Helios 32

User Guide

Version 1.1

Change Description

Version	Revision Date	Description
1.0	2023/8/19	Initial release
1.1	2023/11/6	1. Increase LiDAR weight tolerance range 2. Updated the Angle pulse parameter description

Reading Prompt

Product Description

This product manual is applicable to all specifications and models of Helios 32.

Symbolic Instructions

Warning: The usage process should be strictly followed, otherwise it may lead to potential dangerous situations such as minor injuries or property damage.

Important: The usage process should be observed, otherwise it may cause potential harmful situations such as product damage.

Tip: The usage process should be valued sufficiently to achieve maximum value of the product efficiently and smoothly.

Resource Download

Please click the following link to download the latest product manual, RSview and other resources: https://www.robosense.cn/resources

More Information

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Content

1 Safety Notices

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1.2 User Guidelines

⚠ Please use this product in accordance with the following requirements:

1) Please strictly abide by relevant national laser safety laws and regulations;
2) Please read this product manual in detail before using the product;
3) Please use this product only in the relevant field of application;
4) Please avoid using this product in environments that are explosive, highly corrosive, or beyond the IP protection level of the equipment.

1.3 Illegal Operation

⚠ Please use this product in accordance with the regulations, otherwise it may cause product damage, property loss, and personal injury. Users are responsible for risk arising from unauthorized operations.

1) Do not disassemble or modify this product (including accompanying accessories);

2) Non-specified power supply and accompanying accessories are prohibited;
3) Please avoid abnormal operations such as dropping, colliding, burning, etc.;
4) If you notice any damage to the appearance of the device (arc protection cover), please immediately stop using it;
5) If you notice any abnormal operation of the product, please immediately stop using it and contact RoboSense in a timely manner.

1.4 Requirements for Operating Personnel

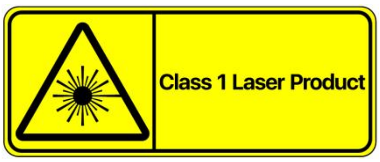
⚠ The use of this product requires certain basic professional knowledge and other related requirements for operating personnel. Unreasonable operations performed by personnel without basic knowledge or training do not constitute a fault of RoboSense and may cause damage to equipment and personal property.

1) Please read the product manual in detail before using the device;
2) Prohibit illegal operations;
3) Before working, personnel must undergo training and obtain relevant construction qualifications;
4) Have some basic knowledge of computer data connection, electrical, and so on.

1.5 Work Safety and Special Hazards

⚠ To avoid risks of accidents, damage to sensor or violating of your product warranty, please read and follow the instructions in this manual carefully before operating the product.

1) Laser Safety: This product meets the following standards for laser products: IEC 60825-1:2014;：



2) High Temperature Warning: Please pay attention to the overheating sign on the LiDAR surface to avoid a hot LiDAR surface that may lead to sensor

failure or undesirable consequences.

3) Retain Instructions: The safety and operating instructions should be retained for future reference.
4) Heed Warnings: All warnings on the product and in the operating instructions should be adhered to.
5) Servicing: Except for what's described in this manual, the sensor has no field serviceable parts. For servicing, please contact RoboSense sales or the authorized distributors.

2 Product Description

2.1 Product Overview

Helios 32 is RoboSense's brand-new, high-precision 3D LiDAR system with a modular architecture design, featuring 32 laser beams. It is primarily used in applications such as robot environment perception, autonomous driving vehicle environment perception, V2X (Vehicle-to-Everything) communication, smart cities, and more.

Helios 32 comes in three different specifications, primarily differing in the vertical field of view (FOV): 70° FOV (-55° ~ +15°), 31° FOV (-16° ~ +15°), 26° FOV (-16° ~ +10°).

Additionally, Helios 32 is equipped with advanced features, including resistance to interference from multiple LiDAR and ambient light, the capability to operate in extreme temperatures as low as -40℃, compliance with vibration requirements for commercial vehicles, and the ability to function reliably in complex and demanding environments.

2.2 Product Structure

The structure of Helios 32 is illustrated in Figure 1 .

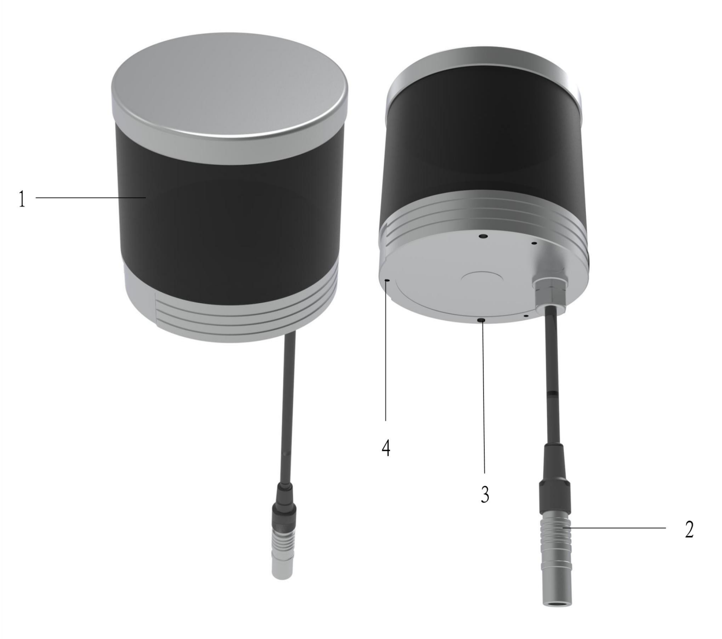


Figure 1 Product Structure Description

It mainly includes the following components:

1) Protective Cover

Both the emitted laser and returned laser need to pass through the specially designed arc-shaped protective cover. Therefore, any obstruction within the laser's field of view (FOV) is strictly prohibited.

2) Aviation Connector

The main body of the LiDAR is connected to the interface box using an aviation connector, which facilitates power supply and data transmission.

3) Mounting Holes

Used to support and fix the position and orientation between the LiDAR and the bracket, it enhances installation efficiency and accuracy.

4) M3 Screw Mounting Holes

Used to secure the LiDAR to the mounting bracket with M3 screws.

2.3 FOV Distribution

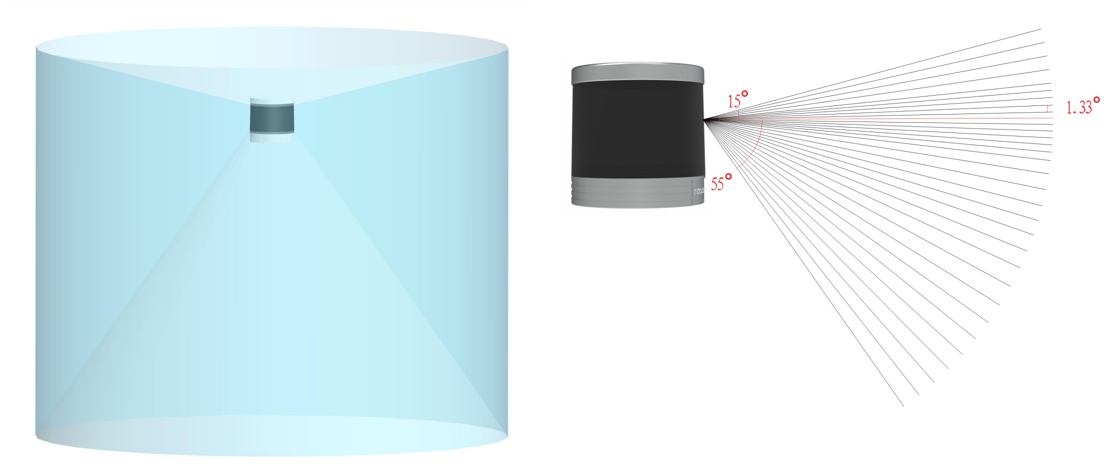
The FOV distribution of Helios 32 is presented in Table 1.

Table 1 Helios 32 FOV

Specification	Horizontal Direction	Vertical Direction

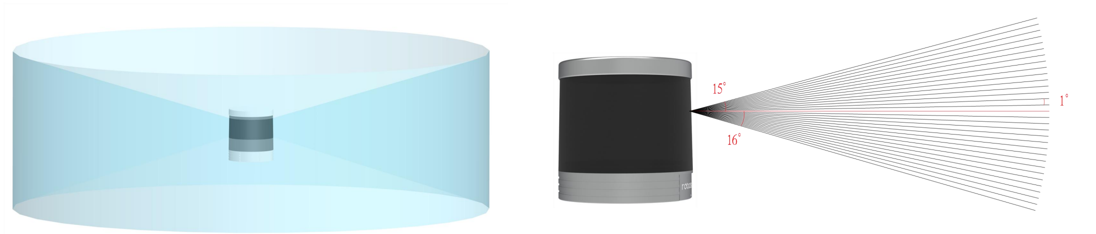
70° FOV	0° ~ 360°	-55° ~ +15°
31° FOV		-16° ~ +15°
26° FOV		-16° ~ +10°

The 32 laser beams are defined as 32 channels, and their corresponding vertical angles are shown in Figure 2 , Figure 3 , and Figure 4 (b).



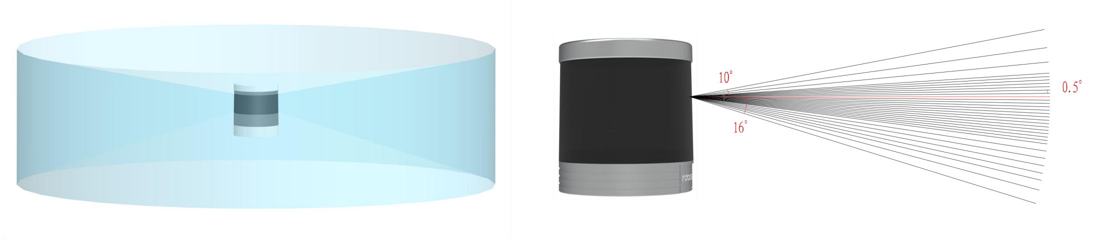
(a) FOV Area Distribution (b) Vertical Angular Distribution

Figure 2 70° FOV Illustration



(a) FOV Area Distribution (b) Vertical Angular Distribution

Figure 3 31° FOV Illustration



(a) FOV Area Distribution (b) Vertical Angular Distribution

Figure 4 26° FOV Illustration

2.4 Specifications

Table 2 Helios 32 Specifications

Specifications	70° FOV	31° FOV	26° FOV
Number of Channels	32		
Laser Wavelength	905 nm		
Laser Safety Level	Class 1 Eye-Safe		
Measurement Range	0.2 m to 150 m (110 m @10% NIST，see Appendix E)		
Blind Zone	0.2 m		
Accuracy [1](Typical)	1 cm(1σ) / 3 cm(3σ)		
Horizontal FOV	360°		
Horizontal Angle Resolution	0.1° / 0.2° / 0.4°		
Frame Rate	5 Hz / 10 Hz / 20 Hz		
Rotation Speed	300 / 600 / 1200 rpm(5 / 10 / 20 Hz)		
Laser Emission Angle (Full Angle)	Horizontal: 5.9 mrad, Vertical: 6.9 mrad	Horizontal: 3 mrad, Vertical: 5 mrad	
Vertical FOV	70°（-55° ~ +15°)	31°（-16° ~ +15°)	26°（-16° ~ +10°)
Vertical Angle Resolution	Up to 1.33° (see Table 34)	Uniform 1° (see Table 35)	Up to 0.5° (see Table 36)
Point Cloud Output	576,000 pts/s (single return mode), 1,152,000 pts/s (dual return mode)		
Ethernet Output	100 Base - T1		
Output Data Protocol	UDP packets over Ethernet		
Lidar Data Packet Contents	3D spatial coordinates, reflection intensity, timestamps, etc.		
Operating Voltage	9 V ~ 32 V	Dimensions	Diameter 100 mm× Height 100 mm
Product Power Consumption[2]	12 W (Typical)	Operating Temperature[3]	-40℃ ~+60℃
Weight	1000g ± 50g(LiDAR Body)	Storage Temperature	-40℃ ~+85℃
Time Synchronization	GPS，PTP & gPTP	Protection Level	IP67 / IP6K9K
Product Model	H32F70	H32F31	H32F26

Note:

It is not recommended to use the high-performance mode and dual return mode simultaneously due to potential packet loss issues caused by large data volume.

[1] The ranging accuracy is based on a 50% NIST diffuse reflectance target. The test results may be influenced by environmental factors, including but not limited to ambient temperature and target distance. The specified accuracy values are generally applicable to most channels, but there may be differences between certain channels.

[2] Device Pow Consumption test results are influenced by external environmental factors, including ambient temperature, target distance, and target reflectivity;

[3] Device Operating Temperature may be affected by external environmental factors, including lighting conditions and airflow variations；

2.5 Product Principle

2.5.1 Coordinate Mapping

As the LiDAR data packet contains only horizontal rotation angles and distance parameters, to present a three-dimensional point cloud, the polar coordinates (angle and distance) are transformed into Cartesian coordinates (x, y, z) according to the following equations:

$$\begin{cases} x = r\,cos\,(\,\omega)\,sin\,(\,\alpha) + \mathrm{R}\,cos\,(\,\alpha); \\ y = r\,cos\,(\,\omega)\,cos\,(\,\alpha) + \mathrm{R}\,sin\,(\,\alpha); \\ z = r\,sin\,(\,\omega); \end{cases}$$

where r is the measured distance, ω is the laser's vertical angle, α is the laser's horizontal rotation angle, R is the plane radius from the optical center to the origin, and x, y, z are the coordinates projected onto the Cartesian X, Y, Z axes.

2.5.2 Reflectivity Interpretation

Helios 32 provides reflectivity information to characterize the reflectance of measured objects. In Helios 32 data, the calibrated reflectivity range is from 1 to 255.

2.5.3 Return Modes

2.5.3.1 Return Modes Principle

Helios 32 supports multiple return modes, including Strongest Return, Last Return, First Return, and Dual Return modes. In the Dual Return mode, detailed information of the target object is displayed, and the data volume is twice that of the Single Return mode.

Helios 32 analyzes multiple return values received and outputs the strongest, last, or first return value based on user selection, or outputs dual return values. In the Strongest Return mode, only the strongest reflected return value is output; in the Last Return mode, only the last detected return in the time domain is output.

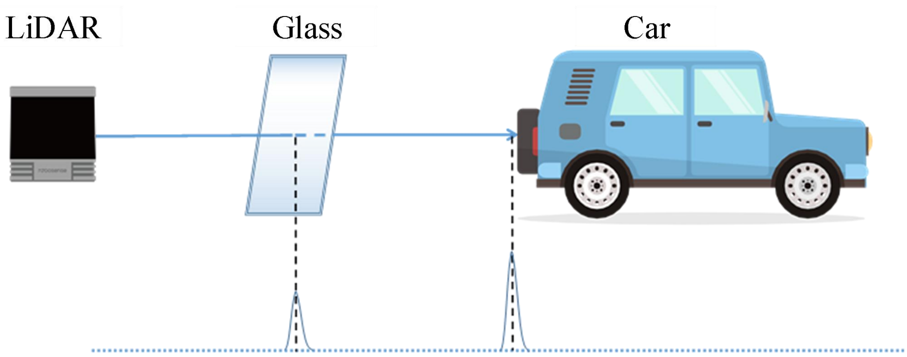


Figure 5 Dual Return Detection

Note:
In Dual Return mode, when the laser hits multiple targets, and the distance between the targets is greater than 1 meter, the LiDAR can detect two echoes, as shown in Figure 5 .

2.5.3.2 Return Mode Flags

By default, Helios 32 is set to the Strongest Return mode. If the user needs to change the settings, please refer to Appendix A.2 in the product parameter setting for configuration. In DIFOP, the 300th byte represents the flag for the return mode, as shown in Table 3:

Table 3 Return Mode and Flags Mapping

DIFOP Offset	Flag	Return Mode
300	00	Dual Return
	04	Strongest Return
	05	Last Return
	06	First Return

2.5.4 Phase Locking

Helios 32's phase locking function allows the device to emit lasers at specific angles when the sensor reaches a whole second. Figure 6 illustrates Helios 32's setup with different phase angles. The red arrows indicate that at the whole second, the sensor rotates to 0°, 135°, and 270° to emit lasers. Refer to Figure 15 for the coordinate system details.

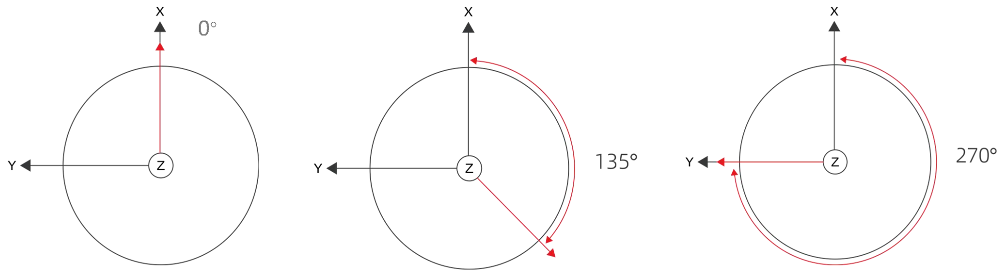


Figure 6 Helios 32 Phase Lock Setting Illustration

The "Phase Lock" parameter setting is available in the Web interface under Setting > Phase Lock Setting. It allows users to set the locked phase angle, which should be an integer ranging from 0 to 359. For more details, refer to section 4.2 of the product manual.

2.5.5 Time Synchronization Mode

Helios 32 supports three time synchronization methods: GPS + PPS, PTP (IEEE 1588 V2 protocol), and gPTP (IEEE 802.1 AS protocol). Users can configure these settings through the Web interface. For more details, refer to section 4.2 of the product manual.

2.5.5.1 GPS Time Synchronization Principle

The GPS module continuously sends GPRMC data and PPS synchronization pulse signals to the product. The PPS synchronization pulse length should be between 20 to 200 ms, and the GPRMC data must be completed within 500 ms of the synchronization pulse. The timing diagram is shown in Figure 7 .

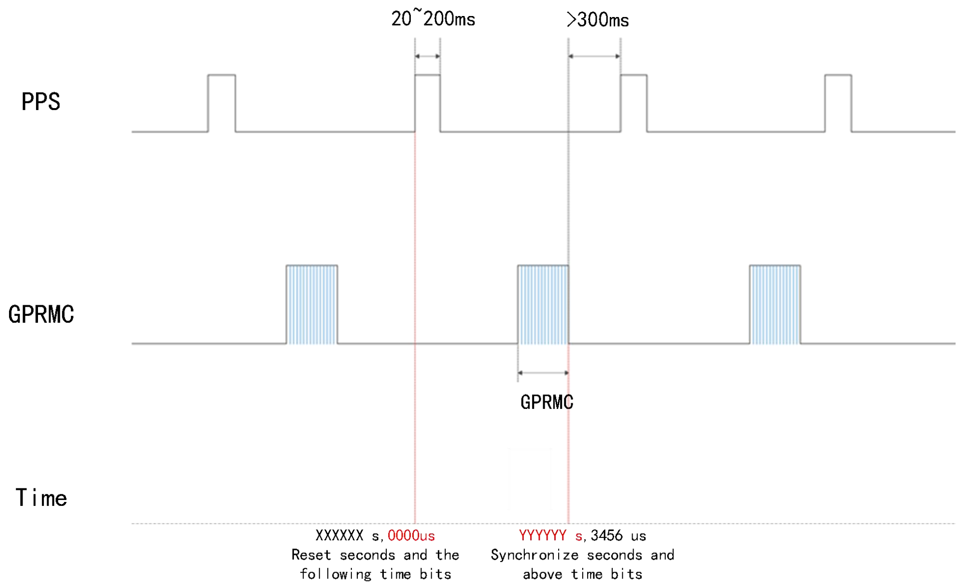


Figure 7 GPS Time Synchronization Timing Diagram

Note:

To ensure accurate time synchronization, it is recommended to set the PPS pulse width between 20 to 200 ms. The completion time of GPRMC is recommended to be within 500 ms after the rising edge of PPS.

2.5.5.2 GPS Time Synchronization Usage

The GPS_REC interface of Helios 32 LiDAR adopts the RS232 electrical level protocol. Refer to Table 4 for the pin definition.

Table 4 Product Time Synchronization Pin Definitions

Communication	**Receiving Pin Definition**	
	GPS REC	**GPS PULSE**
RS232	RS232 Receives serial data with RS232 electrical level standard output from the GPS module	Receives positive synchronization pulse signal output from the GPS module, with a voltage requirement of 3.0 ~ 15.0 V

The external GPS module needs to set the output serial port baud rate to 9600 bps, 8 data bits, no parity bit, and 1 stop bit. Helios 32 only reads GPRMC-formatted data sent by the GPS module. The standard format is as follows:

$ GPRMC,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,<10>,<11>,<12> * hh

<1> UTC time

<2> Positioning status: A = valid positioning, V = invalid positioning

<3> Latitude

<4> Latitude hemisphere N (Northern Hemisphere) or S (Southern Hemisphere)

<5> Longitude

<6> Longitude hemisphere E (Eastern Hemisphere) or W (Western Hemisphere)

<7> Ground speed

<8> Ground course

<9> UTC date

<10> Magnetic declination

<11> Magnetic declination direction: E (East) or W (West)

<12> Mode indication (A = Autonomous positioning, D = Differential, E = Estimated, N = Data invalid)

*hh at the end represents the XOR sum of characters from $ to *

Note:

1) The GPS_REC interface specification on the Helios 32 power box is JST S12B-J11DK-TXR, with pin definitions shown in Table 8.
2) The interval for sending 1 PPS pulse should be controlled within 1s±200 us.
3) Time synchronization through GPS_REC is only allowed when the positioning status in the GPRMC message is valid (A).
4) Helios 32 is compatible with most GPRMC message formats from GPS modules available in the market. If any compatibility issues are found during use, please contact RoboSense.

2.5.5.3 PTP Synchronization Principle

PTP (Precision Time Protocol, IEEE 1588V2 protocol) is a time synchronization protocol used for high-precision time synchronization between devices. It can also be used for frequency synchronization between devices. Compared to various existing time synchronization mechanisms, PTP offers the following advantages:

1) Compared to NTP (Network Time Protocol), PTP can meet higher precision time synchronization requirements. NTP generally achieves sub-millisecond level time synchronization accuracy, while PTP can reach sub-microsecond level accuracy.
2) Compared to GPS (Global Positioning System), PTP has lower construction and maintenance costs.

2.5.5.4 gPTP Synchronization Principle

gPTP (general Precise Time Protocol, IEEE 802.1AS protocol) is a derivative protocol of PTP in Time-Sensitive Networking (TSN). The synchronization mechanism uses the same P2P peer delay mechanism as the PTP protocol and adopts Ethernet L2 layer communication. Unlike PTP, gPTP requires the use of hardware-based timestamps, i.e., hardware timestamps, so the requirements for switches and master clocks are more stringent, complying with the IEEE 802.1AS protocol.

2.5.5.5 PTP/gPTP Wiring Method

To use PTP/gPTP synchronization, the following preparations are required. Refer to section 3.4 of the product manual for connection details:

1) Select PTP/gPTP mode in the Web interface. See section 4.2 of the product manual for details.
2) PTP Master/gPTP Master time source (plug and play, no additional configuration required).
3) Ethernet switch.
4) Devices that support PTP/gPTP protocols and need time synchronization.

Note:

1) The PTP Master device is a third-party device and is not included in the RoboSense shipment. The user needs to purchase it separately.
2) RoboSense products, as Slave devices, only receive time from the Master and do not judge the accuracy of the Master's clock source. If there are sudden changes in the time when parsing LiDAR point cloud data, please check if the time provided by the Master is accurate.
3) After LiDAR synchronization, when the Master is disconnected, the time in the point cloud data packet will be accumulated based on the LiDAR's internal clock. The time will be reset when the LiDAR is powered off and restarted.

3 Product Installation

3.1 Accessory Description

The standard accessories included with Helios 32 LiDAR are listed in Table 5 for reference.

Table 5 Standard Accessory List

No.	Accessory Name	Specification	Quantity
1	LiDAR	Helios 32	1
2	Interface Box	3m cable length	1
3	Power Adapter	DC12 V × 3.34 A /40 W	1
4	Power Cable	1.2 m	1
5	Ethernet Cable	1.5 m	1
6	Screw Pack	M3 × 8	4
		M3 × 12	4
7	Extended Cable (optional)	6 m	1
8	Product Packing List and Shipment Inspection Report	/	1

For specific requirements, refer to the commercial agreement.

3.2 Mechanical Installation

The structural installation diagram of the LiDAR is shown in Figure 8 .

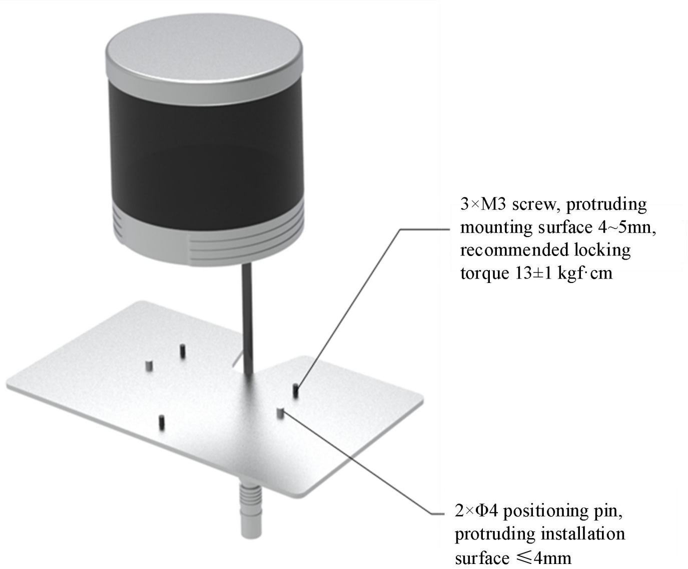


Figure 8 LiDAR Structural Installation Diagram

1) Screw Specifications:
   a) GB/T70.1, M3 × 12, internal hexagon socket head, strength grade 10.9, with an anti-drop.
   b) GB/T70.1, M3 × 8, internal hexagon socket head, strength grade 10.9, with anti-drop.
2) Installation Requirements:
   a) The installation surface should have a flatness better than 0.2 mm.
   b) Use 3 M3 screws for mounting on the bottom surface, with a mounting depth of 4 ~ 5 mm, and recommended tightening torque of 13 ± 1 kgf.cm.
   c) Use 2 Φ4 locating pins on the bottom surface for positioning, ensuring they do not protrude more than 4 mm.
   d) The tilt angle during installation should not exceed 15°.
   e) When installing the LiDAR and both the top and bottom surfaces have contact surfaces, ensure that the distance between the contact surfaces is greater than the height of the LiDAR to avoid squeezing the LiDAR.
   f) When routing the wires during installation, do not make the cables too tight (leave at least 2 cm of installation allowance) to ensure that the cables have some slack.

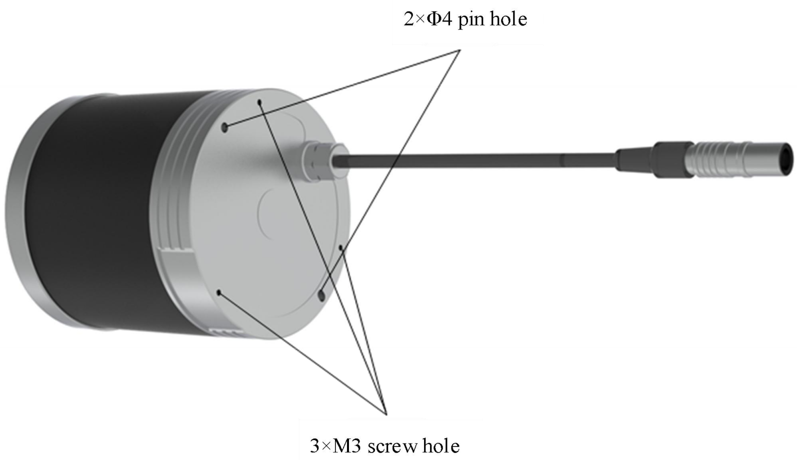


Figure 9 LiDAR Bottom Locator Pin and Screw Diagram

3) Bracket Stiffness and Strength Requirements:
   a) The fixed bracket should have good rigidity to securely mount and maintain the LiDAR in a stable state under various conditions. Therefore, the

first-order modal frequency of the LiDAR and its fixed bracket should be at least greater than 50 Hz.

b) The LiDAR will undergo various random vibrations, mechanical impacts, etc., during use. The bracket must withstand significant loads, so it requires sufficient strength. It is recommended to use aluminum alloy (thickness ≥ 4 mm) or galvanized steel plate (thickness ≥ 2 mm) for the bracket material. Reinforcements should be added in various directions to increase stiffness and strength, and it is advised to avoid designing structures with sharp angles or notches less than 0.3 mm to prevent stress concentration. The strength of the bracket needs to be verified through simulation.

4) Heat Dissipation Requirements:

a) The bracket material should be made of materials with a thermal conductivity greater than 50 W/m·K, such as aluminum alloy or galvanized steel plate. Heat fins should be added to the bracket, and the spacing, height, and direction of the fins should be designed reasonably to increase the heat dissipation area. The direction of the fins should align with the direction of air convection for more effective heat dissipation.

b) Ensure that the LiDAR base or top cover is not covered by non-metallic materials to avoid affecting the overall heat dissipation and causing excessive temperature rise of the LiDAR.

3.3 Interface Description

3.3.1 Aviation Plug Interface and Definitions

The Helios 32 LiDAR has a bottom-mounted aviation plug, as shown in Figure 10 .

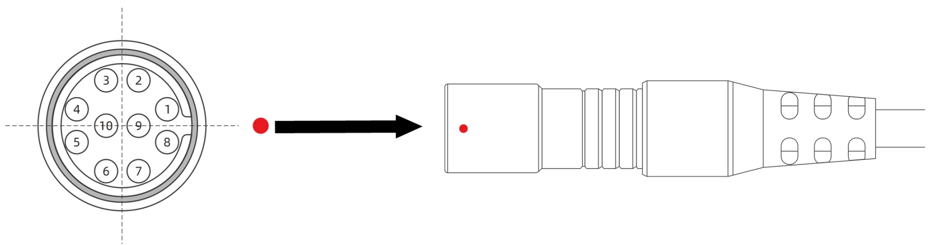


Figure 10 Pin Numbers of the Aviation Plug Interface

For detailed pin definitions of the aviation plug interface, please refer to Table 6

Table 6　Pin Definitions of the Aviation Plug Interface

<table>
<tr><th>Pin No.</th><th>Color</th><th>Signal</th><th>Operating Voltage Range</th><th>Operating Current</th><th>Other</th></tr>
<tr><td>1</td><td>Red</td><td>PWR</td><td rowspan="2">9 ~ 32 V</td><td rowspan="2">1.2 A</td><td rowspan="8">/</td></tr>
<tr><td>2</td><td>Black</td><td>PWR</td></tr>
<tr><td>3</td><td>Gray</td><td>GND</td><td rowspan="2">/</td><td rowspan="2">1.2 A</td></tr>
<tr><td>4</td><td>Blue</td><td>GND</td></tr>
<tr><td>5</td><td>Brown</td><td>GPS_PPS</td><td>3 ~ 15 V</td><td rowspan="6">/</td></tr>
<tr><td>6</td><td>White</td><td>GPS_GPRMC</td><td>-15 V ~ +15 V</td></tr>
<tr><td>7</td><td>Purple</td><td>SYNC_OUT1</td><td rowspan="4">0 ~ 3.3 V</td></tr>
<tr><td>8</td><td>Green</td><td>SYNC_OUT2</td></tr>
<tr><td>9</td><td>Orange</td><td>TRD_N</td><td rowspan="2">Twisted Pair</td></tr>
<tr><td>10</td><td>Yellow</td><td>TRD_P</td></tr>
</table>

3.3.2　Interface Box

The Helios 32 accessory interface box is equipped with status indicator lights and various interfaces, as shown in Figure 11 . It can be connected to power input, RJ45 Ethernet port, and GPS input cable (the cable length for the aviation plug version of the interface box is 3 meters; for other cable length requirements, please contact Robosense).

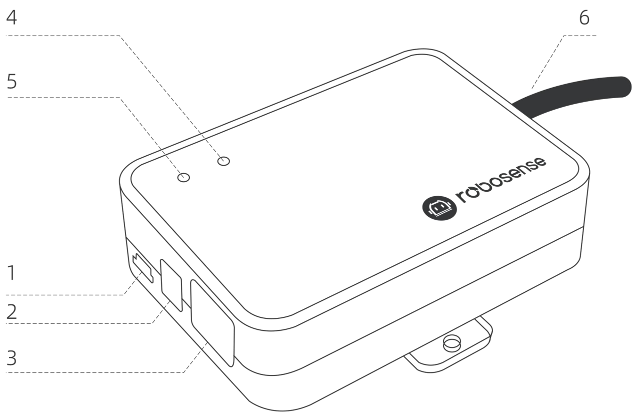


Figure 11　Interface Box Schematic

The details of each interface definition and specifications are provided in Table 7.

Table 7 Interface Box Interface Specifications

No.	Interface Name	Specification
1	Sync Interface	SH 1.0 - 6 P Female Connector
2	Power Interface	Standard DC 5.5 - 2.1 Interface
3	Ethernet Interface	Standard RJ45 Interface
4	Input Indicator Light	Red
5	Output Indicator Light	Green
6	Cable	/

3.3.3 Power Interface

The Helios 32 power interface uses a standard DC 5.5 - 2.1 interface.

When the Interface Box is working normally, the red input and green output indicator lights will be lit. If the external power input is normal, but the indicator lights on the Interface Box are not lit, the Interface Box may be damaged. In this case, please contact Robosense.

3.3.4 RJ45 Ethernet Port

The Helios 32 Ethernet interface follows the EIA/TIA568B standard.

3.3.4.1 GPS Sync Interface

The Helios 32 sync interface is defined as follows: GPS REC is for GPS UART input, and GPS PULSE is for GPS PPS input.

The pin positions of the Interface Box sync interface are shown in Figure 12 .

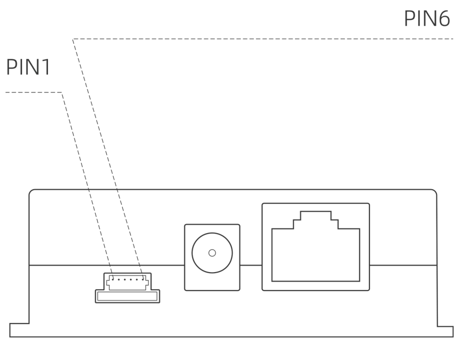


Figure 12 Sync Interface Pin Positions

For the detailed interface definitions, please refer to Table 8.

Table 8 Sync Interface Definitions

Pin Number	Signal
PIN 1	GPS_PPS
PIN 2	+5 V（Output）
PIN 3	GND
PIN 4	GPS_REC
PIN 5	GND
PIN 6	SYNC_OUT1

! Important Note:

When connecting the "Ground" of the Helios 32 LiDAR to an external system, it is crucial that the external system's power supply negative terminal ("Ground") and the GPS system's "Ground" are part of a non-isolated common ground system.

3.4 Quick Connection

The Helios 32 network parameters can be configured, and the default factory setting uses fixed IP and port number mode, as shown in Table 9.

Table 9 Default Factory Network Configuration Table

Device	IP Address	MSOP Package Port Number	DIFOP Package Port Number
Helios 32	192.168.1.200	6699	7788
Computer	192.168.1.102		

When using the product, the user needs to set the computer's IP address to be in the same subnet as the product, for example, 192.168.1.x (where x can be any value between 1 and 254), and the subnet mask is 255.255.255.0. For unknown product network configuration information, please connect the product and use Wireshark to capture the output package of the product for analysis. The IP configuration and connection methods are as follows:

1) Connecting the LiDAR

The connection method is shown in Figure 13 .

a) Connect the LiDAR and Interface Box using the aviation plug.

b) Connect the PC and Interface Box using the RJ45 Ethernet port.

c) After powering on, under normal working conditions, the red and green power indicator lights on the LiDAR's Interface Box will be constantly on. The positions of the indicator lights are shown in Figure 11 .

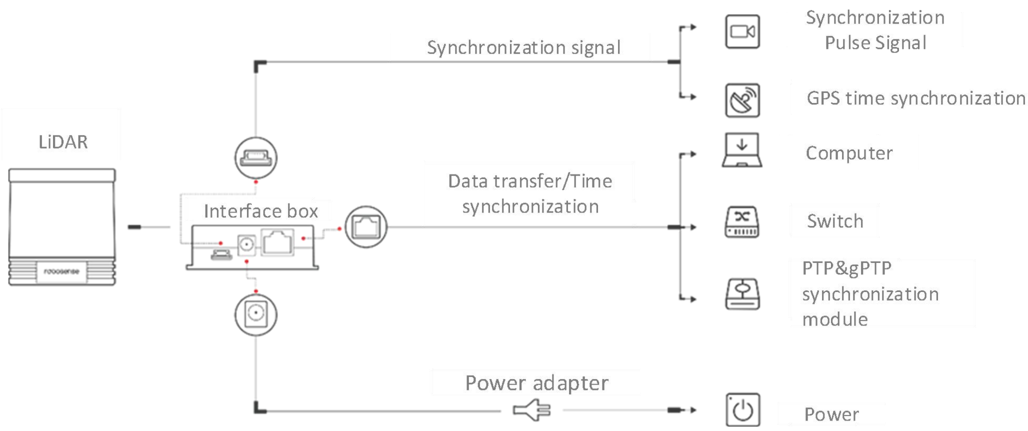


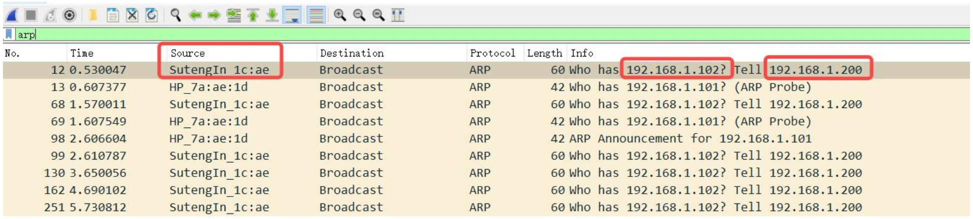
Figure 13 Interface Box Connection Diagram

1) Through the ".pcap" packets captured by Wireshark software, get the Local IP of Computer by analyzing " arp" packets

   a) Perform the following steps after the LiDAR and PC are connected:

   b) Start Wireshark (a third-party network analysis tool) and select the correct network interface to begin capturing packet.

   c) Use the search box in Wireshark and enter "arp" to search for the mutual addressing packets between the LiDAR and PC, as shown in Figure 14 .


arp

No.	Time	Source	Destination	Protocol	Length	Info
12	0.530047	SutengIn 1c:ae	Broadcast	ARP	60	Who has 192.168.1.102? Tell 192.168.1.200
13	0.607377	HP_7a:ae:1d	Broadcast	ARP	42	Who has 192.168.1.101? (ARP Probe)
68	1.570011	SutengIn_1c:ae	Broadcast	ARP	60	Who has 192.168.1.102? Tell 192.168.1.200
69	1.607549	HP_7a:ae:1d	Broadcast	ARP	42	Who has 192.168.1.101? (ARP Probe)
98	2.606604	HP_7a:ae:1d	Broadcast	ARP	42	ARP Announcement for 192.168.1.101
99	2.610787	SutengIn_1c:ae	Broadcast	ARP	60	Who has 192.168.1.102? Tell 192.168.1.200
130	3.650056	SutengIn_1c:ae	Broadcast	ARP	60	Who has 192.168.1.102? Tell 192.168.1.200
162	4.690102	SutengIn_1c:ae	Broadcast	ARP	60	Who has 192.168.1.102? Tell 192.168.1.200
251	5.730812	SutengIn_1c:ae	Broadcast	ARP	60	Who has 192.168.1.102? Tell 192.168.1.200

Figure 14 Analyzing ARP Packets

   d) In Figure 14 , the "SutengIn" in the Source column indicates the source information of the LiDAR, indicating that the Source IP is 192.168.1.200, which is the LiDAR's IP. The request is accessing 192.168.1.102, which is the PC's IP. If the local IP is not the requested access IP, then configure the PC's local IP as 192.168.1.102 as shown in step 3. If the access is successful, proceed to step 4.

2) Configuring the PC's Local IP

   a) In the Control Panel, go to "Network and Internet" and then "Network and Sharing Center." In the "View your active networks" section, click on the corresponding Ethernet connection to enter the corresponding "Ethernet Status," and then click on "Properties."

b) Double-click "Internet Protocol Version 4 (TCP/IPv4)" to enter the IP information settings and use a static IP for configuration.

c) Set the local IP address to 192.168.1.102, subnet mask to 255.255.255.0, and click "OK" to complete the PC's static IP setting.

3) Connection Completed

Note:

1) The time synchronization module (PTP & gPTP, GPS time synchronization module) is not included as a standard product. If you need to use these features, please purchase them separately and follow the connection method shown in Figure 13 .

2) The configuration of the local static IP provided above is only an example for Windows operating systems. For other operating systems, please refer to the actual instructions.

4 Product Usage

4.1 Product Coordinate System

The coordinates and rotation direction of the product are shown in Figure 15 .

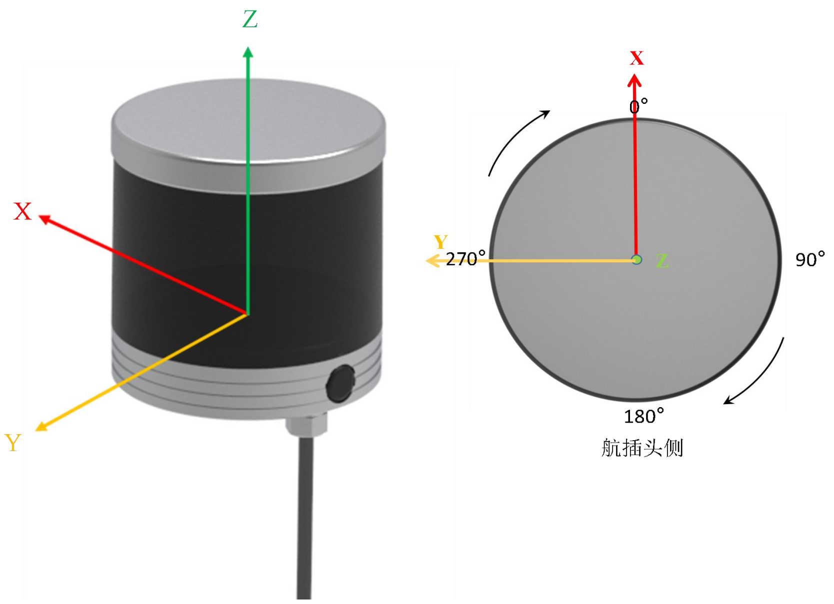


Figure 15 LiDAR Coordinate and Rotation Direction Illustration

Note:
The coordinate origin of the LiDAR is defined at the center of the LiDAR's structure, with a height distance of 63.5 mm from the base.

4.2 Web UI Usage

4.2.1 Web UI Functions

Helios 32 only supports parameter setting, viewing of operational information/status, and firmware upgrades through the web interface.

The Helios 32 web address changes according to the Device IP. The default Device IP is 192.168.1.200. If you have changed the Device IP, the web address will be the newly set IP.

4.2.2 Accessing the Web UI Interface

Once the product is connected and correctly configured as required, use a computer browser to access the product's IP address (default Device IP: 192.168.1.200) to enter the Helios 32 web homepage. The default page is the "Device" tab.

4.2.3 Using the Web UI Interface

For detailed instructions on using the Web UI interface, please refer to Appendix A of the product manual.

4.3 RSView Usage

For data visualization with Helios 32, you can use free tools such as Wireshark and tcp-dump to obtain raw data. RSView can provide a more convenient way to visualize the raw data.

4.3.1 Software Functions

RSView enables real-time visualization of Helios 32 data. It can also replay data saved in ".pcap" file format, but does not support ".pcapng" files at the moment.

In RSView, the distance measurement values obtained by Helios 32 are displayed as points. It supports various custom colors to display data, such as reflection intensity, time, distance, horizontal angle, and laser beam index. The displayed data can be exported and saved in ".csv" format, and RSView version 3.1.3 and later versions support exporting data in ".las" format.

RSView includes the following features:

1) Real-time display of data via Ethernet.
2) Save real-time data as PCAP files.
3) Replay data from recorded PCAP files.
4) Various visualization modes, such as distance, time, horizontal angle, etc.
5) Display point data in tabular format.
6) Export point cloud data as CSV files.
7) Distance measurement tool.
8) Display multiple frames of replayed data simultaneously.

9) Show or hide individual laser beams from Helios 32.

10) Clipping display.

4.3.2 Installing RSView

RSView can be run on Windows 64-bit and Ubuntu 18.04 or higher operating systems. You can download the latest version of RSView software compressed package from the Robosense official website (http://www.robosense.cn/resources). After downloading, make sure the extraction path does not contain Chinese characters. The software does not require installation; simply run the executable file after extraction to use it.

4.3.3 Using RSView

After opening RSView, you can access the user guide by pressing the F1 button or by clicking on the "RS-LiDAR User Guide" option in the Help menu.

4.4 Communication Protocols

Helios 32 communicates with a computer via Ethernet using UDP (User Datagram Protocol). The communication protocols between Helios 32 and the computer fall into two categories, as described in Table 10.

Table 10 Protocol Overview

Protocol Name	Abbreviation	Function	Type	Packet Size	Send Interval
Main data Stream Output Protocol	MSOP	Point cloud data	UDP	1248 bytes	Approx. 666.67 us
Device Information Output Protocol	DIFOP	LiDAR information output	UDP	1248 bytes	Approx. 1 s

Note:

1) Section 4.4 of the product manual describes and defines the payload (1248 bytes) of the protocols.
2) The Main Data Stream Output Protocol (MSOP) encapsulates the laser scanning data, including distance, angle, and reflection intensity, into packets for output.
3) The Device Information Output Protocol (DIFOP) outputs various configuration information about the current state of Helios 32.

4.4.1 MSOP and DIFOP Data Protocols

The UDP packets sent by Helios 32 have a payload of 1248 bytes. The data structure for the Main Data Stream Output Protocol (MSOP) and Device Information Output Protocol (DIFOP) is shown in Figure 16 .

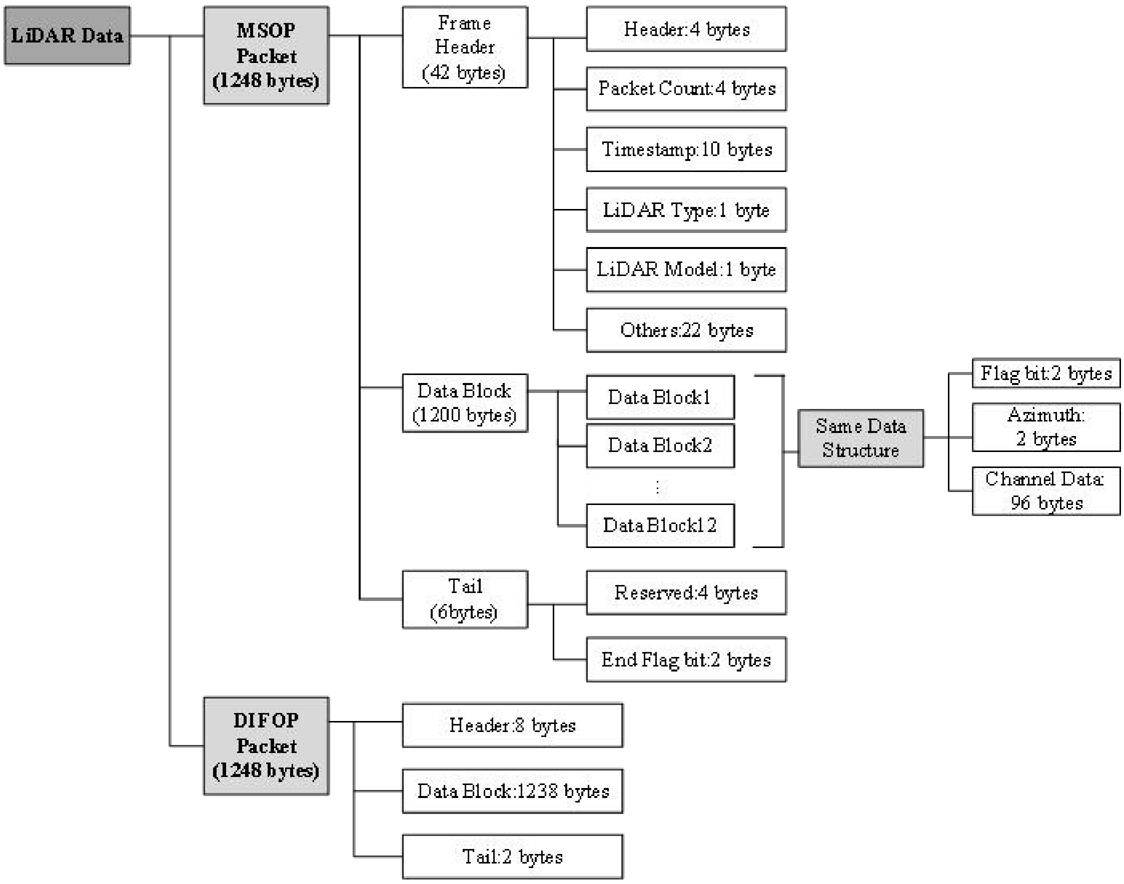


Figure 16 LiDAR Data Structure Illustration

4.4.2 Main Data Stream Output Protocol (MSOP)

Main Data Stream Output Protocol, abbreviated as MSOP, is used for product output and computer parsing. The default port number is 6699.

4.4.2.1 Header

The header consists of 42 bytes and is used to identify the start of the data. The data structure details are shown in Table 11.

Table 11 MSOP Header Data Table

Header(42 bytes)			
Field	**Offset**	**Length (byte)**	**Definition**
Header ID	0	4	55_aa_05_5a
Reserved	4	8	/
Packet Count	12	4	/
Reserved	16	4	/
Timestamp	20	10	The first 6 bytes represent seconds, and the last 4 bytes represent microseconds.
Reserved	30	1	/
LiDAR Type	31	1	It is used to indicate the series of the LiDAR 0x06：Helios
LiDAR Model	32	1	0x01：Helios 32（70° FOV：-55°～+15°） 0x02：Helios 32（31° FOV：-16°～+15°） 0x03：Helios 16 0x04：Helios 32（26° FOV：-16°～+10°）
Reserved	33	9	/

Note:

The defined timestamp is used to record the system time with a resolution of 1 us. For specific details, refer to Appendix C.11 in the product manual for time definition.

4.4.2.2 Data Block Interval

As shown in Table 12, the Data Block interval is the measurement part of the MSOP (Measurement Data Stream Output) packet from the sensor, and it consists of a total of 1200 bytes. The Data Block is composed of 12 individual blocks, each with a length of 100 bytes, representing a complete set of ranging data.

Within each 100-byte Data Block, the space is structured as follows:2 bytes for the flag, represented by the value 0xffee.2 bytes for the Azimuth, which indicates the horizontal rotation angle information. Each azimuth angle corresponds to 32 channels of data, containing one complete set of information for 32 channels. (The relationship between channel numbers and vertical angles can be found in the product manual's Appendix D).

Table 12 Data Block Packet Definition

Description	Data Block (1200 bytes)			
Data Block Number	Data Block 1	Data Block 2	…	Data Block 12
Flag	0xff,0xee	0xff,0xee	…	0xff,0xee
Horizontal Rotation Angle	Azimuth 1	Azimuth 2	…	Azimuth 12
Channel 1	Channel data 1	Channel data 1	…	Channel data 1
Channel 2	Channel data 2	Channel data 2	…	Channel data 2
…	...	...	…	...
Channel 32	Channel data 32	Channel data 32	…	Channel data 32

Note:

In dual-return mode, the odd-numbered columns of Data Block store the first return, while the even-numbered columns store the second return.

1) Channel Data Definition

The channel data, Channel data, is represented by 3 bytes. The high two bytes represent the distance information, and the low byte represents the reflectivity information, as shown in Table 13.

Table 13 Channel Data Representation

Channel data（3 bytes）		
2 bytes Distance		1 byte Reflectivity
Distance1 [15:8]	Distance2 [7:0]	Reflectivity(Reflectivity information)

Note:

Distance is represented by 2 bytes with a resolution of 0.25 cm.

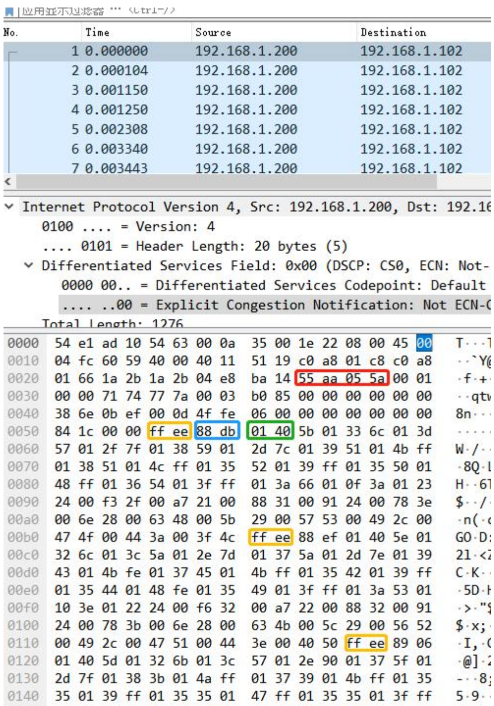


Figure 17 MSOP Packet Illustration

Red box: Header ID

Yellow box: Data Block flag

Blue box: Azimuth value for Channel data 1

Green box: Distance value for Channel data 1

The distance value in the data packet can be calculated as follows:

a) The distance value in hexadecimal: 0x01, 0x40
b) Combine the data to form a 16-bit unsigned integer: 0x0140
c) Convert the distance value to a decimal number: 320
d) Perform calculations based on the different distance resolutions.
e) Result: 320 × 0.25 cm = 80 cm

The angle value in the data packet can be calculated as follows:

a) The angle value in hexadecimal: 0x88, 0xdb
b) Combine the data to form a 16-bit unsigned integer: 0x88db
c) Convert the value to a decimal number: 35035
d) Divide the converted decimal value by 100
e) Result: 35035° / 100 = 350.35°

2) Angle Value Definition:

In each Data Block, the angle value output by Helios 32 represents the angle of the first channel's laser ranging in that Block. The angle value is derived from the angle encoder, where the encoder's zero position corresponds to the zero angle point. The resolution of the horizontal rotation angle value is 0.01°.

4.4.2.3 Tail

The tail consists of 6 bytes, with 4 bytes reserved information and 2 bytes of 0x00, 0xFF.

4.4.3 Device Info Output Protocol (DIFOP)

Device Info Output Protocol, abbreviated as DIFOP, is used for product output and computer reading. The default port number is 7788.

DIFOP is an "output-only" protocol used to periodically send information such as product serial number (S/N), firmware version, computer driver compatibility information, configuration information, angle information, running status, fault diagnosis, etc., to users. Users can read DIFOP to interpret specific information about the currently used product.

A complete DIFOP packet has a data format structure of synchronization header, data area, and tail. Each data packet consists of 8 bytes of synchronization header, 1238 bytes of data area (Data), and 2 bytes of tail. The basic structure of the data packet is shown in Table 14.

Table 14 Data Format Structure of DIFOP Packet

Section	Index	Information	Offset	Length (byte)	Remarks
Header	0	DIFOP Identifier	0	8	a5_ff_00_5a_11_11_55_55
Data	1	Motor Speed Setting	8	2	Appendix C.1
	2	Ethernet	10	22	Appendix C.2
	3	FOV Setting Value	32	4	Appendix C.3
	4	Reserved	36	2	/
	5	Motor Phase Locking	38	2	Appendix C.4
	6	Mainboard Firmware	40	5	Appendix C.5
	7	Bottom Board Firmware	45	5	Appendix C.6
	8	Bottom Board Software	50	5	Appendix C.7
	9	Motor Firmware	55	5	Appendix C.8
	10	Reserved	60	232	/
	11	Serial Number	292	6	Appendix C.9
	12	Reserved	298	2	/
	13	Return Mode	300	1	Section 2.5.3.2
	14	Time Synchronization	301	2	Appendix C.10
	15	Time	303	10	Appendix C.11
	16	Operating Status	313	18	Appendix C.12
	17	Reserved	331	17	/
	18	Fault Diagnosis	342	18	Appendix C.13
	19	Reserved	360	22	/
	20	GPRMC Data	382	86	Appendix C.14
	21	Vertical Angle Calibration	468	96	Appendix C.15
	22	Horizontal Angle Calibration	564	96	Appendix C.16
	23	Reserved	660	586	/
Tail	24	Frame End	1246	2	0f_f0

Note:

1) The Header (DIFOP Identifier) content is 0xA5, 0xFF, 0x00, 0x5A, 0x11, 0x11,

0x55, 0x55, and can be used as a check sequence for the packet. The Tail (Frame Tail) content is 0x0F, 0xF0.

2) The definition and usage of each item's register can be found in Appendix C of the product manual, and the corresponding relationships are detailed in the Remarks column of Table 14.

5 Product Maintenance

5.1 Transportation and Logistics

! Important

Improper transportation can cause product damage!

1) The product should be packaged with shockproof and moisture-proof materials to avoid damage during transportation. It is recommended to use the original packaging;
2) Handle with care during transportation to avoid impact or dropping;
3) When receiving the goods, carefully check the delivery list for any damages (including the product and packaging);
4) If there is any transportation damage, refuse to accept the delivery and contact RoboSense promptly.

5.2 Storage

! Important

Improper storage may cause product damage!

1) Store the product in an indoor environment with normal temperature and dry conditions;
2) Handle the product gently to avoid impact or dropping;
3) The product should be stored in a safe environment to avoid corrosion, mechanical impact, or exposure to environments exceeding the protection level;
4) Regularly inspect the condition of all components and packaging, and it is recommended to check every three months.

5.3 Product Cleaning

To ensure accurate perception of the surrounding environment, keep the RS-LiDAR's circular protective cover clean.

5.3.1 Precautions

! Before cleaning the RS-LiDAR, carefully read and understand the content of this section. Improper cleaning may damage the product.

! When using the LiDAR in harsh environmental conditions, clean the surface regularly to keep the LiDAR clean. Otherwise, it may affect the normal operation of the LiDAR.

5.3.2 Required Materials

1) Clean and dust-free cloth;
2) Neutral solution at moderate temperature (such as soapy water, distilled water, 99% concentration of ethanol, etc.).

5.3.3 Cleaning Method

1) If the LiDAR surface is only covered with some dust:

   a) Use a clean and dust-free cloth, dip it in a small amount of neutral solution;

   b) Gently wipe the LiDAR surface;

   c) Dry it with a clean and dry dust-free cloth.

2) If the LiDAR surface is covered with mud or other solid foreign objects:

   a) First, spray clean water on the dirty part of the LiDAR surface to remove the mud or foreign objects (Note: Do not directly wipe off the mud with a dust-free cloth, as it may scratch the surface, especially the protective cover);

   b) Then spray warm soapy water on the dirty part. The lubricating effect of the soapy water helps to remove the foreign objects. Gently wipe the LiDAR surface with a fiber cloth, but be careful not to scratch the surface;

   c) Finally, rinse off the residual soap on the LiDAR surface with clean water (if there is still residue, clean it again with 99% ethanol) and dry it with a clean and dry dust-free cloth.

6 Fault Diagnosis

This chapter lists some common problems encountered during the use of the product and their corresponding troubleshooting methods. For details, refer to Table 15.

Table 15 Common Fault Troubleshooting Methods

Fault Phenomenon	Solution
Red/Green Indicator Light on the Interface Box is Not On/Flashing	Check if the connection line between the interface box and the power supply terminal is loose; Check if the cable harness is damaged.
The Product Motor Does Not Rotate	Check if the indicator light on the interface box is normal; Check if the connection line between the interface box and the power supply/product terminal is loose and if the cable harness is damaged.
The Product Keeps Restarting During Startup	Check the input power connection and polarity; Check if the voltage and current of the input power meet the requirements (when 12V voltage is applied, the input current should be ≥ 2A); Check if the installation plane of the product is level or if the screws on the bottom of the LiDAR are tightened too tightly.
The Product Internally Rotates, But There is No Data	Check if the LiDAR emits light normally; Check if the network connection is normal; Confirm if the computer-side network configuration is correct; Use other software (such as Wireshark) to check if the data is received; Disable the firewall and other security software that may block the network; Check if the power supply is normal; Try restarting the product.
Wireshark Can Receive Data, But RSView Does Not Display Point Cloud	Close the computer's firewall and run RSView through the firewall; Confirm that the computer's IP configuration matches the destination address set in the product; Confirm that the Sensor Network Configuration in RSView is set correctly; Confirm that the installation directory or configuration file storage directory of RSView does not contain any Chinese characters; Confirm that the data packets received by Wireshark are of

	the MSOP type.

Table 15 (Continuation)

Fault Phenomenon	Solution
The Product Has Frequent Data Loss	Confirm if there is a large number of other network packets or network conflicts in the network; Confirm if there are other network products sending a large amount of data in broadcast mode, causing sensor data blocking; Confirm if the computer's performance and interface performance meet the requirements; Remove all other network products and directly connect to the computer to confirm if data loss occurs.
Unable to Synchronize GPS/PTP/gPTP Time	Confirm if the synchronization mode has been switched to the correct mode on the web page; Under the GPS+PPS time synchronization mode: Confirm if the GPS module's baud rate is 9600 bps, 8 data bits, no parity bit, and 1 stop bit; Confirm if the GPS module outputs 3.3V TTL or RS232 level; Confirm if the 1PPS pulse is continuous and the wiring is correct; Confirm if the NMEA message format of GPRMC is correct; Confirm if the GPS module and interface box share the same ground; Confirm if the GPS module receives a valid fix; Confirm if the GPS module is validly positioned (outdoors); Under the PTP / gPTP time synchronization mode: Confirm if the PTP / gPTP Master synchronization protocol complies with the current PTP / gPTP protocol; Confirm if the PTP / gPTP Master is working properly.
No Data Output After Passing Through the Router	Close the DHCP function of the router or set the IP address of the sensor to the correct IP address internally in the router.
ROS Driver Displays a Fixed Blank Area Rotating When Showing Point Cloud	This phenomenon is normal. It occurs because the ROS driver splits the data into fixed packages for frame display. The blank part of the data will be displayed in the next frame.
RSView software outputs point clouds as a single ray	For Windows 10 systems, set RSView to run in Windows 7 compatibility mode to resolve the issue.

Note:

If the above troubleshooting steps fail to resolve the issue, please contact RoboSense for further assistance.

7 After-sales Service

If the solutions provided in Chapter 6 of the troubleshooting guide do not solve the problem, please promptly contact RoboSense.

Official Website: https://www.robosense.cn/contact

Email: support@robosense.cn

Phone: 0755-86325830 / 15338772453

Additional Information:

1) Please wait for a confirmation response from RoboSense after-sales service before sending the product back.
2) When sending the product back, please use the original packaging or an equivalent cushioned and moisture-resistant packaging.

Appendix A Web UI Operation

A.1 Product Information

The web interface of the LiDAR provides the default product information page, as shown in Figure 18 :

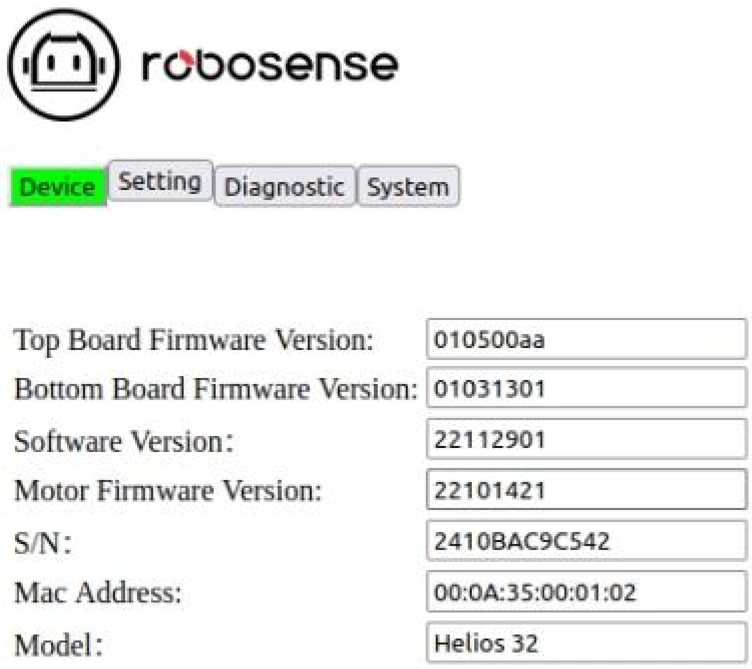


Figure 18 Web Interface Home Page

1) Top Board: Mainboard firmware version.
2) Bottom Board: Baseboard firmware version.
3) Software Version: Software version.
4) Motor Firmware Version: Motor version.
5) S/N: Product serial number.
6) Mac Address: MAC address.
7) Model: Product name.

A.2 Product Parameter Settings

The "Setting" tab on the web page is the LiDAR parameter setting page where you can change Device IP, Port number, Return mode, Rotation speed, and Angle trigger settings. The illustrations and descriptions are shown in Figure 19 and Figure 20 :

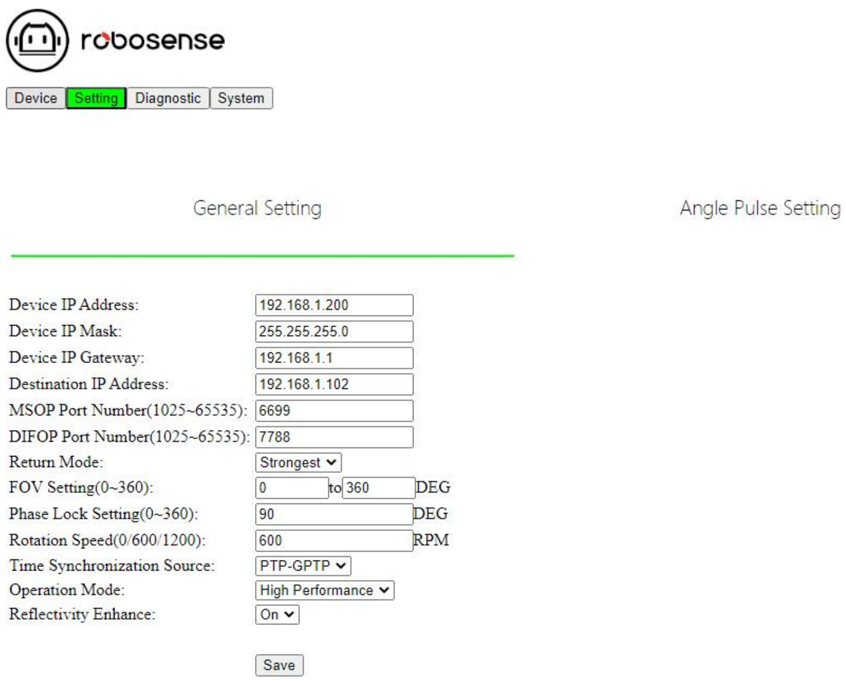


Figure 19 Web Interface LiDAR Settings

1) Support unicast (default) / broadcast mode. Set the Destination IP to 255.255.255.255 for broadcast mode. The default factory setting is 192.168.1.102.
2) The data ports for MSOP and DIFOP can be changed, with a value range of 1025 to 65535.
3) Dropdown options for "Return Mode" include strongest (default) / last / first / dual return modes.
4) FOV (Field of View) can be set within the angle range of 0 to 360 degrees. Once set, only point cloud data within the specified FOV will be output.
5) The designated rotation speed can be set to 300 rpm, 600 rpm (default), or 1200 rpm.
6) Dropdown options for "Time Synchronization Source" include GPS, PTP-P2P, PTP-E2E-L4, PTP-E2E-L2, and PTP-gPTP to determine the time synchronization

method.

7) Dropdown options for "Operation Mode" include Standby / High Performance (default) modes. In Standby mode, the LiDAR motor and transmitter stop working.

8) Dropdown options for "Reflectivity Enhance" offer different reflectivity mapping modes. "OFF" represents the original reflectivity mode, while "On" enables lane enhancement mode to improve lane distinction.

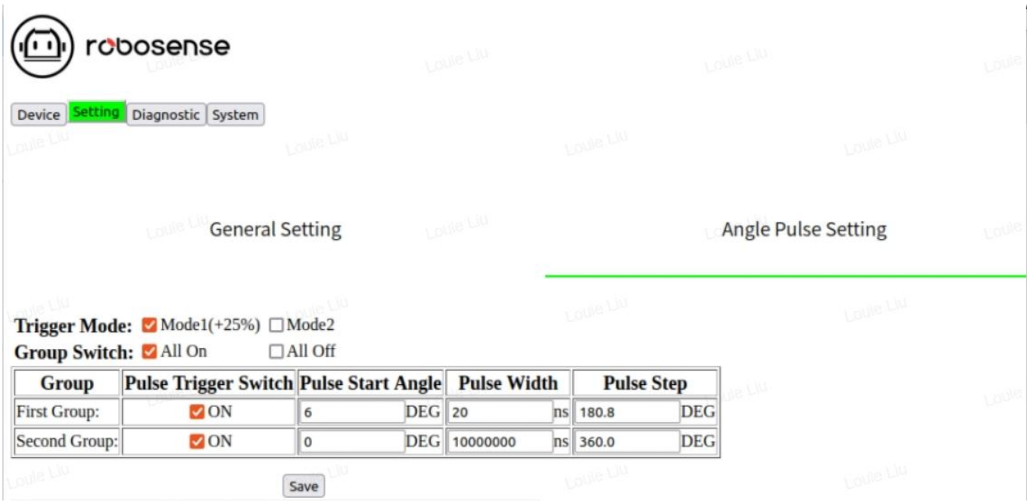


Figure 20 Web UI Angle Trigger Settings

1) Angle Pulse Setting: Configure angle-triggering function in this section. The angle-triggering function is turned off by default.

2) Trigger Mode: There are two starting angle modes. Mode 1 increases the starting pulse width by 25% (default), and Mode 2 keeps the starting pulse width unchanged.

3) Group Switch: Enable/Disable "Pulse Trigger Switch." When "All On" is checked, all SYNC trigger settings are enabled. The default is "All Off."

4) Group: This section corresponds to SYNC OUT groups. Helios 32 contains SYNC OUT1 & SYNC OUT2, but the power box only connects to SYNC OUT1. Refer to Table 8 for specific definitions.

5) Pulse Trigger Switch: Enable/Disable the triggering function. When Pulse Trigger Switch is checked "ON," the options become editable; when unchecked, they are grayed out and not editable.

6) Pulse Start Angle: Set the corresponding starting angle, with a default value of 0°.

Input values format must be integer.

7) Pulse Width: Set the corresponding pulse width, with a default value of 10 ms. Input values must be multiples of 20 ns, and the duty cycle can go up to a maximum of 50%.

8) Pulse Step: Set the corresponding pulse step, the default value format must be floating with resolution of 0.1 degree.

Note:

1) Device IP and Destination IP should be in the same network segment; otherwise, the connection may fail.
2) The values for MSOP and DIFOP range from 1025 to 65535, and MSOP port and DIFOP port cannot be set to the same port.
3) After making changes, click "Save" to apply the settings. A successful prompt indicates that the settings have taken effect.

A.3 Product Diagnostics / Operating Status

This page allows real-time monitoring of the LiDAR's operating status, including voltage, current, real-time speed, runtime, temperature, and other information, as shown in Figure 21 :

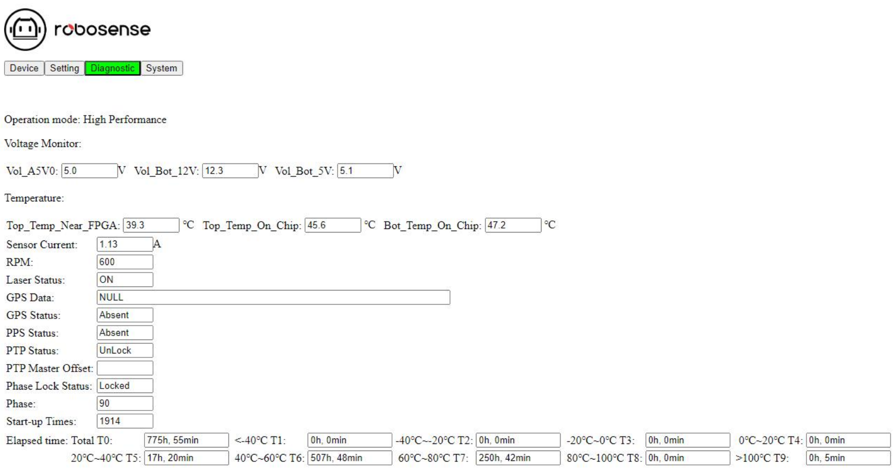


Figure 21 Web Interface Operating Status / Diagnostics

1) Voltage Monitor: Monitors the product's voltage. When the product is in Standby mode, this section will be highlighted in red.

2) User can view the current operating temperature of the product.

3) User can check the RPM (Rotations Per Minute) to get real-time information about the current rotational speed of the product.

4) Laser Status: The laser can be set to either "On" (default) or "Off." When the product is set to Standby mode, it will be set to "Off."

5) User can view the Start-up Times to get the total number of times the product has been started. The count increases by one each time the power is cycled and the product restarts.

6) User can check the Elapsed time Total T0 to get the overall running time of the product and the accumulated working time of the product at various temperatures.

ⓘ Note:

1) The page refresh rate is 1 second.

2) If the voltage/current section turns red, please check if the product is in Standby mode. If not, check if the product is operating normally.

A.4 Product Firmware Upgrade

Click on the "System" on the web page. This page allows the firmware upgrade for the mainboard, baseboard, software, web interface, and motor. Follow the steps below:

1) Contact RoboSense to obtain the upgrade firmware. Once the firmware is ready, click "Choose File," as shown in Figure 22 .

Figure 22 Step 1 - Click "Choose File"

2) Select the folder containing the corresponding firmware for the upgrade, then click "Open" (avoid using Chinese characters in the file path), as shown in Figure 23 .

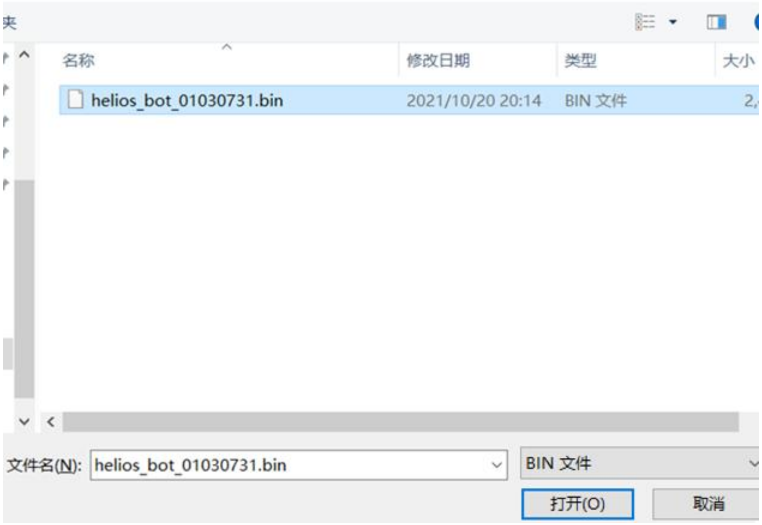


Figure 23 Step 2 - Select Firmware for Upgrade

3) After selecting the firmware for upgrade, the filename will change to the selected firmware name, indicating that it is successfully loaded, as shown in Figure 24 . Click "Update" to proceed with the upgrade.

Figure 24 Step 3 - Click "Update"

4) After successfully updating the firmware, the web page will display a success message, and the product will automatically restart. Once the restart is complete, you can log back in to the web page homepage to check if the firmware version has been upgraded successfully, as shown in Figure 25 .

```
Init for upgrade, please wait...
Init ...
Init ***
Bottom Board Firmware is Upgrading...
Erasing 0%
Erasing 19%
Erasing 39%
Erasing 59%
Erasing 79%
Erasing 99%
Bot bin Erase Complete! Begin to Write...
Writing 0%
Writing 19%
Writing 39%
Writing 50%
Writing 69%
Writing 89%
Successful! Update the new firmware of bottom board! Lidar is rebooting!
```

Figure 25 Step 4 - Upgrade Successful

Note:

1) The upgrade package names must meet the following requirements to ensure successful firmware upgrade. Otherwise, errors may occur:
2) Mainboard upgrade file: Sequential logic requires the necessary prefix "Helios *top*" and the necessary suffix ".bin".
3) Bottom board upgrade file: Sequential logic requires the necessary prefix "Helios *bot*" and the necessary suffix ".bin".
4) Software upgrade file: Sequential logic requires the necessary prefix "Helios *app*" and the necessary suffix ".elf".
5) Web App upgrade file: Sequential logic requires the necessary prefix "Helios *cgi*" and the necessary suffix ".tar.gz".
6) Motor upgrade file: Sequential logic requires the necessary prefix "Helios *mot*" and the necessary suffix ".hex".

Appendix B ROS & ROS2 Package

rslidar_sdk is the ROS-based driver SDK. You can download it from the RoboSense GitHub repository or contact RoboSense for access.

1) rslidar_sdk depends on rs_driver, which is the basic RoboSense driver. Download rs_driver from the GitHub platform.
2) If you are using ROS2, rslidar_sdk also depends on rslidar_msg, which defines the message format. Download the msg file from the GitHub platform.
3) The SDK package contains comprehensive usage guidelines. Before using the driver SDK, please read the README file and documentation under the doc folder.

Note:

SDK Download Link: https://github.com/RoboSense-LiDAR/rsLiDAR_sdk

rs_driver Download Link: https://github.com/RoboSense-LiDAR/rs_driver

msg Download Link: https://github.com/RoboSense-LiDAR/rslidar_msg

Appendix C Register Definitions

This appendix provides additional information to section 4.4, defining the various registers in the protocol. All calculations are in big-endian format. The "Value" represents the decimal value obtained after converting the offset bytes.

C.1 Motor Speed (MOT_SPD) Register

Table 16 Motor Speed Register

Motor Speed Register (2 bytes)		
Index	byte 1	byte 2
Function	MOT_SPD	

Register Description:

1) This register is used to read the motor speed setting value.
2) For example, if the set value is 600 RPM, and the byte 1 = 0x02 and byte 2 = 0x58, then the Value = 600 RPM.

C.2 Ethernet (ETH) Register

Table 17 Ethernet Register

Ethernet Register (22 bytes)								
Index	byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7	byte 8
Function	LIDAR_IP				DEST_PC_IP			
Index	byte 9	byte 10	byte 11	byte 12	byte 13	byte 14	byte 15	byte 16
Function	MAC_ADDR						MSOP	
Index	byte 17	byte 18	byte 19	byte 20	byte 21	byte 22	/	/
Function	Reserved		DIFOP		Reserved		/	

Register Description:

1) LIDAR_IP: The source IP address of the LiDAR, occupying 4 bytes.
2) DEST_PC_IP: The IP address of the destination PC, occupying 4 bytes.
3) MAC_ADDR: The MAC address of the LiDAR.
4) MSOP and DIFOP each occupy 2 bytes.

C.3 FOV Setting (FOV_SET) Register

Table 18 FOV Setting Register

FOV Setting Register (4 bytes)				
Index	byte 1	byte 2	byte 3	byte 4
Function	FOV_START		FOV_END	

ⓘ Register Description:

1) This register is used to read the FOV (Field of View) setting value.
2) FOV_START and FOV_END have a range of 0 to 36000, corresponding to angles from 0 to 360°. Details are as follows:

   a) FOV_START: byte 1 = 0x5d, byte 2 = 0xc0, Value = 24000.

   b) FOV_END: byte 3 = 0x1f, byte 4 = 0x40, Value = 8000.

   c) With two decimal places, the FOV range is set to 240° to 80°.

C.4 Motor Phase (MOT_PHASE) Register

Table 19 Motor Phase Register

Motor Phase Register (2 bytes)		
Index	byte 1	byte 2
Function	MOT_PHASE	

ⓘ Register Description

1) This register is used to read the motor lock phase setting.
2) MOT_PHASE ranges from 0 to 360, corresponding to angles from 0° to 360°.Details are as follows:

   a) MOT_PHASE: byte 1=0x00, byte 2=0x64, Value=100

   b) Indicates that the motor lock phase is set to 100°.

C.5 Main Board Firmware Version (TOP_FRM)

Table 20 Main Board Firmware Version

Main board firmware version (5 bytes)					
Index	byte 1	byte 2	byte 3	byte 4	byte 5
Function	TOP_FRM				

ⓘ Register Description

If byte 1=0x00, byte 2=0x01, byte 3=0x05, byte 4=0x05, byte 4=0x00, then the firmware version is 00 01 05 05 00.

C.6 Bottom Board Firmware Version (BOT_FRM)

Table 21 Bottom Board Firmware Version

Bottom board firmware version (5 bytes)					
Index	byte 1	byte 2	byte 3	byte 4	byte 5
Function	BOT_FRM				

ⓘ Register Description

If byte 1=0x00, byte 2=0x01, byte 3=0x05, byte 4=0x05, byte 4=0x00, then the firmware version is: 00 01 05 05 00.

C.7 APP Software Version (SOF_FRM)

Table 22 Software Version

APP software version (5 bytes)					
Index	byte 1	byte 2	byte 3	byte 4	byte 5
Function	SOF_FRM				

ⓘ Register Description

If byte 1=0x00, byte 2=0x01, byte 3=0x03, byte 4=0x10, byte 4=0x00, then the firmware version is: 00 01 03 10 00.

C.8 Motor Firmware Version (MOT_FRM)

Table 23 Motor Firmware Version

Motor firmware version (5 bytes)					
Index	byte 1	byte 2	byte 3	byte 4	byte 5
Function	MOT_FRM				

ⓘ Register Description

If byte 1=0x00, byte 2=0x22, byte 3=0x10, byte 4=0x14, byte 4=0x21, then the firmware version is: 00 22 10 14 21.

C.9 Serial Number (SN)

Table 24 Serial Number Register

Serial Number Register (6 bytes)						
Index	byte 1	byte 2	byte 3	byte 4	byte 5	byte 6
Function	SN					

ⓘ Register Description:

1) Similar to a MAC address, the 6-byte hexadecimal value indicates the product's serial number.

C.10 Time Synchronization Information (TIME_SYNC_INF)

Table 25 Time Synchronization Information Register

Time Synchronization Information Register (2 bytes)		
Index	byte 1	byte 2
Function	Time_Sync_Mode	Time_Sync_State

ⓘ Register Description:

1) Byte 1 indicates the time synchronization mode state, defined as follows:

   0x00: GPS sync

   0x01: E2E-L4 sync

   0x02: P2P sync

   0x03: gPTP sync

   0x04: E2E-L2 sync

2) Byte 2 indicates the time synchronization success state, defined as follows:

   0x00: Not synchronized

   0x01: GPS sync successful

   0x02: PTP sync successful

C.11 Time (UTC_TIME)

Table 26 Time Register

Time Register (10 bytes)										
Index	byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7	byte 8	byte 9	byte10
Function	sec						us			

ⓘ Register Description:

The value of 'us' ranges from 0 to 999999.

C.12 Operating Status (STATUS)

Table 27 Operating Status Register

Operating Status Register (18 bytes)								
Index	byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7	byte 8
Function	Whole Machine Current		Reserved		Whole Machine Voltage		Bottom Board 5V	
Index	byte 9	byte 10	byte 11	byte 12	...	...	byte 28	byte 29
Function	Mainboard 5V		Internal Debug Use					

ⓘ Register Description:

1) The value of the whole machine current consists of 2 bytes. The current calculation formula is:

   Whole Machine Current = Value / 4096 × 5A

2) Helios 32 has 3 routes of monitored voltage values, with each voltage value consisting of 2 bytes. The calculation formulas for each voltage are as follows:

   Whole Machine Voltage = Value / 4096 × 24.5

   Bottom Board 5 V = Value / 4096 × 11

   Mainboard 5 V = Value / 4096 × 10

3) The unit for the above voltage calculation formulas is volts (V).

C.13 Fault Diagnosis (FAULT_DIGS)

Table 28 Fault Diagnosis Register

Fault Diagnosis Register (40 bytes)								
Index	byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7	byte 8
Function	Bottom Board FPGA Temperature		Internal Debug Use				Mainboard Bottom Surface Temperature	
Index	byte 9	byte 10	byte 11	byte 12	byte 13	...	...	byte 17
Function	Mainboard FPGA Temperature		Real-time RPM		Internal Debug Use			
Index	byte 18	byte 18	byte 19	...	...	byte 38	byte 39	byte 40
Function	GPS Status	Internal Debug Use						

Table 29 GPS Signal Input Status Register (GPS_ST)

Sequence Function Status Value Status Description			
Sequence	**Function**	**Status Value**	**Status Description**
bit 0	PPS Flag: PPS_LOCK	0	PPS signal invalid
		1	PPS signal valid
bit 1	GPRMC Flag: GPRMC_LOCK	0	GPRMC signal invalid
		1	GPRMC signal valid
bit 2	UTC Lock Flag: UTC_LOCK	0	UTC time not synchronized
		1	UTC time synchronized
bit 3	GPRMC Input Status	0	No input
		1	Input available
bit 4	PPS Input Status	0	No input
		1	Input available
bit 5 ~ bit7	Reserved	x	N/A

ⓘ Register Description:

1) Helios 32 has 3 routes of monitored temperature, with each temperature consisting of 2 bytes. The temperature calculation formulas are:

   Bottom Board FPGA Temperature = 503.975 × Value / 4096 - 273.15

   Mainboard Bottom Surface Temperature = 200 × Value / 4096 - 50

   Mainboard FPGA Temperature = 503.975 × Value / 4096 - 273.15

2) Byte 18 is the GPS signal input status register. It uses 3 bits to indicate whether the connected PPS signal and GPRMC signal are valid and whether the system time is synchronized to UTC. Bit definitions are shown in Table 29.

   Real-time RPM = Value, consists of 2 bytes.

C.14 GPRMC Data Packet - ASCII Code Data

The GPRMC data packet reserves 86 bytes to store the received GPRMC message, which is output from the external GPS module. The data can be parsed and viewed in ASCII code.

C.15 Vertical Angle Calibration (COR_VERT_ANG)

Table 30 Vertical Angle Calibration Register

Vertical Angle Calibration Register (96 bytes)									
Index	byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7	byte 8	byte 9
Function	Channel 1 Vertical Angle			Channel 2 Vertical Angle			Channel 3 Vertical Angle		
Index	byte 10	byte 11	byte 12	byte 13	byte 14	byte 15	byte 16	byte 17	byte 18
Function	Channel 4 Vertical Angle			Channel 5 Vertical Angle			Channel 6 Vertical Angle		
Index	byte 19	byte 20	byte 21	byte 22	byte 23	byte 24	byte 25	byte 26	byte 27
Function	Channel 7 Vertical Angle			Channel 8 Vertical Angle			Channel 9 Vertical Angle		
Index	byte 28	byte 29	byte 30	byte 31	byte 32	byte 33	byte 34	byte 35	byte 36
Function	Channel 10 Vertical Angle			Channel 11 Vertical Angle			Channel 12 Vertical Angle		
Index	byte 37	byte 38	byte 39	byte 40	byte 41	byte 42	byte 43	byte 44	byte 45
Function	Channel 13 Vertical Angle			Channel 14 Vertical Angle			Channel 15 Vertical Angle		
Index	byte 46	byte 47	byte 48	byte 49	byte 50	byte 51	byte 52	byte 53	byte 54
Function	Channel 16 Vertical Angle			Channel 17 Vertical Angle			Channel 18 Vertical Angle		
Index	byte 55	byte 56	byte 57	byte 58	byte 59	byte 60	byte 61	byte 62	byte 63
Function	Channel 19 Vertical Angle			Channel 20 Vertical Angle			Channel 21 Vertical Angle		
Index	byte 64	byte 65	byte 66	byte 67	byte 68	byte 69	byte 70	byte 71	byte 72
Function	Channel 22 Vertical Angle			Channel 23 Vertical Angle			Channel 24 Vertical Angle		
Index	byte 73	byte 74	byte 75	byte 76	byte 77	byte 78	byte 79	byte 80	byte 81
Function	Channel 25 Vertical Angle			Channel 26 Vertical Angle			Channel 27 Vertical Angle		
Index	byte 82	byte 83	byte 84	byte 85	byte 86	byte 87	byte 88	byte 89	byte 90
Function	Channel 28 Vertical Angle			Channel 29 Vertical Angle			Channel 30 Vertical Angle		
Index	byte 91	byte 92	byte 93	byte 94	byte 95	byte 96	/	/	/
Function	Channel 31 Vertical Angle			Channel 32 Vertical Angle			/		

Register Description:

1) The angle value is represented as positive or negative. Each channel's vertical angle is composed of 3 bytes, where the first byte indicates whether it is positive or negative, and the second and third bytes together form the angle's value.
2) To determine the sign (positive or negative) of the angle, check the attribute of the first byte. If the attribute of the first byte is 0x00, the channel's vertical angle is positive. If the attribute is 0x01, the channel's vertical angle is negative.
3) The angle resolution is 0.01°.
4) For example, if the value of the Channel 1 register is byte 1=0x00 (positive value), byte 2=0x00, and byte 3=0xE7 (converted to decimal 231). Then, the vertical angle value of Channel 1 is 2.31°.

C.16 Horizontal Angle Calibration (COR_HOR_ANG)

Table 31 Horizontal Angle Calibration Register

Horizontal Angle Calibration Register (96 bytes)									
Index	byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7	byte 8	byte 9
Function	Channel 1 Horizontal Angle			Channel 2 Horizontal Angle			Channel 3 Horizontal Angle		
Index	byte 10	byte 11	byte 12	byte 13	byte 14	byte 15	byte 16	byte 17	byte 18
Function	Channel 4 Horizontal Angle			Channel 5 Horizontal Angle			Channel 6 Horizontal Angle		
Index	byte 19	byte 20	byte 21	byte 22	byte 23	byte 24	byte 25	byte 26	byte 27
Function	Channel 7 Horizontal Angle			Channel 8 Horizontal Angle			Channel 9 Horizontal Angle		
Index	byte 28	byte 29	byte 30	byte 31	byte 32	byte 33	byte 34	byte 35	byte 36
Function	Channel 10 Horizontal Angle			Channel 11 Horizontal Angle			Channel 12 Horizontal Angle		
Index	byte 37	byte 38	byte 39	byte 40	byte 41	byte 42	byte 43	byte 44	byte 45
Function	Channel 13 Horizontal Angle			Channel 14 Horizontal Angle			Channel 15 Horizontal Angle		
Index	byte 46	byte 47	byte 48	byte 49	byte 50	byte 51	byte 52	byte 53	byte 54
Function	Channel 16 Horizontal Angle			Channel 17 Horizontal Angle			Channel 18 Horizontal Angle		
Index	byte 55	byte 56	byte 57	byte 58	byte 59	byte 60	byte 61	byte 62	byte 63
Function	Channel 19 Horizontal Angle			Channel 20 Horizontal Angle			Channel 21 Horizontal Angle		
Index	byte 64	byte 65	byte 66	byte 67	byte 68	byte 69	byte 70	byte 71	byte 72
Function	Channel 22 Horizontal Angle			Channel 23 Horizontal Angle			Channel 24 Horizontal Angle		
Index	byte 73	byte 74	byte 75	byte 76	byte 77	byte 78	byte 79	byte 80	byte 81
Function	Channel 25 Horizontal Angle			Channel 26 Horizontal Angle			Channel 27 Horizontal Angle		
Index	byte 82	byte 83	byte 84	byte 85	byte 86	byte 87	byte 88	byte 89	byte 90
Function	Channel 28 Horizontal Angle			Channel 29 Horizontal Angle			Channel 30 Horizontal Angle		
Index	byte 91	byte 92	byte 93	byte 94	byte 95	byte 96	/	/	/
Function	Channel 31 Horizontal Angle			Channel 32 Horizontal Angle			/		

ⓘ Register Description:

1) The angle value is represented as positive or negative. Each channel's horizontal angle is composed of 3 bytes, where the first byte indicates whether it is positive or negative, and the second and third bytes together form the angle's value.
2) To determine the sign (positive or negative) of the angle, check the attribute of the first byte. If the attribute of the first byte is 0x00, the channel's horizontal offset angle is positive. If the attribute is 0x01, the channel's horizontal offset angle is negative.
3) The angle resolution is 0.01°.
4) For example, if the value of Channel 1's register is byte 1=0x01 (negative angle), byte 2=0x00, and byte 3=0x04 (converted to decimal, it is 4), then Channel 1's horizontal offset angle is -0.04°.

Appendix D Accurate Point Time Calculation

In each MSOP Packet, there are 12 Blocks, and each Block contains a complete set of 32-channel laser data. Therefore, one Packet consists of 12 complete sets of laser data. It takes 55.56 microseconds for all 32 channels to complete one round of transmission and charging.

Helios 32 has added anti-interference measures, so the emission timing is not regular. For the time calculation of single return and double return points, please refer to Table 32 and Table 33.

Table 32 Time Offset of Each Single Return Laser Point in MSOP Packet (us)

Data Block											
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
0	55.56	111.12	166.68	222.24	277.8	333.36	388.92	444.48	500.04	555.6	611.16
1.73	57.29	112.85	168.41	223.97	279.53	335.09	390.65	446.21	501.77	557.33	612.89
3.46	59.02	114.58	170.14	225.7	281.26	336.82	392.38	447.94	503.5	559.06	614.62
5.19	60.75	116.31	171.87	227.43	282.99	338.55	394.11	449.67	505.23	560.79	616.35
6.92	62.48	118.04	173.6	229.16	284.72	340.28	395.84	451.4	506.96	562.52	618.08
8.65	64.21	119.77	175.33	230.89	286.45	342.01	397.57	453.13	508.69	564.25	619.81
10.38	65.94	121.5	177.06	232.62	288.18	343.74	399.3	454.86	510.42	565.98	621.54
12.11	67.67	123.23	178.79	234.35	289.91	345.47	401.03	456.59	512.15	567.71	623.27
13.84	69.4	124.96	180.52	236.08	291.64	347.2	402.76	458.32	513.88	569.44	625
15.57	71.13	126.69	182.25	237.81	293.37	348.93	404.49	460.05	515.61	571.17	626.73
17.3	72.86	128.42	183.98	239.54	295.1	350.66	406.22	461.78	517.34	572.9	628.46
19.03	74.59	130.15	185.71	241.27	296.83	352.39	407.95	463.51	519.07	574.63	630.19
20.76	76.32	131.88	187.44	243	298.56	354.12	409.68	465.24	520.8	576.36	631.92
22.49	78.05	133.61	189.17	244.73	300.29	355.85	411.41	466.97	522.53	578.09	633.65
24.22	79.78	135.34	190.9	246.46	302.02	357.58	413.14	468.7	524.26	579.82	635.38
25.95	81.51	137.07	192.63	248.19	303.75	359.31	414.87	470.43	525.99	581.55	637.11
27.68	83.24	138.8	194.36	249.92	305.48	361.04	416.6	472.16	527.72	583.28	638.84
29.41	84.97	140.53	196.09	251.65	307.21	362.77	418.33	473.89	529.45	585.01	640.57
31.14	86.7	142.26	197.82	253.38	308.94	364.5	420.06	475.62	531.18	586.74	642.3
32.87	88.43	143.99	199.55	255.11	310.67	366.23	421.79	477.35	532.91	588.47	644.03
34.6	90.16	145.72	201.28	256.84	312.4	367.96	423.52	479.08	534.64	590.2	645.76
36.33	91.89	147.45	203.01	258.57	314.13	369.69	425.25	480.81	536.37	591.93	647.49
38.06	93.62	149.18	204.74	260.3	315.86	371.42	426.98	482.54	538.1	593.66	649.22
39.79	95.35	150.91	206.47	262.03	317.59	373.15	428.71	484.27	539.83	595.39	650.95
41.52	97.08	152.64	208.2	263.76	319.32	374.88	430.44	486	541.56	597.12	652.68

Table 32 (Continuation)

Data Block											
1	2	3	4	5	6	7	8	9	10	11	12
43.25	98.81	154.37	209.93	265.49	321.05	376.61	432.17	487.73	543.29	598.85	654.41
44.98	100.54	156.1	211.66	267.22	322.78	378.34	433.9	489.46	545.02	600.58	656.14
46.71	102.27	157.83	213.39	268.95	324.51	380.07	435.63	491.19	546.75	602.31	657.87
48.44	104	159.56	215.12	270.68	326.24	381.8	437.36	492.92	548.48	604.04	659.6
50.17	105.73	161.29	216.85	272.41	327.97	383.53	439.09	494.65	550.21	605.77	661.33
51.9	107.46	163.02	218.58	274.14	329.7	385.26	440.82	496.38	551.94	607.5	663.06
53.63	109.19	164.75	220.31	275.87	331.43	386.99	442.55	498.11	553.67	609.23	664.79

Table 33 Time Offset of Each Dual Return Laser Point in MSOP Packet (us)

Data Block											
1	2	3	4	5	6	7	8	9	10	11	12
0.00	0.00	55.56	55.56	111.12	111.12	166.68	166.68	222.24	222.24	277.80	277.80
1.74	1.74	57.30	57.30	112.86	112.86	168.42	168.42	223.98	223.98	279.54	279.54
3.47	3.47	59.03	59.03	114.59	114.59	170.15	170.15	225.71	225.71	281.27	281.27
5.21	5.21	60.77	60.77	116.33	116.33	171.89	171.89	227.45	227.45	283.01	283.01
6.94	6.94	62.50	62.50	118.06	118.06	173.62	173.62	229.18	229.18	284.74	284.74
8.68	8.68	64.24	64.24	119.80	119.80	175.36	175.36	230.92	230.92	286.48	286.48
10.42	10.42	65.98	65.98	121.54	121.54	177.10	177.10	232.66	232.66	288.22	288.22
12.15	12.15	67.71	67.71	123.27	123.27	178.83	178.83	234.39	234.39	289.95	289.95
13.89	13.89	69.45	69.45	125.01	125.01	180.57	180.57	236.13	236.13	291.69	291.69
15.62	15.62	71.18	71.18	126.74	126.74	182.30	182.30	237.86	237.86	293.42	293.42
17.36	17.36	72.92	72.92	128.48	128.48	184.04	184.04	239.60	239.60	295.16	295.16
19.10	19.10	74.66	74.66	130.22	130.22	185.78	185.78	241.34	241.34	296.90	296.90
20.83	20.83	76.39	76.39	131.95	131.95	187.51	187.51	243.07	243.07	298.63	298.63
22.57	22.57	78.13	78.13	133.69	133.69	189.25	189.25	244.81	244.81	300.37	300.37
24.30	24.30	79.86	79.86	135.42	135.42	190.98	190.98	246.54	246.54	302.10	302.10
26.04	26.04	81.60	81.60	137.16	137.16	192.72	192.72	248.28	248.28	303.84	303.84
27.78	27.78	83.34	83.34	138.90	138.90	194.46	194.46	250.02	250.02	305.58	305.58
29.51	29.51	85.07	85.07	140.63	140.63	196.19	196.19	251.75	251.75	307.31	307.31
31.25	31.25	86.81	86.81	142.37	142.37	197.93	197.93	253.49	253.49	309.05	309.05
32.98	32.98	88.54	88.54	144.10	144.10	199.66	199.66	255.22	255.22	310.78	310.78
34.72	34.72	90.28	90.28	145.84	145.84	201.40	201.40	256.96	256.96	312.52	312.52
36.46	36.46	92.02	92.02	147.58	147.58	203.14	203.14	258.70	258.70	314.26	314.26
38.19	38.19	93.75	93.75	149.31	149.31	204.87	204.87	260.43	260.43	315.99	315.99
39.93	39.93	95.49	95.49	151.05	151.05	206.61	206.61	262.17	262.17	317.73	317.73
41.66	41.66	97.22	97.22	152.78	152.78	208.34	208.34	263.90	263.90	319.46	319.46
43.40	43.40	98.96	98.96	154.52	154.52	210.08	210.08	265.64	265.64	321.20	321.20
45.14	45.14	100.70	100.70	156.26	156.26	211.82	211.82	267.38	267.38	322.94	322.94

Table 33 (Continuation)

Data Block											
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
46.87	46.87	102.43	102.43	157.99	157.99	213.55	213.55	269.11	269.11	324.67	324.67
48.61	48.61	104.17	104.17	159.73	159.73	215.29	215.29	270.85	270.85	326.41	326.41
50.34	50.34	105.90	105.90	161.46	161.46	217.02	217.02	272.58	272.58	328.14	328.14
52.08	52.08	107.64	107.64	163.20	163.20	218.76	218.76	274.32	274.32	329.88	329.88
53.82	53.82	109.38	109.38	164.94	164.94	220.50	220.50	276.06	276.06	331.62	331.62

Appendix E Channel Capability Range Chart for Various Models

Table 34 70° FOV - Channel Capability Range Chart

Channel No.	Vertical Angle(°)	Range @ 10% Target Reflectivity (m)	Maximum Range (m)
1	15	90	100
2	13	90	100
3	11	90	100
4	9	90	100
5	7	90	100
6	5.5	90	100
7	4	110	150
8	2.67	110	150
9	1.33	110	150
10	0	110	150
11	-1.33	110	150
12	-2.67	110	150
13	-4	110	150
14	-5.33	90	100
15	-6.67	90	100
16	-8	90	100
17	-10	40	50
18	-16	40	50
19	-13	40	50
20	-19	40	50
21	-22	40	50
22	-28	40	50
23	-25	40	50
24	-31	40	50
25	-34	40	50
26	-37	40	50
27	-40	40	50
28	-43	40	50
29	-46	20	30
30	-49	20	30
31	-52	20	30
32	-55	10	20

Table 35 31° FOV - Channel Capability Range Chart

Channel No.	Vertical Angle(°)	Range @ 10% Target Reflectivity (m)	Maximum Range (m)
18	15	90	120
2	14	90	120
17	13	90	120
1	12	90	120
20	11	90	120
4	10	110	150
19	9	110	150
3	8	110	150
22	7	110	150
6	6	110	150
21	5	110	150
5	4	110	150
24	3	110	150
8	2	110	150
23	1	110	150
7	0	110	150
26	-1	110	150
10	-2	110	150
25	-3	110	150
9	-4	110	150
28	-5	110	150
12	-6	110	150
27	-7	110	150
11	-8	110	150
30	-9	110	150
14	-10	110	150
29	-11	90	120
13	-12	90	120
32	-13	90	120
16	-14	90	120
31	-15	90	120
15	-16	90	120

Table 36 26° FOV - Channel Capability Range Chart

Channel No.	Vertical Angle(°)	Range @ 10% Target Reflectivity (m)	Maximum Range (m)
16	10	90	120
32	7	90	120
14	5	110	150
30	3.5	110	150
31	3	110	150
7	2.5	110	150
12	2	110	150
23	1.5	110	150
15	1	110	150
28	0.5	110	150
29	0	110	150
5	-0.5	110	150
10	-1	110	150
21	-1.5	110	150
13	-2	110	150
26	-2.5	110	150
27	-3	110	150
3	-3.5	110	150
8	-4	110	150
19	-4.5	110	150
11	-5	110	150
24	-5.5	110	150
25	-6	110	150
1	-6.5	110	150
6	-7	110	150
9	-8	110	150
22	-9	90	120
4	-10	90	120
17	-11	90	120
20	-12	90	120
2	-13.5	90	120
18	-16	90	120

Appendix F Channel Ranging Capability Table

Table 37 Channel Ranging Capability

Real Reflectivity	Reflectivity Enhance	Real Reflectivity	Reflectivity Enhance	Real Reflectivity	Reflectivity Enhance	Real Reflectivity	Reflectivity Enhance	Real Reflectivity	Reflectivity Enhance	Real Reflectivity	Reflectivity Enhance
1	1	44	68	87	106	130	144	173	183	216	221
2	1	45	69	88	107	131	145	174	183	217	222
3	1	46	70	89	108	132	146	175	184	218	222
4	2	47	71	90	109	133	147	176	185	219	223
5	3	48	71	91	110	134	148	177	186	220	224
6	4	49	72	92	111	135	149	178	187	221	225
7	7	50	73	93	112	136	150	179	188	222	226
8	8	51	73	94	112	137	151	180	189	223	227
9	9	52	74	95	113	138	151	181	190	224	228
10	10	53	76	96	114	139	152	182	190	225	229
11	15	54	77	97	115	140	153	183	191	226	229
12	17	55	78	98	116	141	154	184	192	227	230
13	20	56	79	99	117	142	155	185	193	228	231
14	24	57	80	100	118	143	156	186	194	229	232
15	27	58	81	101	119	144	157	187	195	230	233
16	31	59	81	102	119	145	158	188	196	231	234
17	34	60	82	103	120	146	159	189	197	232	235
18	37	61	83	104	121	147	159	190	198	233	236
19	40	62	84	105	122	148	160	191	198	234	237
20	42	63	85	106	123	149	161	192	199	235	237
21	44	64	86	107	124	150	162	193	200	236	238
22	48	65	87	108	125	151	163	194	201	237	239
23	49	66	88	109	126	152	164	195	202	238	240
24	50	67	89	110	127	153	165	196	203	239	241
25	51	68	90	111	127	154	166	197	204	240	242
26	52	69	91	112	128	155	167	198	205	241	243
27	53	70	92	113	129	156	168	199	206	242	244

28	54	71	92	114	130	157	168	200	206	243	245

Table 37 (Continuation)

Real Reflectivity	Reflectivity Enhance	Real Reflectivity	Reflectivity Enhance	Real Reflectivity	Reflectivity Enhance	Real Reflectivity	Reflectivity Enhance	Real Reflectivity	Reflectivity Enhance	Real Reflectivity	Reflectivity Enhance
29	55	72	93	115	131	158	169	201	207	244	245
30	56	73	94	116	132	159	170	202	208	245	246
31	57	74	95	117	133	160	171	203	209	246	247
32	58	75	95	118	134	161	172	204	210	247	248
33	59	76	96	119	135	162	173	205	211	248	249
34	60	77	97	120	136	163	174	206	212	249	250
35	60	78	98	121	136	164	175	207	213	250	251
36	61	79	99	122	137	165	175	208	214	251	252
37	62	80	100	123	138	166	176	209	214	252	253
38	63	81	101	124	139	167	177	210	215	253	253
39	64	82	102	125	140	168	178	211	216	254	255
40	65	83	103	126	141	169	179	212	217	255	255
41	66	84	104	127	142	170	180	213	218	/	/
42	67	85	105	128	143	171	181	214	219	/	/
43	68	86	106	129	143	172	182	215	220	/	/

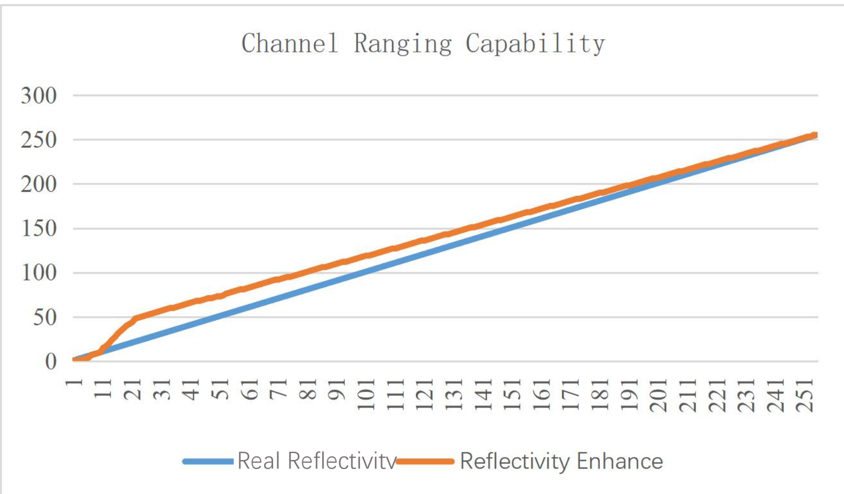
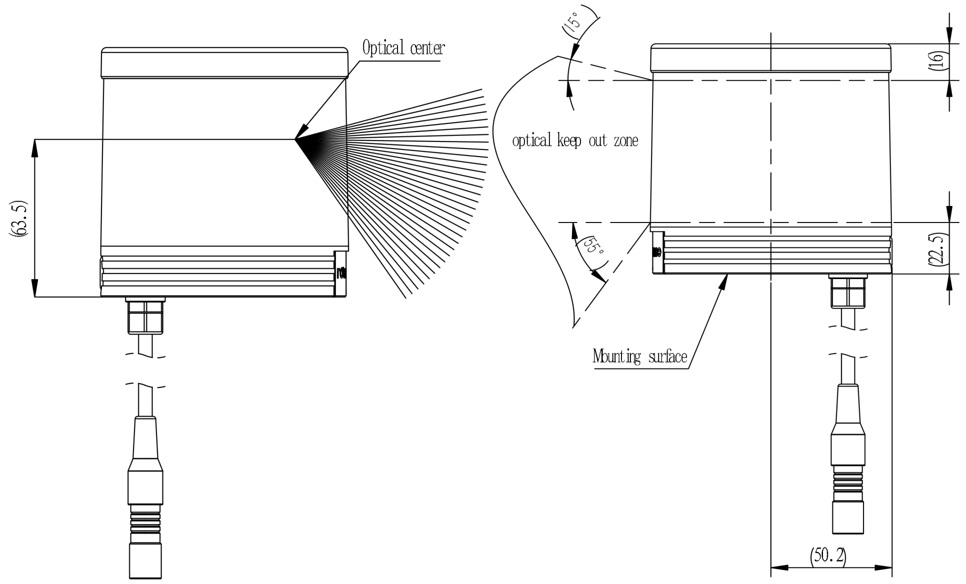


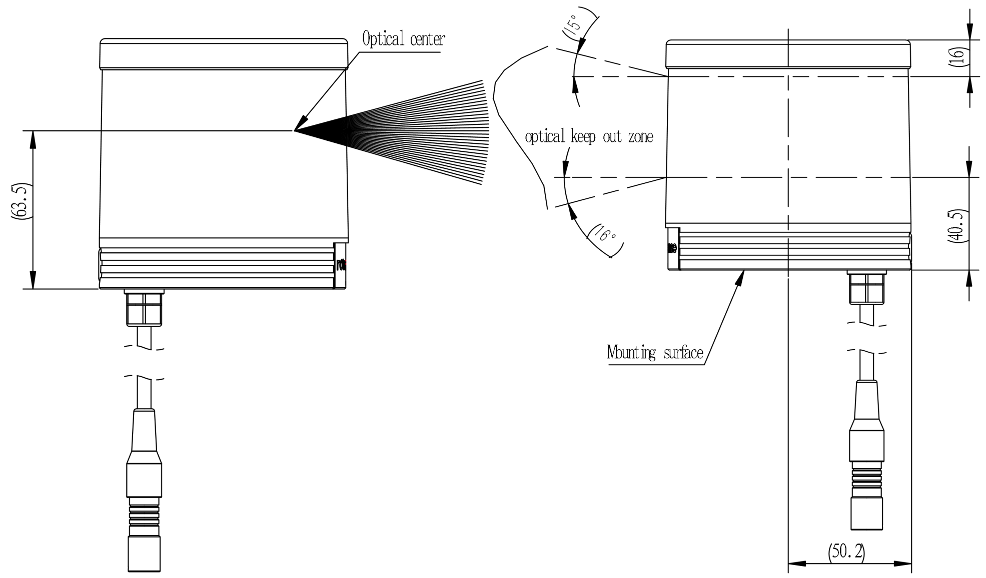
Figure 26 Reflectivity Mapping Chart

Appendix G Mechanical Drawings

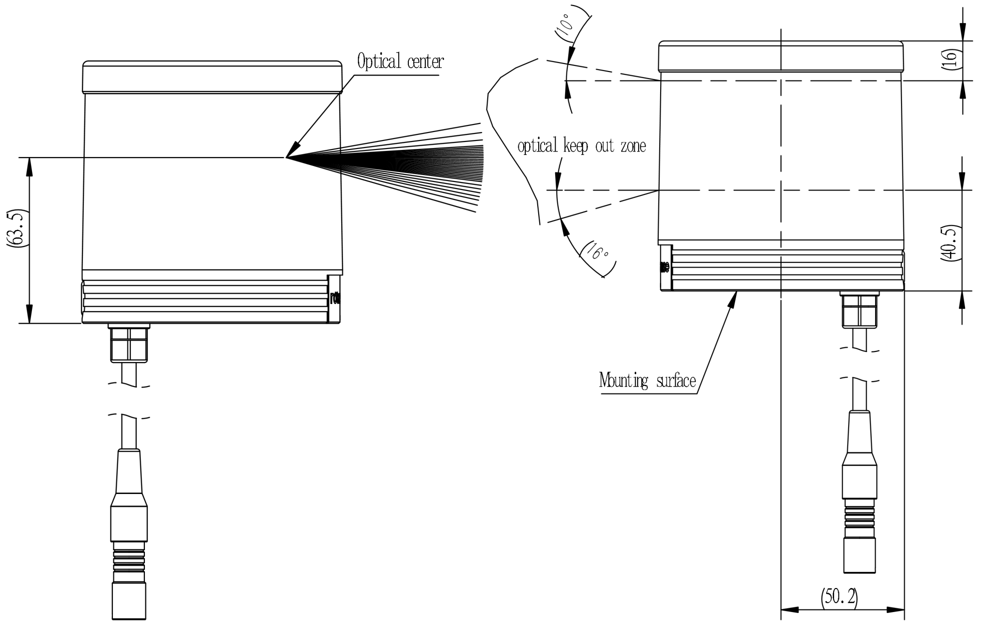
70° FOV：



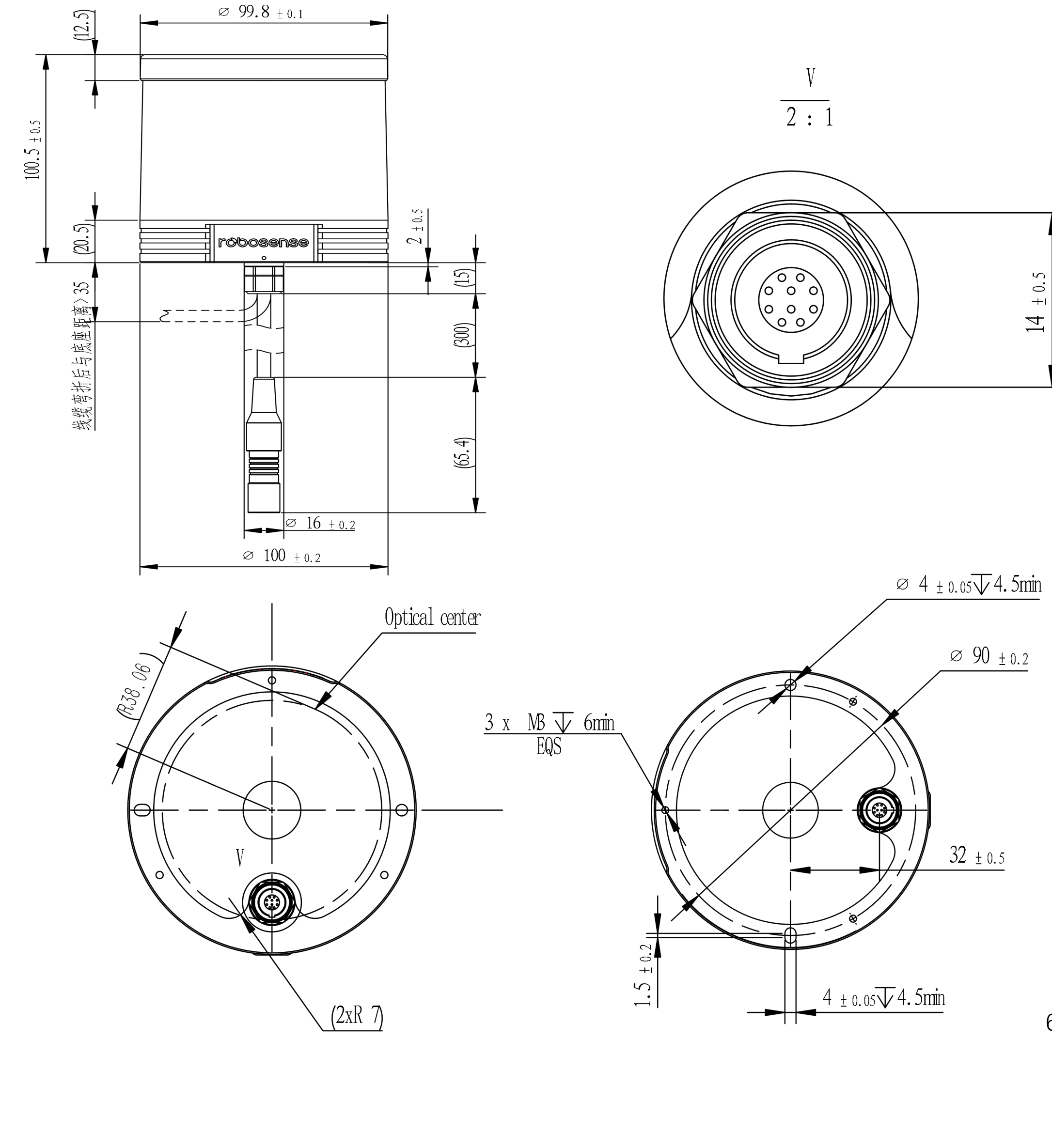
31° FOV：



26° FOV：



Common:



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