# CE30-A Solid State LiDAR

# Operation Manual

www.benewake.com
Benewake (Beijing) Co., Ltd.

## Product

Product model: CE30-A

Product name: Solid-state LiDAR

### Manufacture

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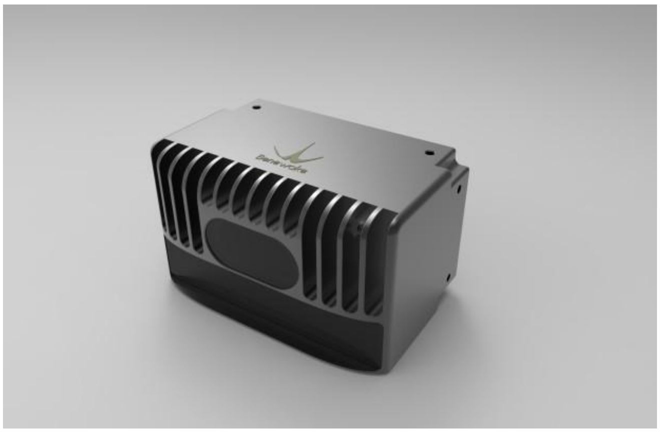
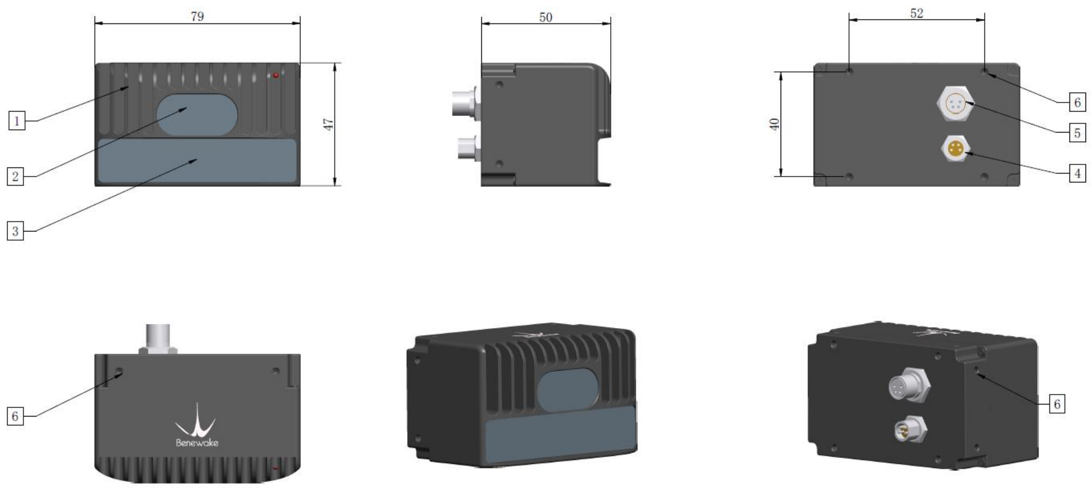
# 1 CE30 Introduction



CE30 is an IR DE-LiDAR developed on the basis of ToF principle. With the optimized obstacle avoidance mode, the detecting region of interest can be set up. The single-point projection distance of the nearest obstacle can be transferred through CANBUS. Compared with single-channel scanning LiDARs, CE30 does not contain any rotating components. The reliability of long-time work and a wider vertical detection range can be ensured.

Product Properties

- Complete solid-state LiDAR
- 3D environment detection
- Horizontal field of view: > 120°; vertical field of view: 9°
- Set region of interest in the obstacle avoidance mode
- Calculate the nearest point and output with CANBUS




1. Shell
2. Receiving panel (working area, no coving)
3. Sending panel (working area, no coving)
4. Power supply/CANBUS (M8 aerial socket)
5. Ethernet port (M8 aerial socket)
6. Equipment installing hole (M3)

*Fig. 1 Outline of DELIADAR CE30*

# 2 Indicator Instruction

1) Blue light: ready state, ready for connection and running
2) Blue flash: running state
3) Red flash: missing of relevant running files
4) Red light: fatal error (abnormal signal, abnormal interface communication, abnormal I2C, etc.)
5) If the red light and the blue light are on at the same time, the indicator turns to be purple.

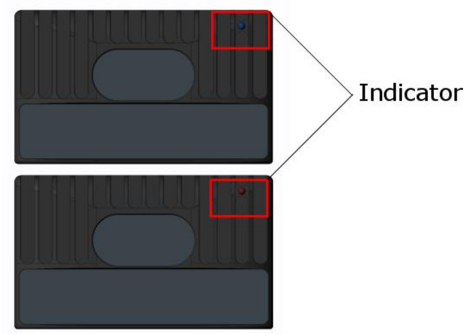



*Fig. 2 Indicator Drawing*

# 3 Software Operation Instruction

1) Connect all the accessories in accordance with Fig. 3 Illustration for Connection of Components.

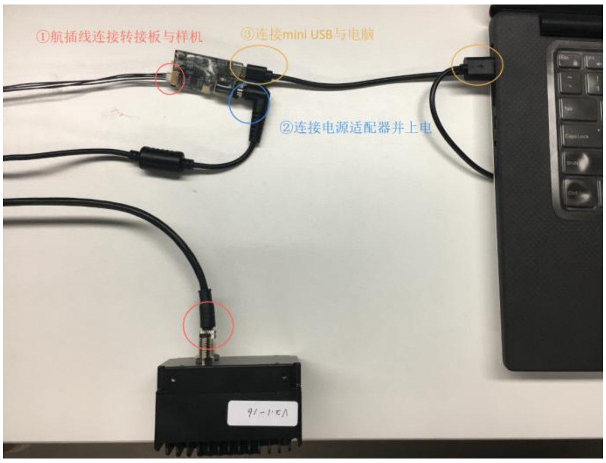



*Fig. 3 Illustration for Connection of Components*

2) Plug into 12V-DC2.5 power. The supply current must be above 2A. Connect the mini USB interface on the adapter plate with the computer.
3) Wait for about 35s for normal start of the LiDAR. Then the heartbeat packet is transferred with blue light flashing, indicating the state of waiting orders.
4) Operate according to Fig. 4 to start the software. Demonstration and data recording can be achieved with the software.

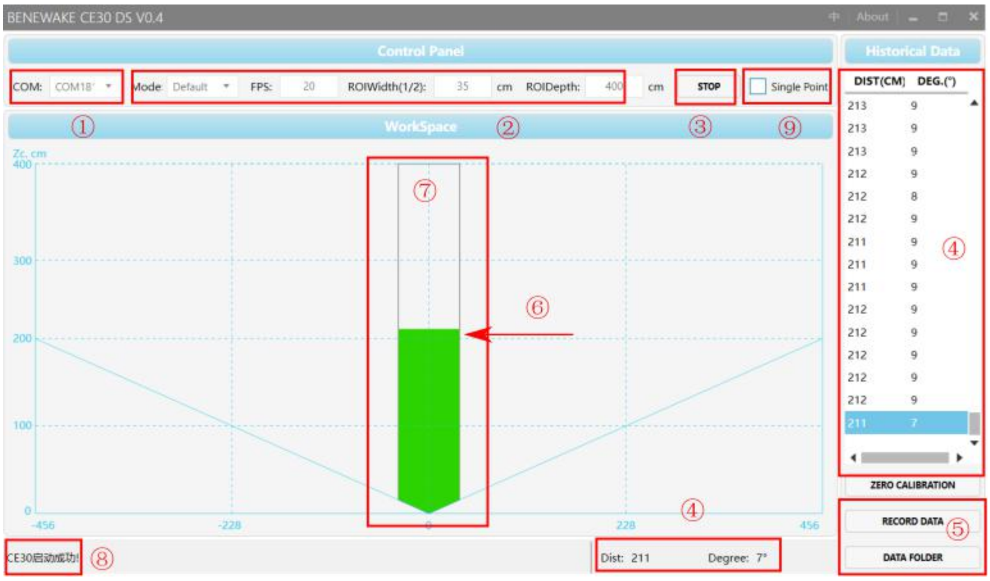



*Fig. 4 Illustration of Software Functions*

Note

① The software could automatically identify two kinds of UART: one for data and another is for debugging information. Please choose appropriate UART number in accordance with computer properties.

② Default setting of obstacle avoidance area is 35 cm in half-width of the ROI and 400 cm in depth.

③ Start/ stop test button

④ View data by rolling the window

⑤ Button of data recording （In unit of minute. When multiple clicks of the button within one minutes, only the data of the last click will be recorded.）

⑥ Position of the nearest obstacle detected by LiDAR

⑦ Obstacle avoidance region: with presence of an object, as shown in Fig. 4 above, the software will label the area between LiDAR and the obstacle as the safe zone with coloring, or else the background will be white.

⑧ Running state

⑨ Single-point mode

If the single-point mode is chosen, as shown in Fig. 5 below, the software will indicate the specific position of the obstacle in ROI. (Instruction: during the measurement of a wide flat obstacle, the output angle might be the angle of any point on the object, because the LiDAR only outputs one point.)

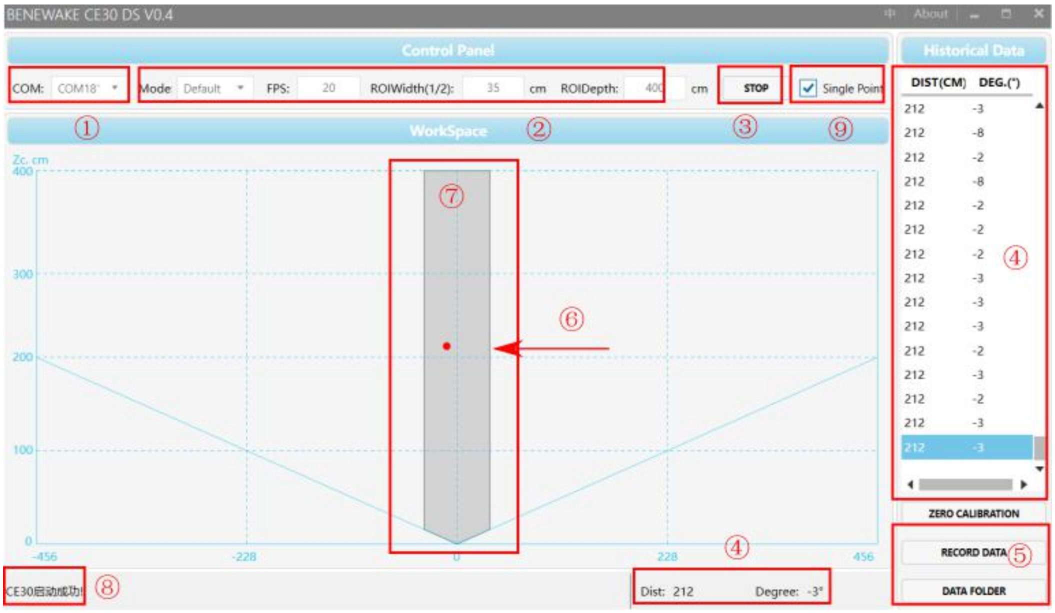



Fig. 5 Illustration of Single-point Mode

## 4 Description on Line Sequence

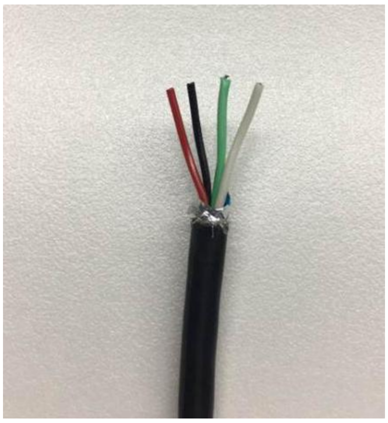


Fig. 6 Description on Line Sequence: Red - positive, Black - negative, Green - CANH, White – CANL

Attention!

① Current of power adapter shall be above 2A.

② During energization of LiDAR, there is merely a slim chance of prolonged starting time. If LiDAR is not started after 2 minutes, it is recommended to disconnect the power supply and reboot it.

③ After testing, please make sure to disconnect the power supply first.

④ For a CE30-A LiDAR with TCP communication protocol, it is not recommended to disconnect the client-side and the Ethernet cable at the same time.

## 5 Installation Instruction

The front working surface of LiDAR should exceed or at least parallel with the installation platform, see Fig. 7.

The recommended mounting height of the LiDAR is 20cm. (The distance from the bottom of the LiDAR to the ground)

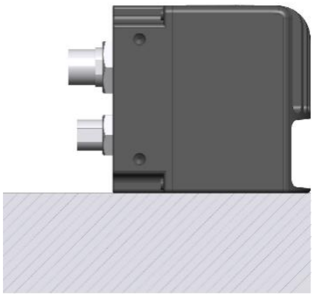


*Fig. 7 Recommendations on LiDAR Installation Position. The front working surface of LiDAR must exceed or at least be parallel with the installation platform. Otherwise, there may be certain interference and influence the data accuracy.*

## 6 Method of Center Calibration

1) There might be deflection of the LIDAR after installation in the robot. Calibration shall be done to ensure the normal warning and obstacle avoidance of the forward area.
2) As shown in Fig. 8, click the "0 angle calibration" button on the software, and calibration instruction will be shown in Fig. 9.


*Fig. 8 Software "0 Angle Calibration" button*

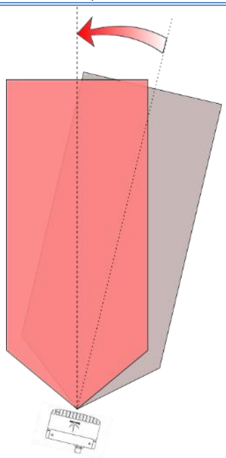


*Fig. 9 Illustration of Center Calibration Function. Specify the front direction and calibrate after installation. This operation only changes the coordinates without influencing the accuracy.*

3) Put a 2 cm-wide white rod (whose height must exceed the installation height of LiDAR) at 2m in front of the robot, and empty ±30° of the LiDAR's detecting region. Remove all the high-reflective objects within the ROI.

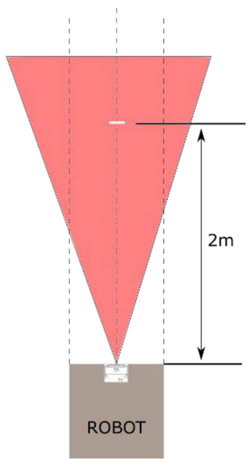



*Fig. 10 Illustration of Center Calibration Operation. There shall not be any obstacle in front area and no moving objects in operation.*

4) Press the calibration button after setting up environment.

5) Wait for 2 seconds for calibration. Distance data will be automatically uploaded, and the calibration results will be stored after disconnecting the power supply. Please be cautious with this operation.

# 7 Head Dissipation Component and Reference Design

In normal operation, the CE30 LiDAR has an average heat power consumption of around 5W. As shown below is the reference design of heat dissipation component of CE30 LiDAR. Users have the option to design heat dissipation component depending upon actual installation requirements and application scenario.

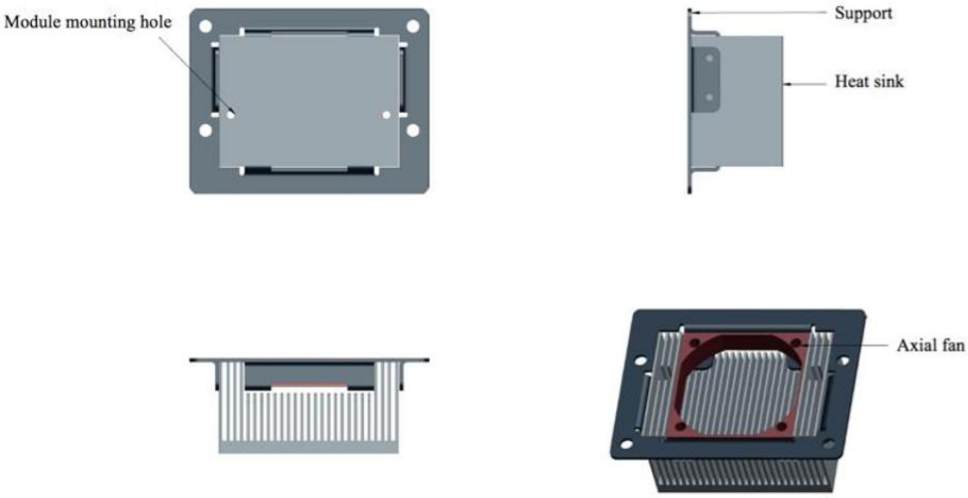
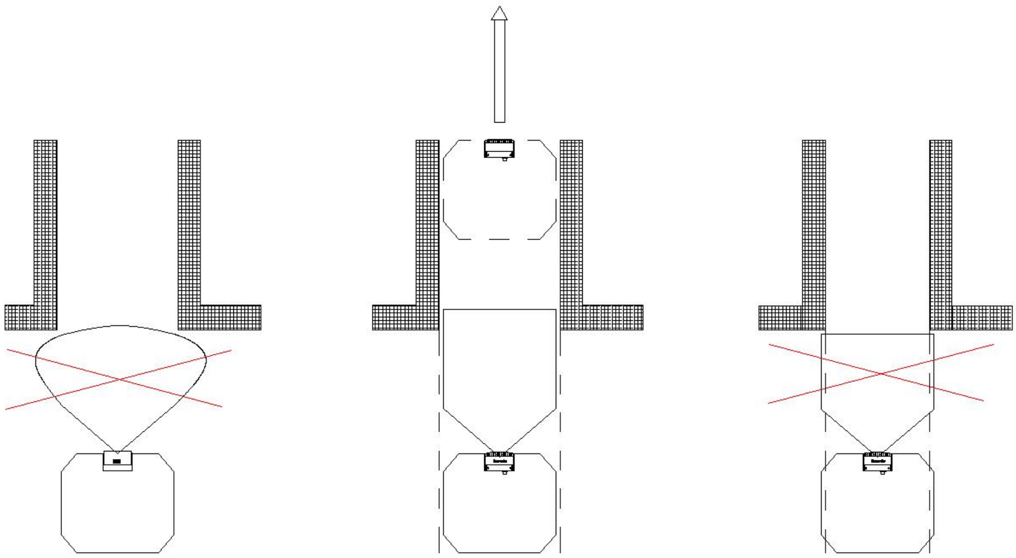



*Fig. 11 Optional Heat Dissipation Component*

# 8 Application Case

## 8.1 Accurate Crossing



*Case 1 ROI width shall be same as robot width, ensuring accurate crossing.*

## 8.2 Detection of Low Obstacles

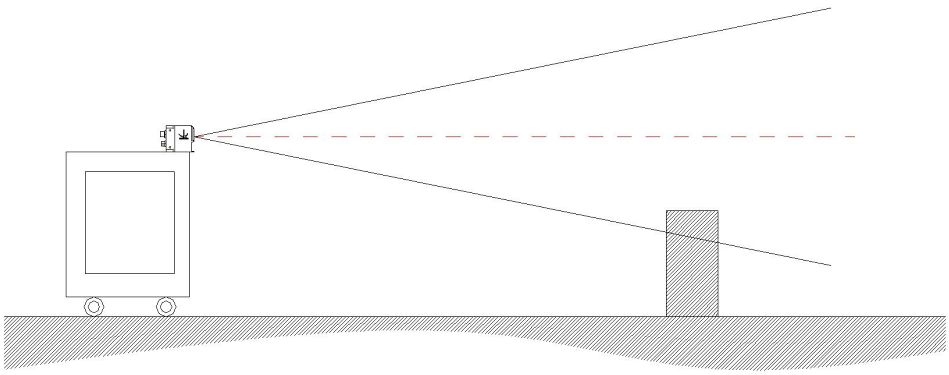


*Fig. 12 An Application of Obstacle Avoidance Mode. Compared to 2D single-channel scanning LiDAR (as shown with red line), CE30-A can better avoid low obstacles on the ground.*

# 9 Test Instruction and Description

The instruction is to demonstrate the properties of the CE30-A. The test advice is shown through the examples such that the users can get into use very quickly.

## 9.1 Accuracy and repeatability

Accuracy is the deviation between the LiDAR measurements and the real value. And repeatability is the fluctuation of multiple measurements.

Test method:

1) Set the size of the ROI to be 70*300cm. Place a whiteboard at different positions, for examples 100cm, 200cm and 300cm. Record the data and analyze the fluctuation of the multiple measurements during a period. Take 1σ and the value should be less than 3cm.
2) Set the size of the ROI to be 70*300cm. From 100-400cm, place a whiteboard at every 10cm and read the measured value. Compare the real value and the measured value. The absolute difference should be less than 6cm.

## 9.2 Detecting range

Evaluate is the detection range is consistent with the user setting.

### 9.2.1 Accuracy at ROI margin

To evaluate the detection ability of the LiDAR at the ROI margin.

Test method:

Take a whiteboard of size 40cm*40cm. From 10cm – 300cm, gradually move the whiteboard into the ROI region at every 20cm. Record the position where the whiteboard is first detected inside the ROI, and plot the detection region.

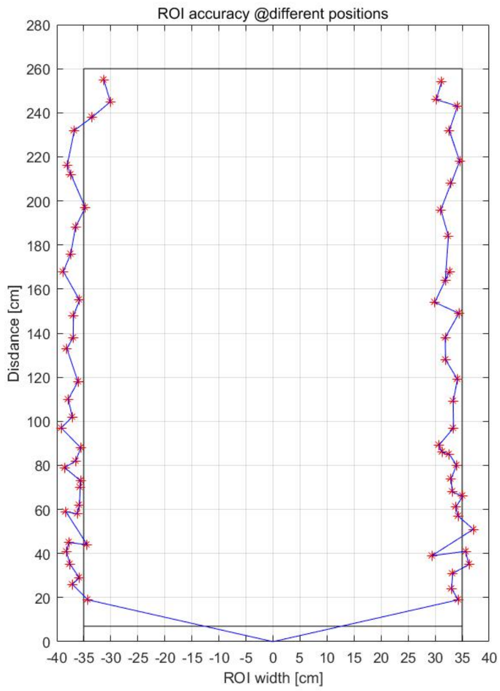



*Fig. 13 Real ROI region. The left image is the real detected ROI. The right image is the calibrated result considering the mounting error.*

### 9.2.2 Non-detection zone

To evaluate the size of the non-detection zone of the LiDAR in short range. The evaluation is again two kinds of objects: plane-type objects and stick-type objects.

1) Plane-type object: place the object parallel to the detection plane of the LiDAR. Shift the object closer to the LiDAR and the distance output is turning. Record the position of the object when the output value is 8cm. Then shift the object closer to the LiDAR and the output remains 8cm.
2) Stick-type object: shift the object horizontally in short range and record the border of the non-detection zone.

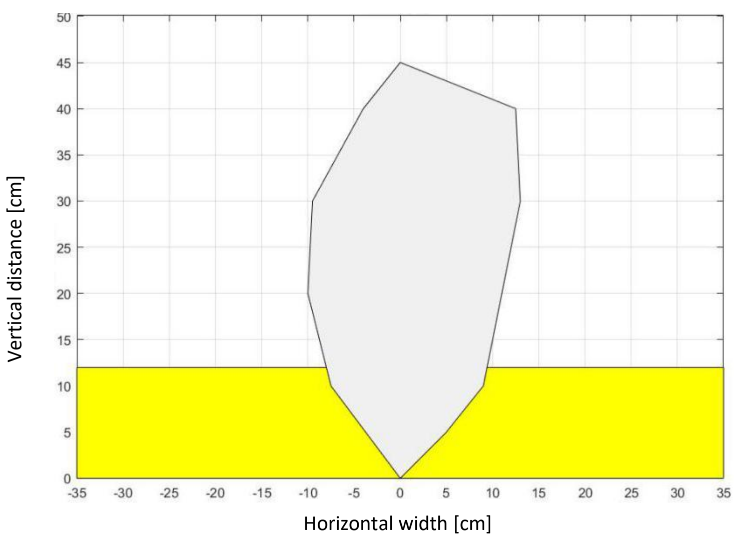


*Fig. 14 The performance of the LiDAR in short range. The yellow region is the non-detection zone of the plane-type object and the grey region is the non-detection zone of the stick-type object.*

## 9.3 The accuracy of different materials

To evaluate the detection difference of obstacles of different reflectivity.

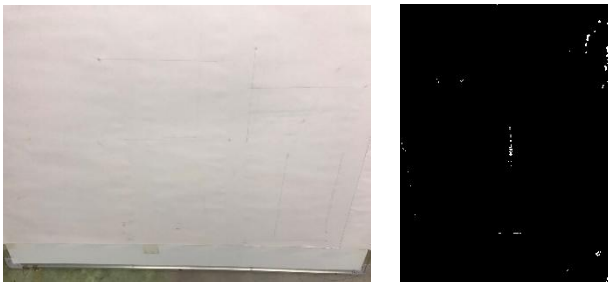


*Fig. 15 Two obstacles with different reflectivity to be evaluated. Left: whiteboard (reflectivity 90%). Right: blackboard (reflectivity 10%)*

Test method:

Move the obstacle from 10cm to 300cm at a step of 10cm along the central line of the LiDAR and compare the difference between the measures data and the real distance.

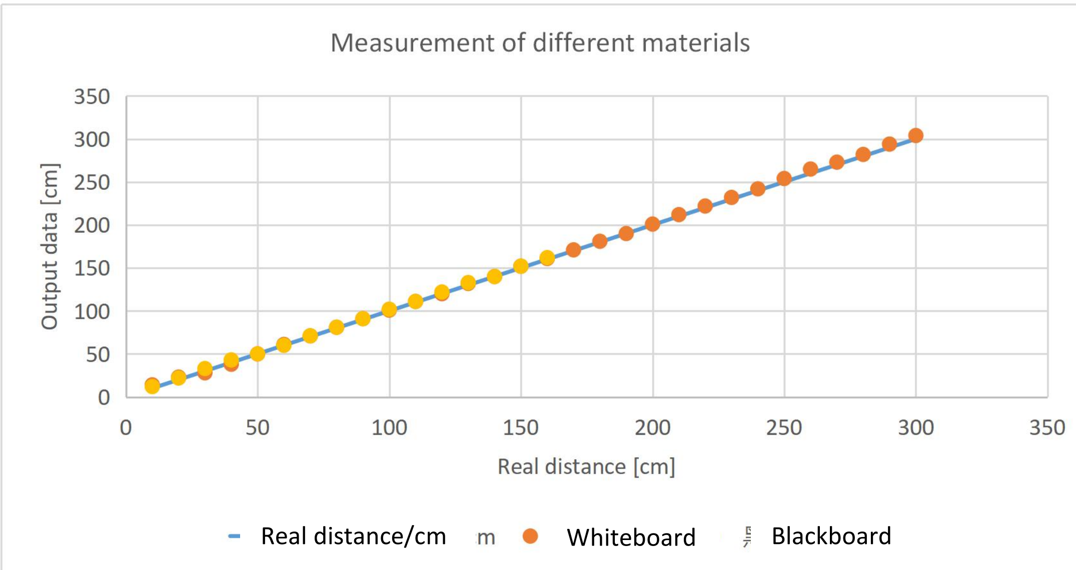



*Fig. 16 Test result of different materials(example). The horizontal axis refers to the real distance. The vertical axis is the measured result of different materials, in cm.*

It can be seen that the LiDAR can detect different materials at different positions. The accuracy of different materials will be evaluated in the following[1].

[1] The evaluation condition is under standard room temperature, without ambient light. When the LiDAR is operating for 20 mins, a whiteboard of 100*100cm with reflectivity 90% is placed in the centre of the FOV for evaluation. Different angles also lead to different maximum detection range.

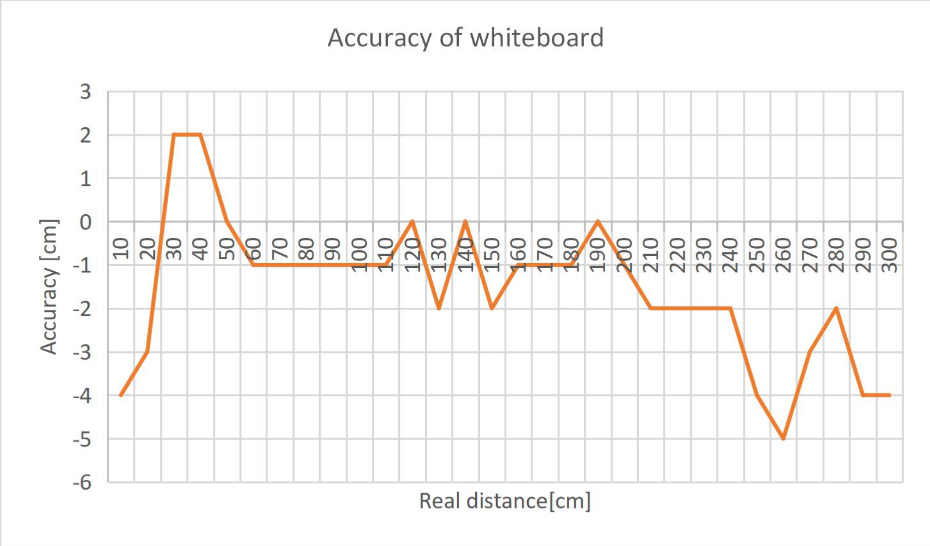



*Fig. 17 Accuracy of whiteboard detection, in cm.*

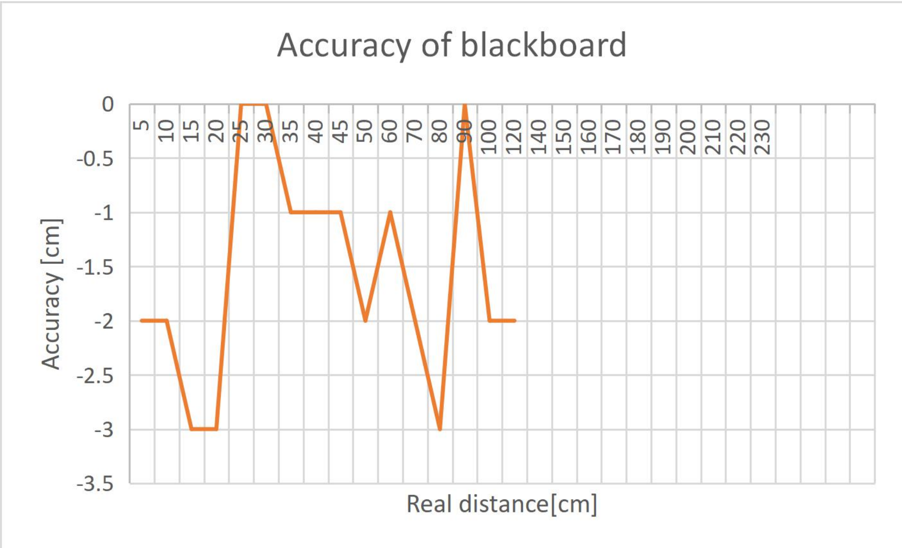



*Fig. 18 Accuracy of blackboard detection, in cm.*

The following table gives the reflectivity of different materials for reference.

*Table 1 The reflectivity of common materials*

| No. | Material | Reflectivity |
|---|---|---|
| **1** | Black sponge | 2.4% |
| **2** | Black cloth | 3% |
| **3** | Black rubber | 4% |
| **4** | Coal (depending on the type) | 4~8% |
| **5** | Black car lacquer | 5% |
| **6** | Black carton | 10% |
| **7** | Opaque black plastic | 14% |
| **8** | Clean rough wood | 20% |
| **9** | newspaper | 55% |
| **10** | Translucent plastic bottle | 62% |

| | | |
|---|---|---|
| **11** | Box cardboard | 68% |
| **12** | Clean pine | 70% |
| **13** | Opaque white plastic | 87% |
| **14** | White carton | 90% |
| **15** | Kodak standard whiteboard | 100% |
| **16** | Unpolished white metal surface | 130% |
| **17** | Shiny light-colored metal surface | 150% |
| **18** | Stainless steel | 200% |
| **19** | Reflector, reflective sticker | >300% |

## 9.4 Response time

The original refresh rate of the LiDAR is 20Hz. Hence the obstacle can be detected promptly.

Test method:

As the AGV moves, throw an object 1m in front of the AGV. The LiDAR can instantly detect the obstacles and report to the AGV.

## 9.5 Ambient light

To evaluate the performance of the LiDAR under ambient lights outdoors.

Test method:

Read the strength of the ambient light with a light meter. Move different obstacles in front of the LiDAR from 0cm to 400cm, and compare the difference between the measured data and the real distances.

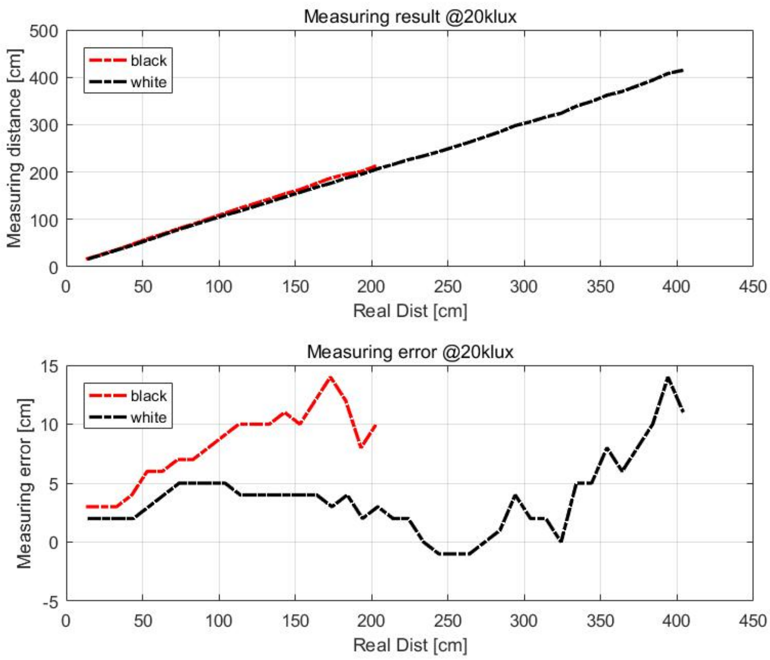



*Fig. 19. Under 20klux ambient light outdoors[2].*

*(Upper) the measuring result of white board. (Lower) Measuring error of white board.*

[2] The default evaluation condition is under standard room temperature. When the LiDAR is running for 20 mins, a whiteboard of 100*100cm with reflectivity 90% is placed in the centre of the FOV for evaluation.

## 9.6 Temperature

To evaluate the influence of the temperature on the performance of the LiDAR.

Test method:

Place the LiDAR at different room temperatures. Evaluate the measuring error of the LiDAR at different distances[3].

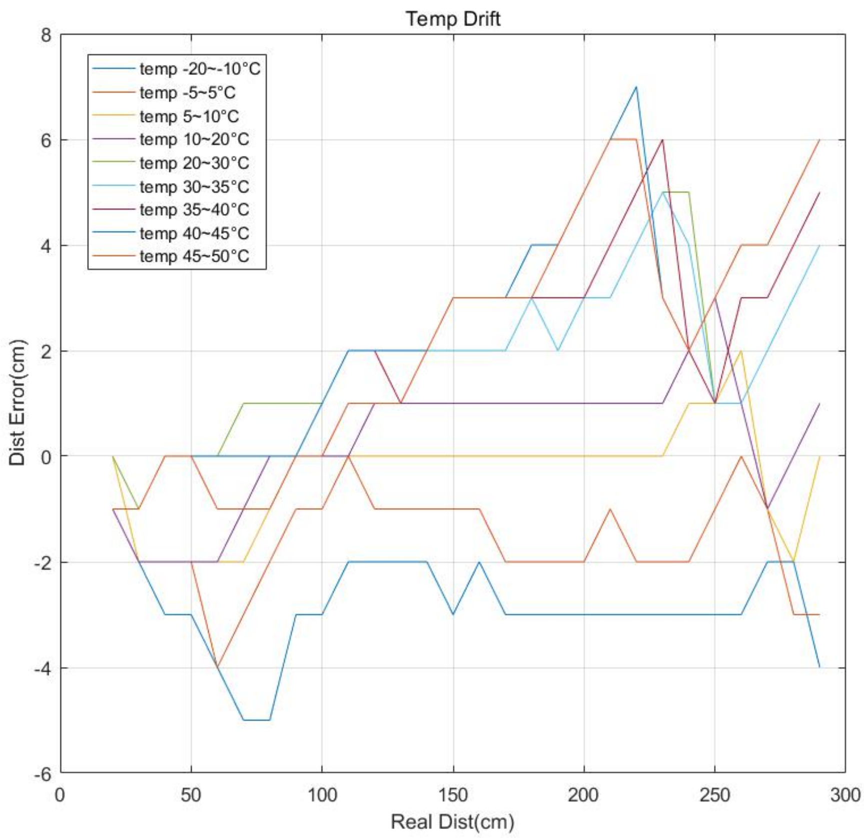



*Fig. 20. Temp drift of the LiDAR at different room temperatures*

## 9.7 Crosstalk

To evaluate the crosstalk between two LiDAR. From the test result, the crosstalk is the severest when two LiDAR are looking at each other. Hence this crosstalk mode is taken as the critical test mode.

Test method:

[3] The default evaluation condition is without ambient light. When the LiDAR is running for 20 mins, a whiteboard of 100*100cm with reflectivity 90% is placed in the centre of the FOV for evaluation.

Embed the LiDAR within a box (to simulate the situation when the LiDAR is installed in a robot). Set the distance between two LiDAR as 1m and 2m, and record the crosstalk data.

*Fig. 21. The LiDAR is embedded in a box for crosstalk test (installation example)*

Test result example:

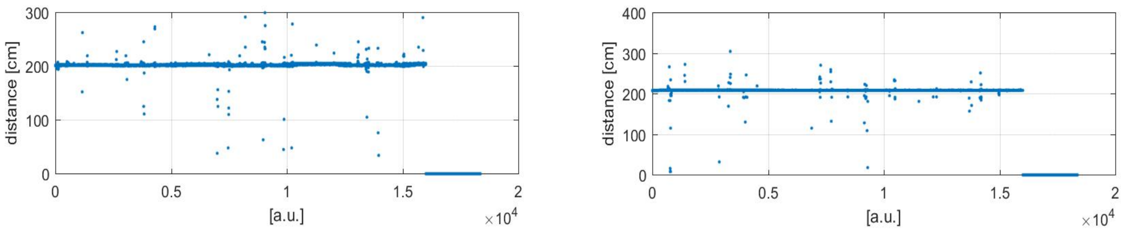



*Fig. 22. The test result when two LiDAR are 2m from each other*

Note: the anti-crosstalk algorithm introduced might cause the decrease of refresh rate, minimum 15fps.

# 10 Influence Factors of Measurement

## 10.1 Multi Optical Path

Based on ToF LiDAR principle, if there are multiple echo regions as shown in the figure below at the working height of the radar, the multi-path phenomenon will be triggered: the LiDAR receives the light returned by the path 1 and the path 2 at the same time, which may result in a larger measurement value.

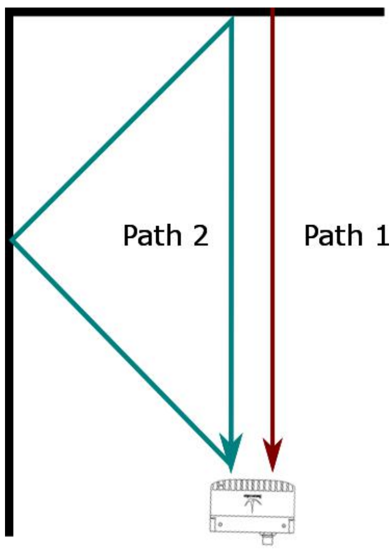



*Fig. 23 Multi optical path phenomenon*

## 10.2 Stray Light

As shown below, when solid-state ToF LiDAR is working, in addition to the light reflected by the object 1, the light scattered by object 2 and object 3 that close to the LiDAR will enter the lens. Such stray light can lead to a deviation of the object 1's ranging.

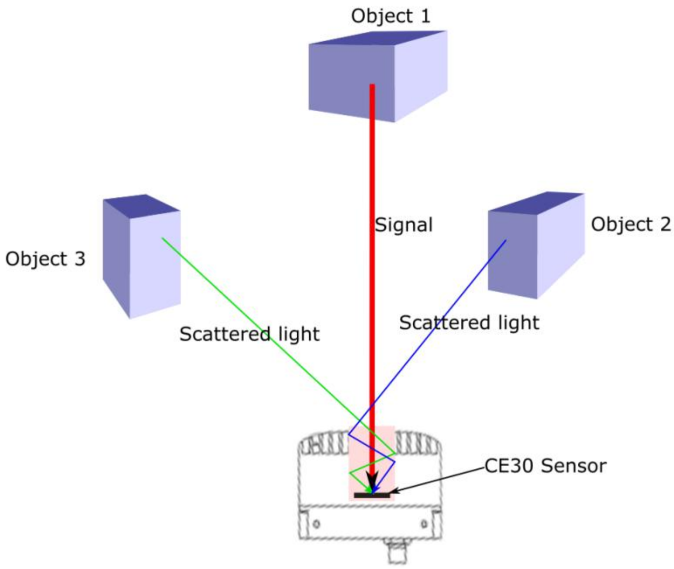



*Fig. 24 Illustration of stray light*

## 10.3 Multi Distance Objects

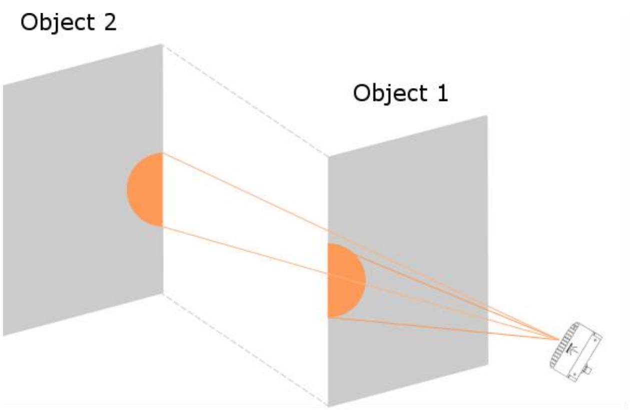



*Fig. 25 Multi distance objects*

The light radiated by the LiDAR is reflected by the object onto the sensor of the LiDAR. If some pixels receive signals from both front and rear obstacles at the same time, the output distance of this pixel may be the value between the two obstacles. The degree of deviation is related to the distance between the two obstacles and the material.