Lidar improvement

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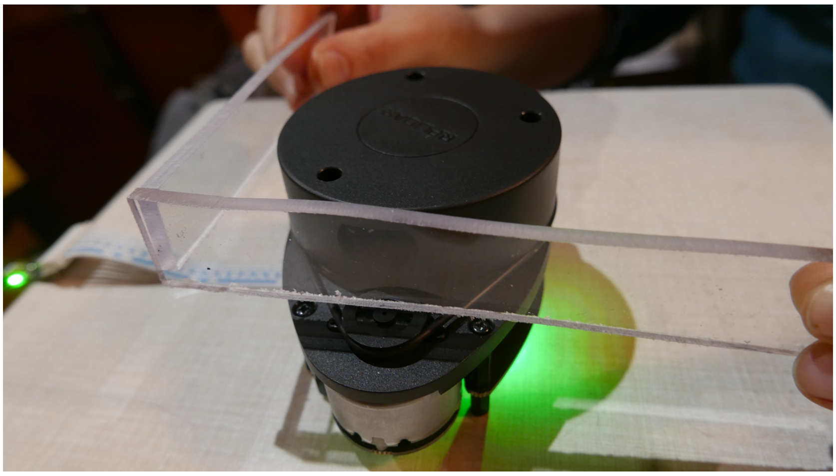
Overview:

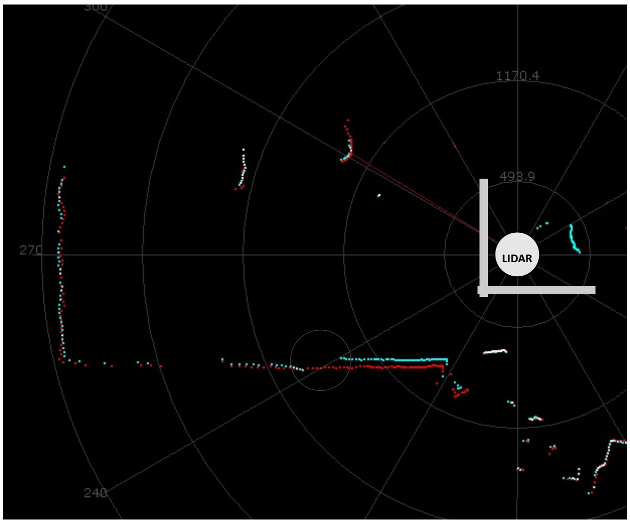
Preparing to construct the housing for the lidar module, I decided to check what window shape would be the best. During the first tests, it turned out that the lidar optical system is very sensitive to distortions caused by the optical properties of the shape and material of which the windows are made.
Tests have shown that windows made of straight sections of organic glass cause only local, but significant distortions. A window made of a pipe gives a very high distortion, the greater the farther away the scanned surface is. These distortions in the case of a pipe are also dependent on the wall thickness and distance from the optical system. The thicker the wall and the closer to the optics, the greater the distortion.

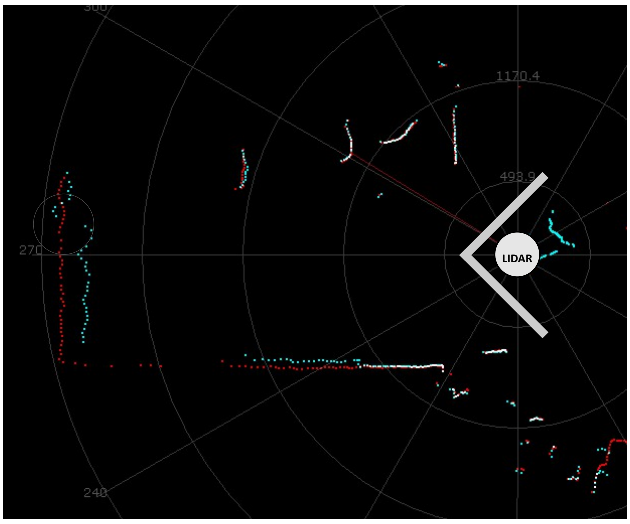
Tests of the original lidar design

A. 4 mm thickness flat acrylic glass, about 20 mm distance between lidar and glass:



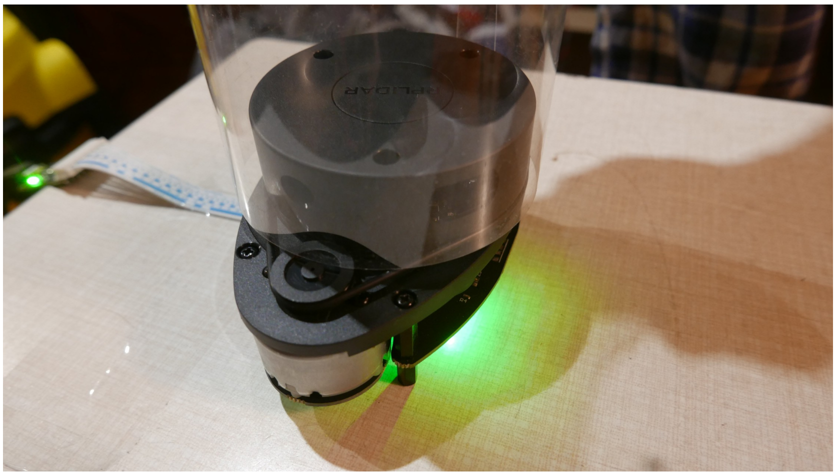
Test conditions



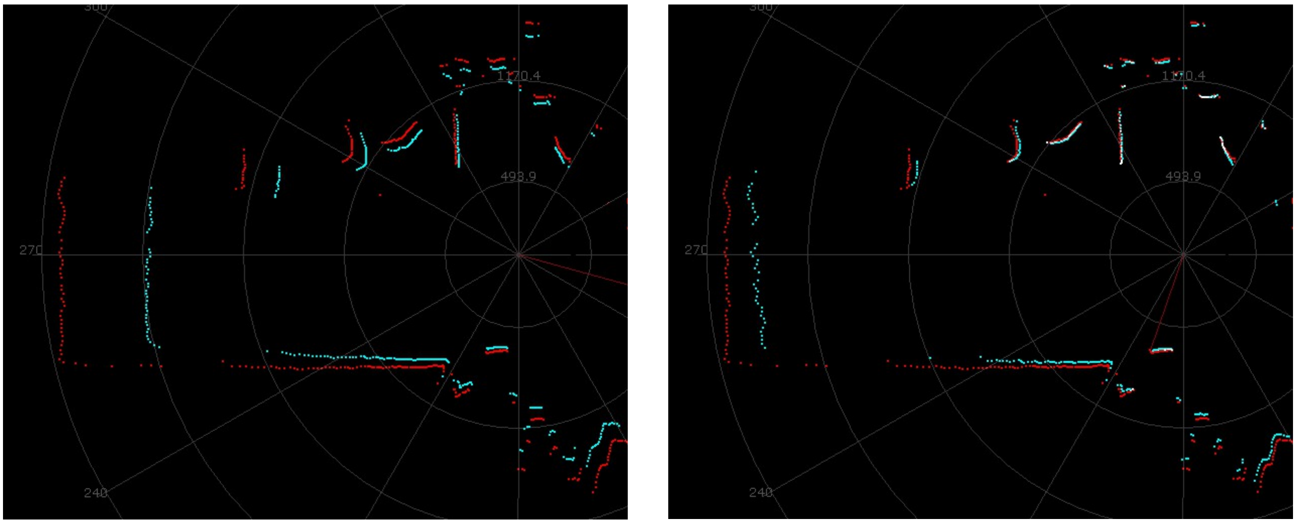


Scans. Blue dots: current state; red dots: reference image without distortion.
Grey lines shows window position.
A dark gray circle shows the location of the largest distortions.

B. Tube made of 0.2 mm thickness high surface quality polypropylene film.

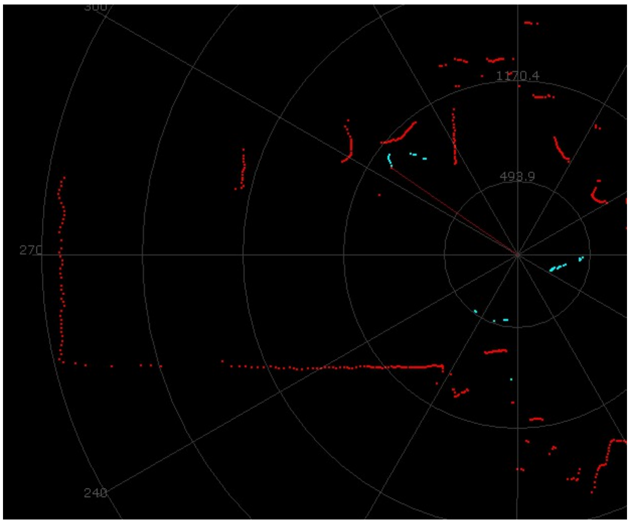


Test conditions



Scans. Blue dots: current state; red dots: reference image without distortion.
Left image: distance between lidar and film about 5 mm
Right image: distance between lidar and film about 20 mm

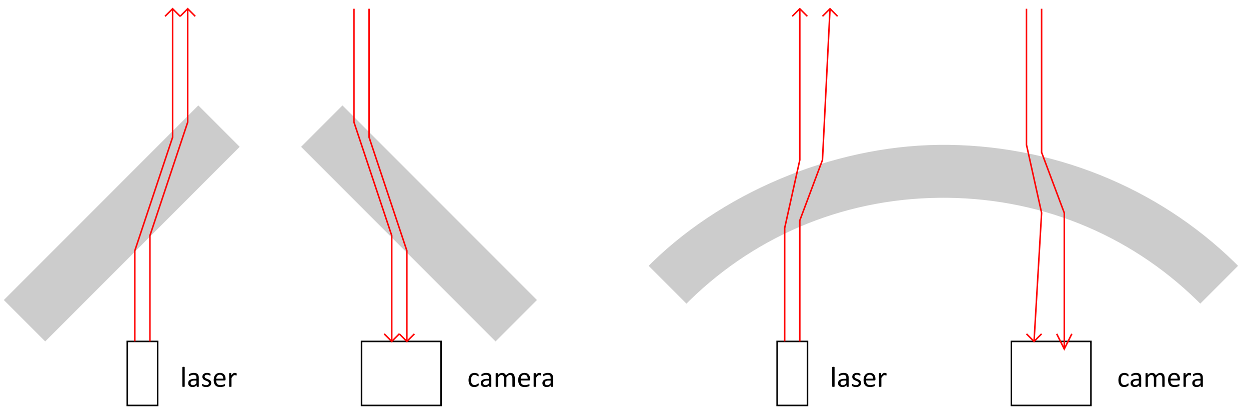
C. 80 mm diametr dummy camera housing



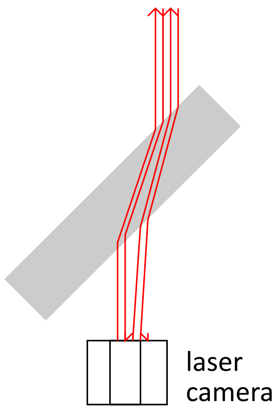
Scan. Blue dots: current state; red dots: reference image without distortion.

Conclusions:

The conducted experiments show that the shape of the lidar optical path is distorted in various ways. It mainly depends on the angle at which the lidar optics are set to the window material. In flat glass, the optical path is mainly shifted. In bent glass, the lens effect, which can almost completely disturb the operation of lidar, has the greatest impact. Most of these distortions are affected by the fact that the laser and camera work at different angles to the window material. Some solution to the problem could be reworking the lidar so that the laser and camera work in one axis. Then the laser and camera shifts should be the same. The conducted experiments and problem analysis show that a window from a tube (bent glass) will work worse than from straight glass sections.



Simplified optical model of different shapes of window
Left: flat glass. Right: bended glass (acts as a lens).

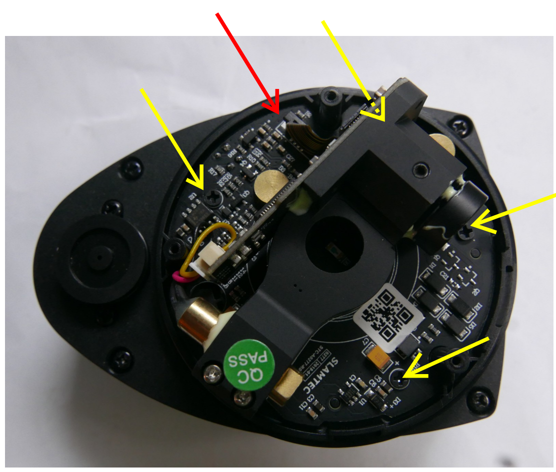


Proposed modification of lidar, in which the laser and camera will work in the same axis.

Modification of the lidar module:

A.

- Remove drive belt
- Remove top cover.
- Disconnect the connecting tape from pcb pulling the brown lock out of the connector (red arrow)
- Unscrew 4 screws (yellow arrows):



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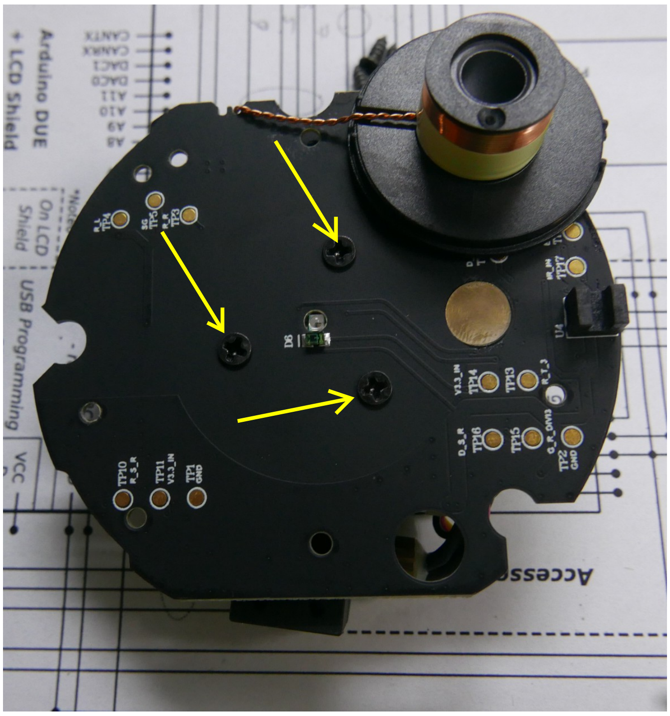
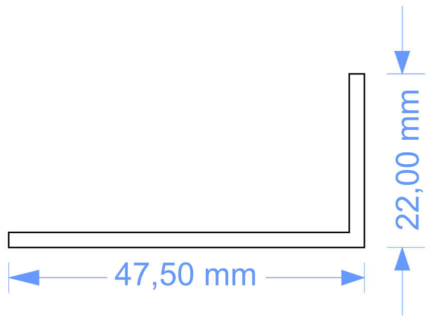
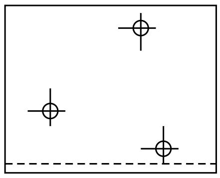


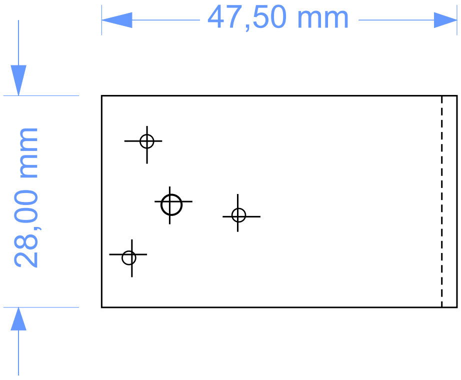
C.

- Prepare a new fastening element for lidar optics. Use an aluminum angle 2 mm thick.



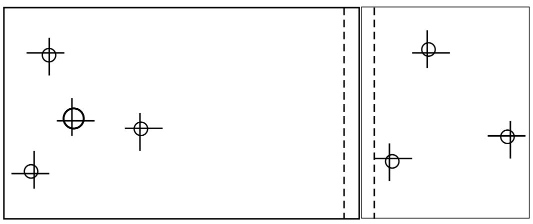


holes:
1.5 mm dia and thread M2
(metric!) for original screws
or 2 - 2.2 mm for screws with nut



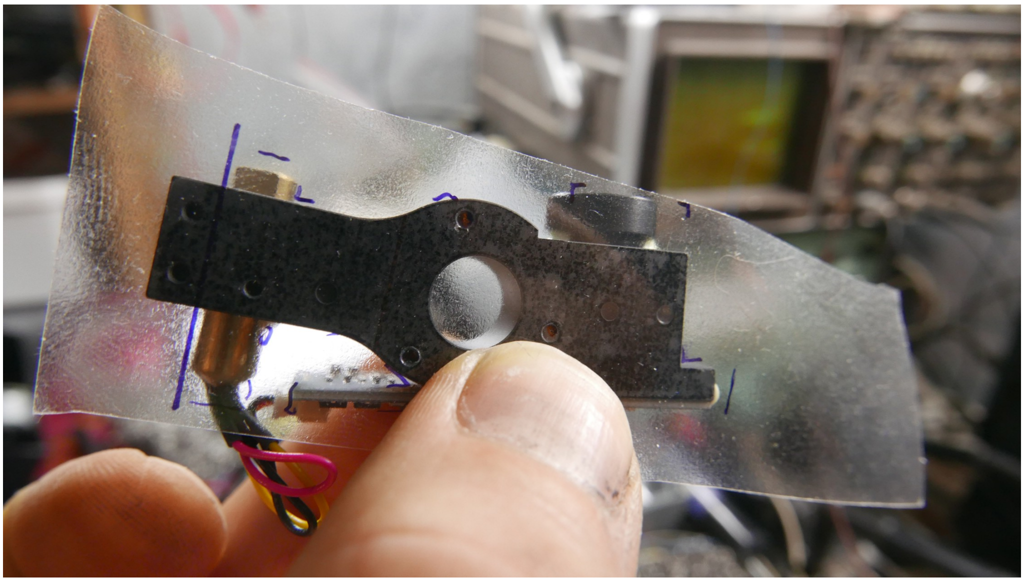
holes:
Outside: 2 - 2.2 mm.

Center: 3 mm

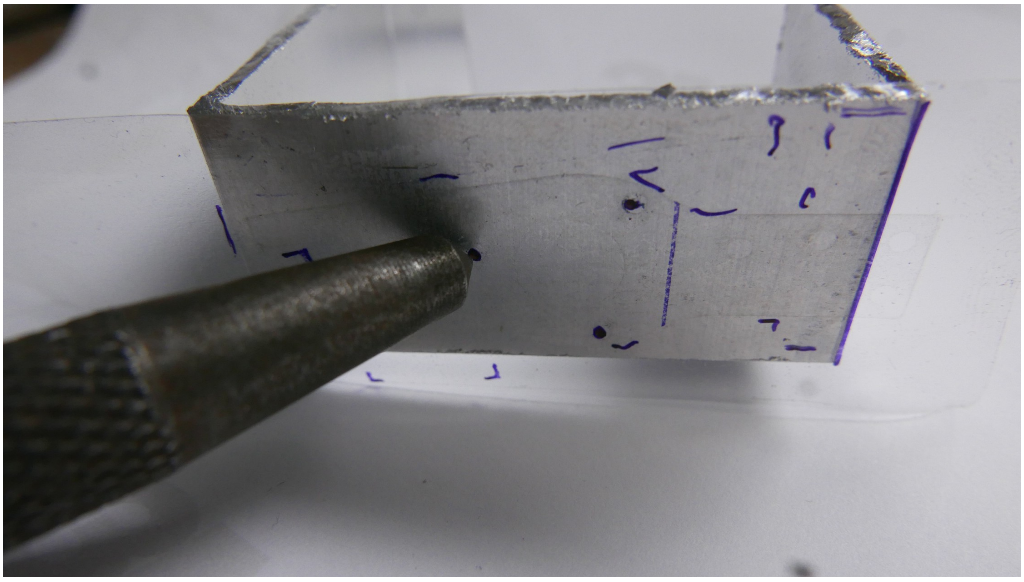


expanded drawing (1:1)

You can draw holes with a transparent adhesive tape. You can also print an unfolded drawing, stick it on aluminum and punch the holes with a center punch

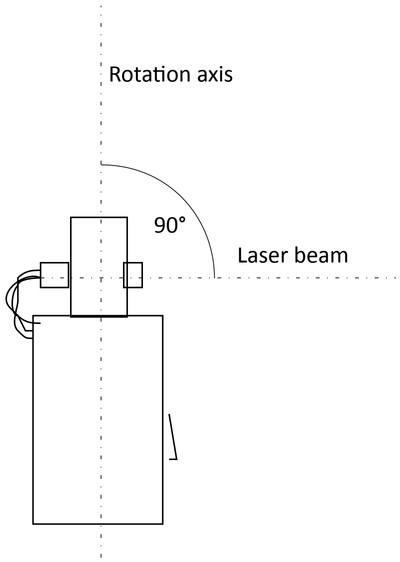


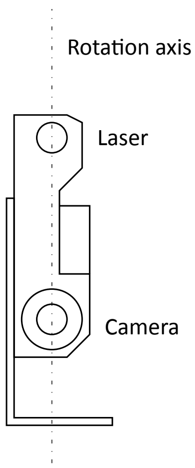
Trace the location of the holes

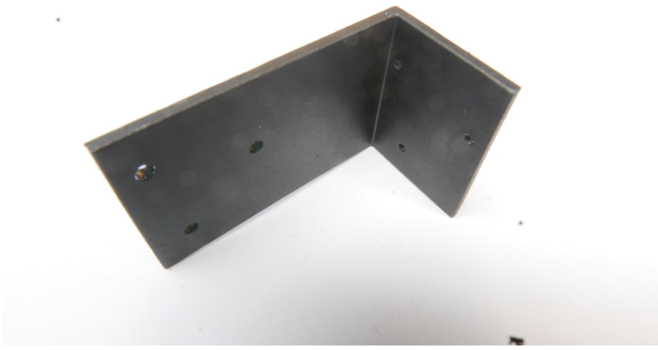


Move the holes to aluminum with a punch.

Attention.
The laser beam must be at right angles to the axis of rotation!
The axis of rotation must pass through the laser axis!







Ready element (without center hole)

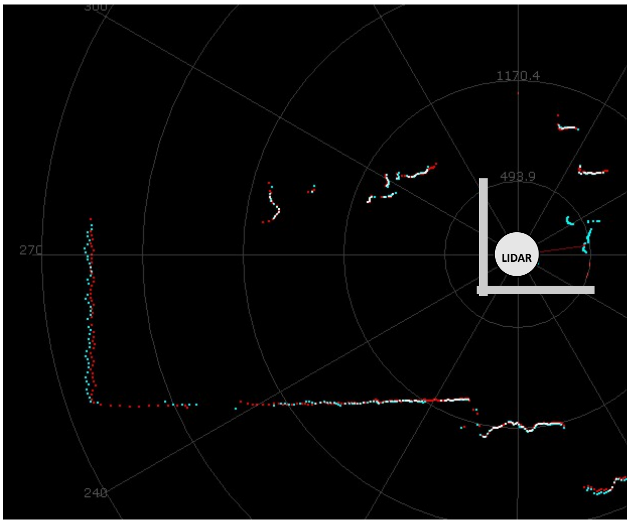
D.
- Mount M3/30 screw to the center hole using one nut.
- Mount element to the PCB using original screws (don't forget about the washers) using original screws or use M2/8 countersunk head screws with M2 nuts.
- Mount the optics to the bracket using M2/5 screws.
- Connect the tape to the connector.
- Install the drive belt.

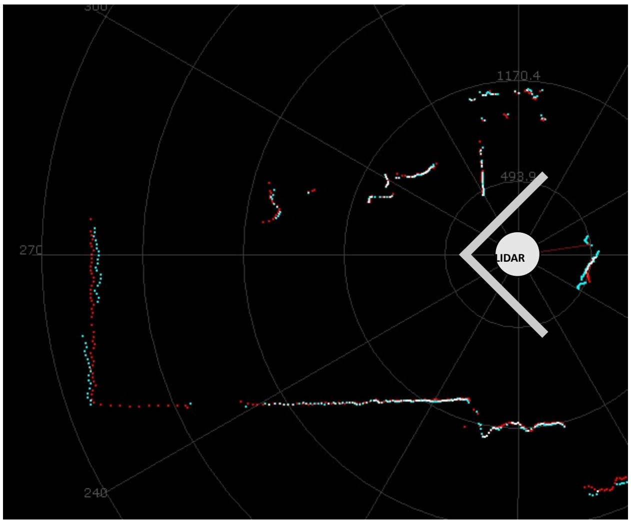
Ready module with balancing weights

E. Balancing:
Theoretically, the module is ready for work. But with a 5V motor voltage, its vibration will be noticeable and may make measurements difficult, especially on the long scanning distances. So it would be good to balance the rotating part. And this should be dynamic balancing!
I did it with two elements. In front of the camera lens, I put a M5 brass nut (can be steel) on the cover mounting post. The nut is fastened by an unnecessary cover screw through a 3 mm washer. The second element is a little more complicated. I used a brass roller with a diameter of 12 mm, which is 8 mm long and has a M3 thread inside. But you can try in a different way. For example, replace the M3/30 screw with the M4/40 screw and use several widened washers as ballast. You can also try fishing rod weights. They are small and in different shapes.
If you do not have access to special equipment, the balancing process should be carried out by trial and error. Check the vibrations after each change to the settings. It will help hang the lidar module on a string. The axis of rotation must be vertical.

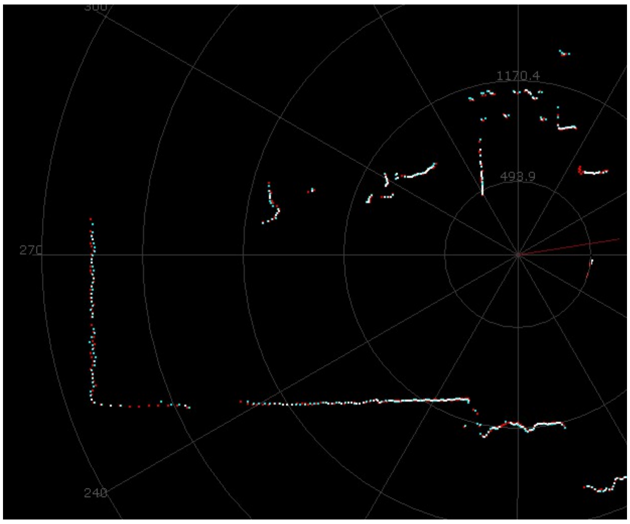
Results:

A. 4 mm thickness acrylic glass, about 20 mm distance between lidar and glass:

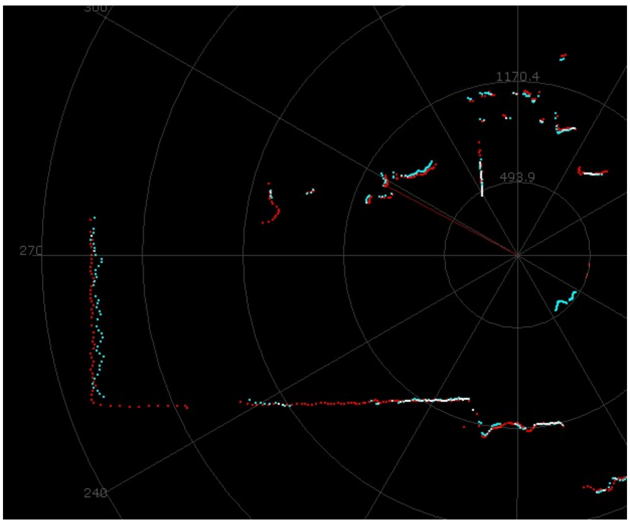




B. Tube made of 0.2 mm thickness high surface quality polypropylene film, distance between lidar and film about 5 mm



C. 60 mm diamter acryl tube, 3 mm thickness.



material	maximum error before update	maximum error after update
4 mm thickness flat acrylic glass with 90° corners	19%	3%
Tube made of 0.2 mm PP film, 5 mm distance between film and lidar	19%	< 1%
80 mm diametr dummy camera housing	no reading	
60 mm diamter acryl tube, 3 mm thickness		4%

Table comparing the maximum measurement error between lidar without window and with window.