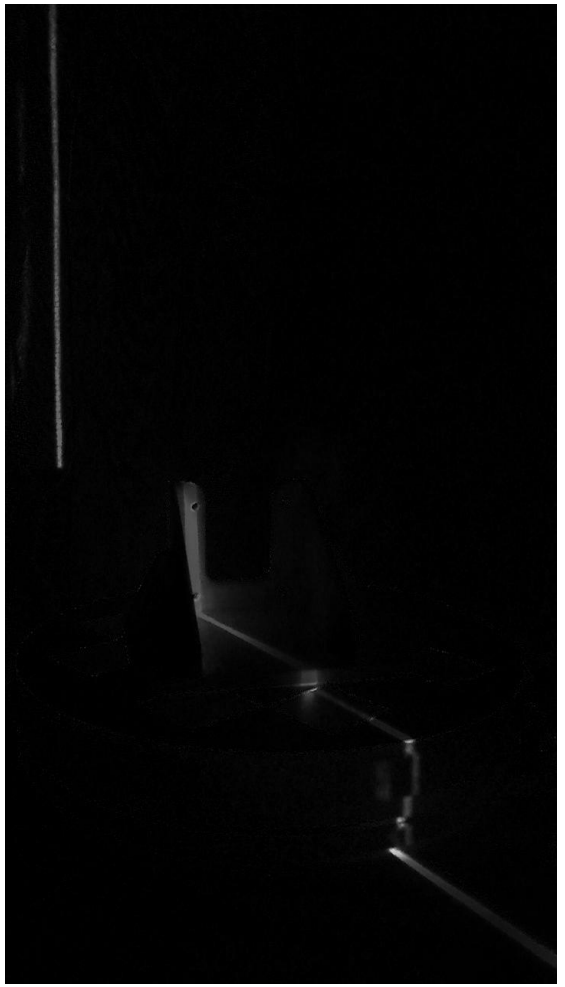
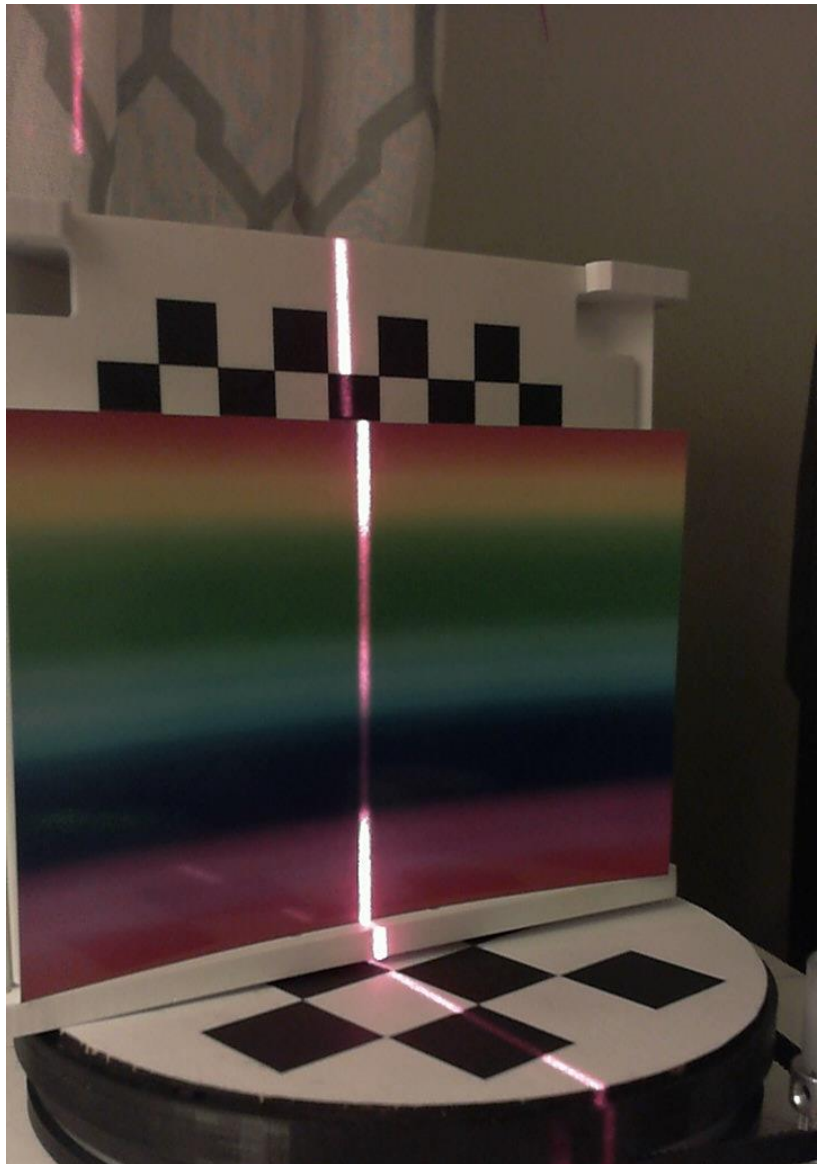




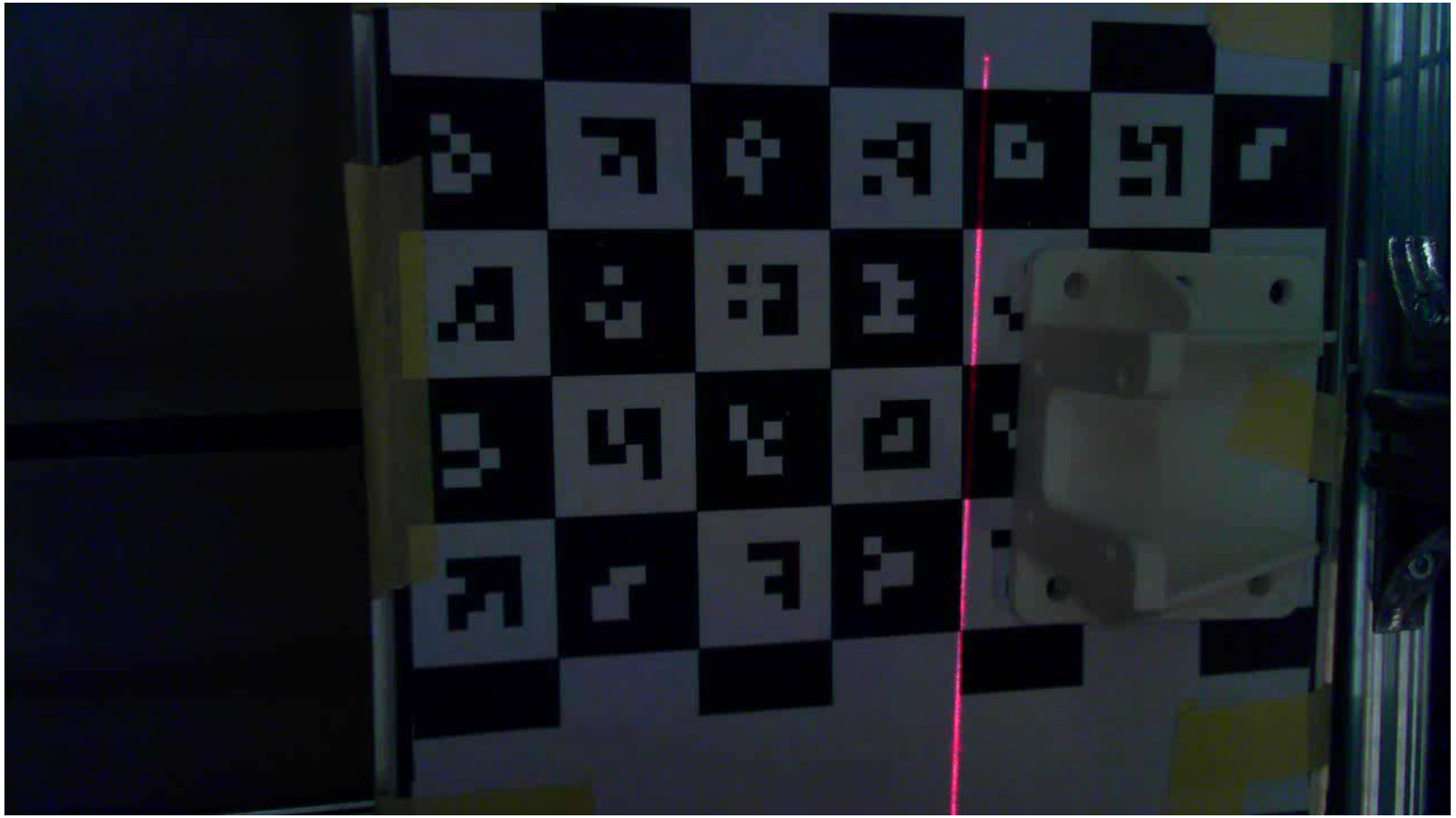


Solution 3: Capture Multiple Exposures

Try all colors !



Continuous Scanning using CALTag board

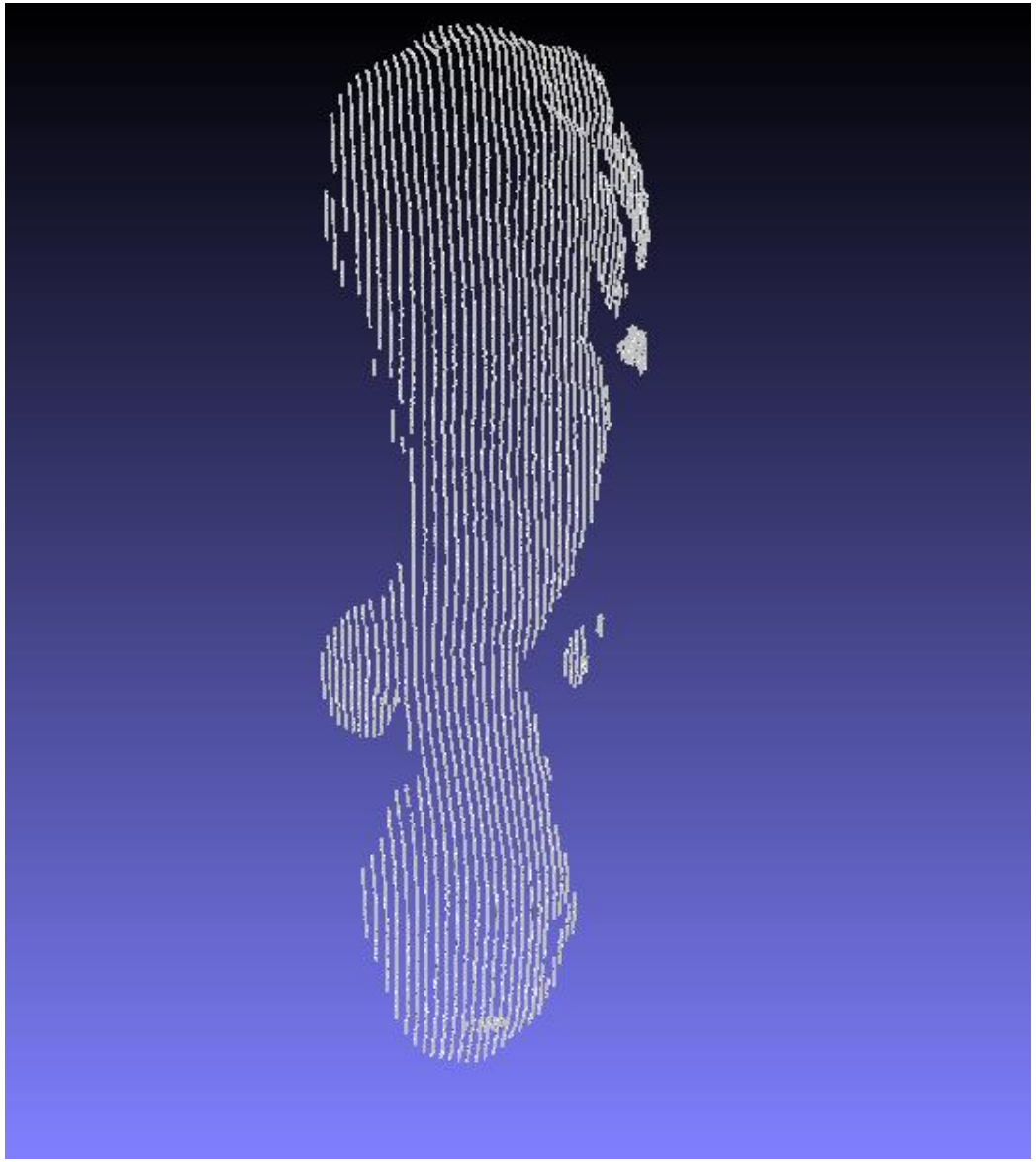


Benefits and Limitations

- **Reduced Cost**: get benefit of the printer mechanical structure for movement and calibration.

Benefits and Limitations

- Uniform sampling along X and Y directions (Compared to turn -table)

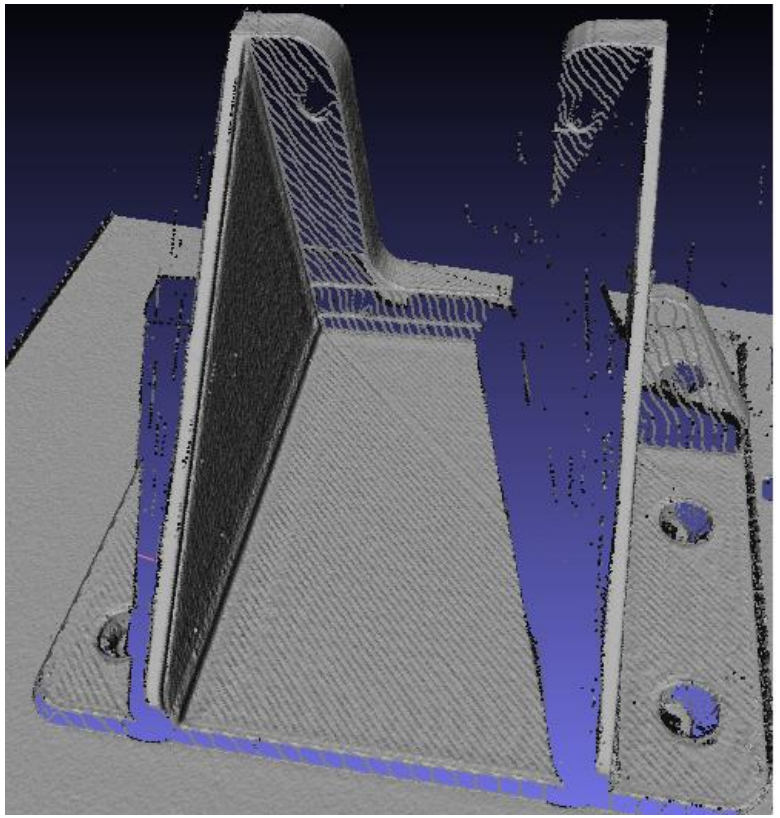


Benefits and Limitations

- But the turn-table scanner is better for objects with round shape!

Benefits and Limitations

- Needs more images and produces less details compared to “Structured Light” scanners



Other Benefits

- Printing on **existing objects**
- **Continue printing**
- Real time **feedback** as in eyes
- **Quality** assurance of 3D printed parts
- **Quality** assurance of the 3D printer movement
- Modify the object directly while it’s on the **same bed**