0755-86325830

RS-Ruby Lite

User Manual

www.robosense.ai

Revision History

Version Number	Description	Date	Edited by
1.0.0	Initial release	2020-08-03	PD
1.0.1	1.Add Quick Start of LiDAR Mounting 2.Adjust accuracy to +/- 3cm 3.Add the Calculation of exact Time Point	2020-09-01	PD

Terminology

MSOP	Main data Stream Output Protocol
DIFOP	Device Information Output Protocol
FOV	Field of View
PTP	Precision Time Protocol
NTP	Network Time Protocol
GPS	Global Positioning System
UTC	Universal Time Coordinated
Wave_mode	Flag of Wave Mode
Temp	Temperature Information
Resv	Reservation
Symbol	Symbol Bit
Ret_id	Identification of Return Wave
Azimuth	Horizontal Angle of LiDAR
Timestamp	Time Point of Encapsulation of a UDP Packet
Header	The Header of a UDP Packet
Tail	The Tail of a UDP Packet
Thermolysis	Loss of Heat from the Object

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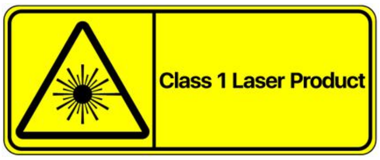
Congratulations on your purchase of a RS-Ruby LiDAR Sensor. Please read carefully this User's Manual before operating the product. Wish you have a pleasurable product experience with RS-Ruby.

1 Safety Notice

In order to reduce the risk of electric shock and to avoid violating the warranty, Please do not privately open the housing and modify the structure of LiDAR.

- **Laser safety**-The laser safety complies with IEC60825-1:2014:



- **Read Instructions** - All safety and operating instructions should be read before operating the product.

- **Caution** - Warning hot surface.

- **Follow the Instructions** - All operating and use instructions should be followed.

- **Retain Instructions** -The safety and operating instructions should be retained for future reference.

- **Heed Warnings** - All warnings on the product and in the operating instructions should be adhered to.

- **Maintenance** - The user should not attempt to maintain the product beyond what is described in the operating instructions. All other Maintenance should be referred to RoboSense.

2 Introduction

RS-Ruby Lite, the 80-beam LiDAR developed by RoboSense, is the world leading multi-beam LiDAR that is particularly utilized in perception of environment for autonomous driving.
RS-Ruby Lite is realized by solid-state hybrid LiDAR. The technical details are listed below:

- measurement rang: 230 meters
- accuracy: ± 3 centimeter
- Data rate: up to 1,440,000 points/second (signal return)
- Horizontal field of view (FOV): 360°
- Vertical field of view (FOV): -25°~15°

80 emitters in RS-Ruby Lite can supply high-frequency laser impulse to scan environment around LiDAR by rapidly spinning optical module. Advanced digital signal processing and ranging algorithms calculate point cloud data and reflectivity of objects to enable the machine to "see" the world and to provide reliable data for localization, navigation and obstacle perception.

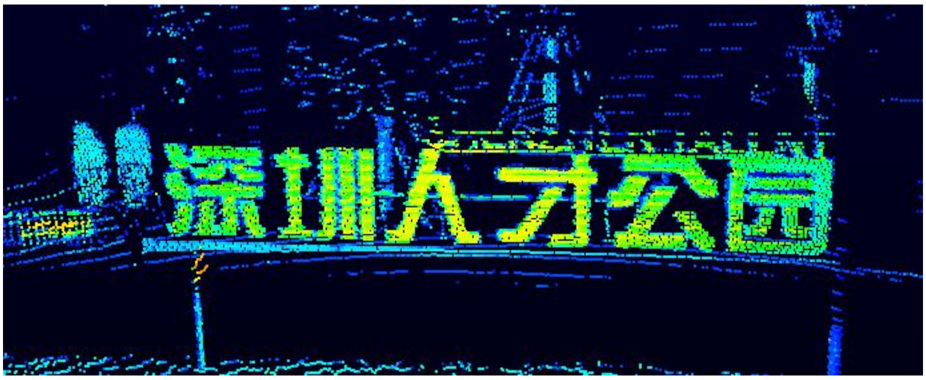


Figure 1: Representation of RS-Ruby Lite Imaging.

The basic operating Instructions of LiDAR:

- Connect the device of RS-Ruby Lite with PC;
- Parse the data packets to capture the values of azimuth, measure distances and calibrated reflectivity;
- Calculate X, Y, Z coordinates from reported azimuth, measured distance, and vertical angle;
- Store the data of point cloud according to demand;
- Check the status of set-up information of device;
- Reset the status of network configuration, timing and rotation speed according to demand.

3 Product Specifications[1]

Table 1: Product Parameters.

Sensor	● TOF measuring distance, including the reflectivity ● 80 channels ● Range: from 1m to 230m (160m@10%NIST)[2] ● Accuracy: ±3cm (typical value)[3] ● FOV(vertical): -25°~+15° ● Angle resolution(vertical): at least 0.1° ● FOV (horizontal): 360° ● Angle resolution (horizontal/ azimuth): 0.1°(5Hz)/0.2° (10 Hz)/0.4° (20 Hz) ● Rotation speed: 300/600/1200 rpm (corresponding to 5/10/20 Hz)
Laser	● Class 1 ● Wavelength: 905nm ● Full angle of beam divergence: horizontal 1.5 mrad, vertical 3.6 mrad
Output	● Data rate: ~1.44 million points/second ● 1000M Base Ethernet LAN interface ● Communication protocol: UDP ● The Information that is included in Data Segment: Distance Rotation angle/Azimuth Calibrated reflectivity Timestamp (Timer resolution 1 us)
Mechanical/ Electrical/ Operational	● Power consumption: 38 W(typical)[4] ● Working voltage: 19-32 VDC (19V is recommended) ● Weight: 3.75kg ● Dimensions: Diameter 166mm × Height 148.5mm ● Ingress Protection Rating: IP67 ● Operation temperature: -30℃~+60℃[5] ● Storage temperature: -40℃~+85℃

[1] The following data is only for mass-produced products. Any samples, testing machines and other non-mass-produced versions may not be referred to this specification. If you have any questions, please contact RoboSense sales.
[2] The measurement target of rang is a 10% NIST Diffuse Reflectance Calibration Targets, the test performance is depending on circumstance factors, not only temperature, range and reflectivity but also including other uncontrollable factors.
[3] The measurement target of accuracy is a 50% NIST Diffuse Reflectance Calibration Targets, the test performance is depending on circumstance factors, not only temperature, range and reflectivity but also including other uncontrollable factors.
[4] The test performance of power consumption is depending on circumstance factors, not only temperature, range and reflectivity but also including other uncontrollable factors.
[5] The operating temperature is depending on circumstance factors, not only light condition, air flow but also including other uncontrollable factors.

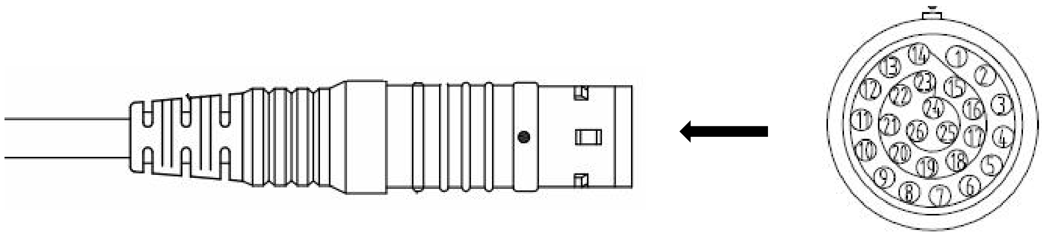
4 Interface

4.1 Power Supply

The supply voltage should remain in the range of 19~32 VDC with utilization of Interface-Box. The recommend supply voltage is 19 VDC. The power consumption is about 38 W.

4.2 Data Output Interface of LiDAR

The data output access of RS-Ruby Lite is physically protected by an aviation terminal connector. From the LiDAR to the aviation connector the cable length is 1 meter. The pins of the aviation terminal connector are defined as follow:



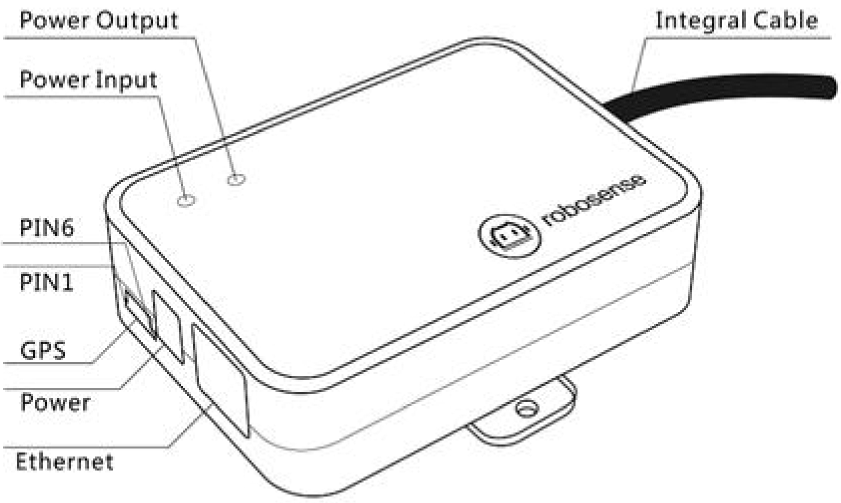
Pin	Wire Color	Function
1	Black/Brown	GROUND
2	Black	Gigabit network differential signal
3	Brown	Gigabit network differential signal
4	Black/Green	GROUND
5	Red	Gigabit network differential signal
6	Orange	Gigabit network differential signal
7	White/Orange	GROUND
8	Yellow	Gigabit network differential signal
9	Green	Gigabit network differential signal
10	White/Purple	GROUND
11	Blue	Gigabit network differential signal
12	Purple	Gigabit network differential signal
13	Yellow/Brown	GROUND
14	Black/Red	GROUND
15	Black/Orange	PWR
16	Black/Yellow	PWR
17	White/Black	PWR
18	White/Brown	PWR
19	White/Red	PWR
20	White/Yellow	PWR
21	White/Green	Reserved serial signal

22	White/Blue	Reserved serial signal
23	Yellow/Green	GPS_PULSE
24	Yellow/Gray	GPS_REC
25	Yellow/Blue	Reserved signal
26	Yellow/Purple	GROUND

Figure 2: Aviation Connector Pin Number of RS-Ruby Lite.

4.3 Interface Box

In order to connect the RS-Ruby Lite conveniently, there is an interface box provided.
There are accesses for power supply, Ethernet and GPS on the Interface Box. Meanwhile, there are also indicator LEDs for checking the status of power supply.
For those accesses, a SH1.0-6P female connector is the interface for GPS signal input. Another interface is a DC 5.5~2.1 female connector for power input. The last one is a Rj45 Ethernet connector for RS-Ruby Lite data transport. The cable on Interface-Box with Aviation connector is 3m. If you have other requests for cable length, please contact technical support of RoboSense. The definition of GPS PIN map and corresponding voltage level are shown as follow:



Pin No.	Function
1	GPS_PULSE
2	+5V
3	GND
4	GPS_REC
5	GND
6	NC

Figure 3: Interface Definition of Interface Box.

Notice: When RS-Ruby Lite connects its grounding system with an external system, the external power supply system should share the same grounding system with that of the GPS.
When the power input is in order, the red LED which indicates the power input status will be

lighted. The green LED lights always by default. While red LED is dark, Interface Box is in protection status. While red or green LED (GPS Module connected) is dark, please check whether the power supply is out of order or damaged. If it is not intact, that could prove that the Interface Box is damaged. Please send the damaged Interface Box back to RoboSense Service.

GPS interface definition: GPS REC stands for GPS input, GPS PULSE stands for GPS PPS input.

Interface of power supply is standard DC 5.5-2.1 connector.

4.4 Interface Box Connection

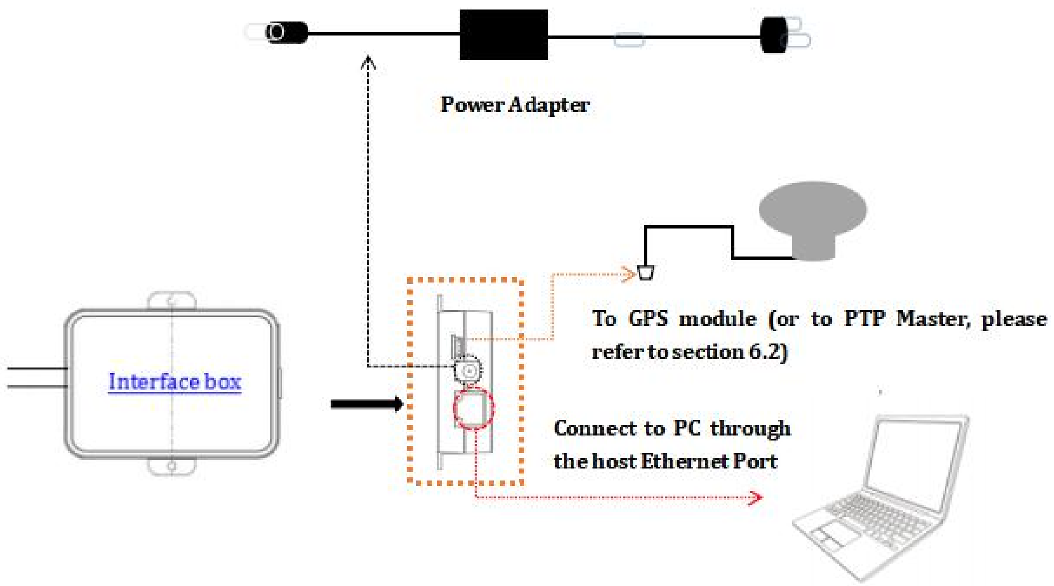


Figure 4: Diagram of Interface Box Connection.

5 Communication Protocol

RS-Ruby Lite adopts IP/UDP protocol and communicates with computer through gigabit Ethernet. In this User Guide the length of UDP packet is set up to 1248 byte. The IP address and port number of RS-Ruby Lite is set in the factory as shown in the Table 2, but can be changed by user as needed.

Table 2: The IP Address and Port Number Set in the Factory.

	IP Address	MSOP Port No.	DIFOP Port No.
RS-Ruby Lite	192.168.1.200	6699	7788
PC	192.168.1.102		

The default MAC Address of each RS-Ruby Lite is already set up in the factory with uniqueness. In order to establishing the communication between a RS-Ruby Lite and a computer, the IP Address of the computer should be set at the same network segment. For instance, IP Address is 192.168.1.X (X can be taken by a value from 1~254), subnet mask: 255.255.255.0. If the internet setting of the sensor is unknown, please set the subnet mask as 0.0.0.0, connect the sensor to the computer, and capture UDP packet to get the information of IP and Port through Wireshark.

The output message from RS-Ruby Lite is called MSOP. The Information of MSOP is shown as follow:

Table 3: Overview of the MSOP.

Protocol	Abbreviation	Function	Type	Size
Main data Stream Output Protocol	MSOP	Scan Data Output	UDP	1248 byte
Device Information Output Protocol	DIFOP	Device Info Output	UDP	1248 byte

Note: In the following chapters only the valid payload (1248 byte) will be discussed.

5.1 MSOP

I/O type: Device outputs data and computer parses data.

Default port number is 6699.

MSOP packet outputs data information of the 3D environment. Each MSOP packet from sensor is 1248-byte in length and consists of reported distance, calibrated reflectivity values, azimuth values and a timestamp in UDP header.

Each MSOP packet payload is 1248-byte in length and consists of an 80-byte header and a 976-byte data field containing 4 blocks of 244-byte data records and a last 192-byte tail.

The basic data structure of a MSOP packet for single return is as shown in Figure 5:

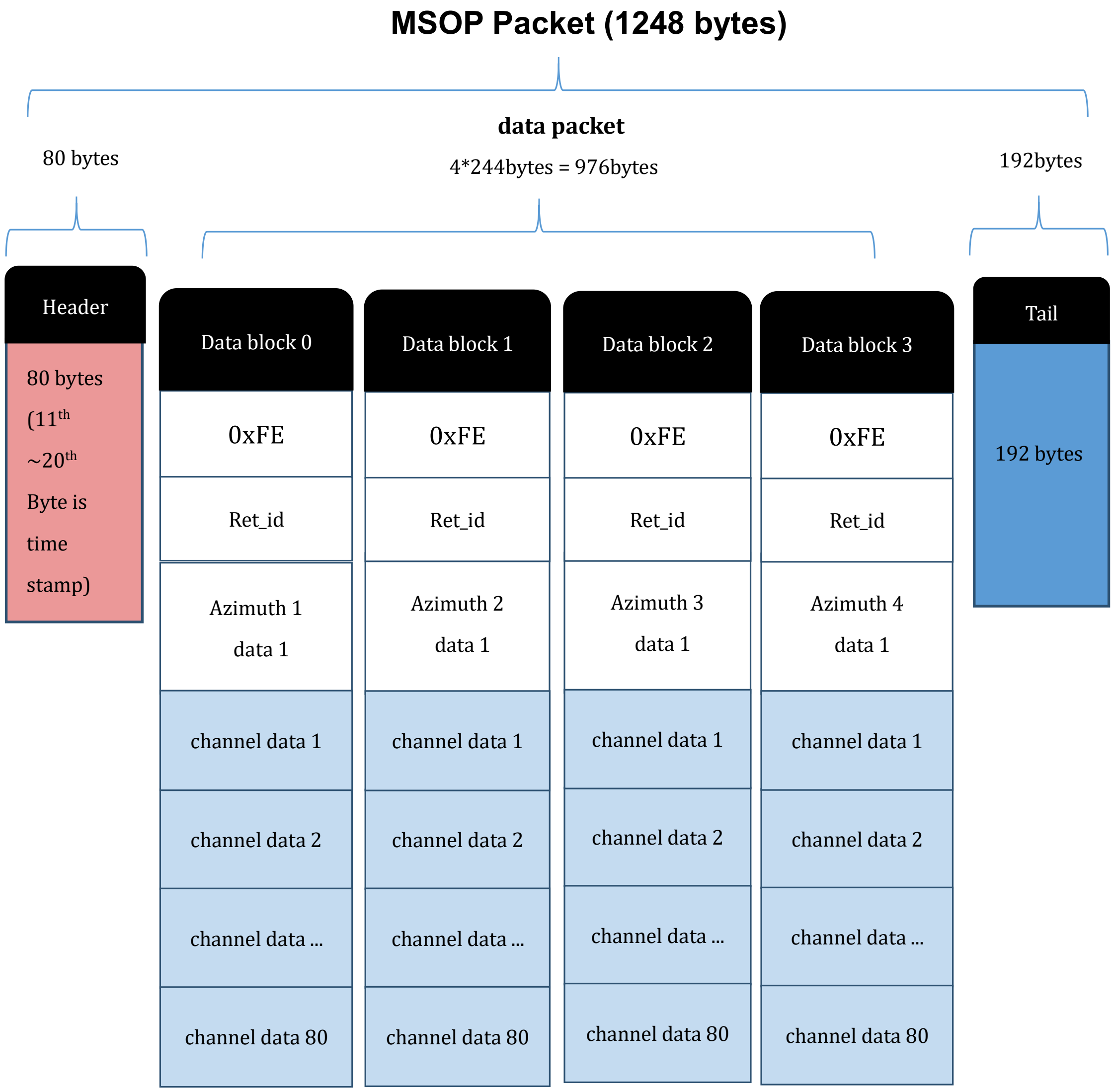


Figure 5: MSOP Packet of RS-Ruby Lite in Single Return Mode.

5.1.1 Header

The 80-byte Header is used to mark the start position of data, return mode setting, sensor temperature and timestamp. The detail of the header is as shown in Table 4.

Table 4: Format of Header.

Header (80bytes)					
Header	Resv	Wave_mode	Temp	Time	Resv
4bytes	3bytes	1byte	2bytes	10bytes	60bytes

Header: this can be used for packets identification: 0x55, 0xAA, 0x05, 0x5A (Default Value)

Wave_mode: Big-Endian mode, lower 4 bits are used to represent the return mode of the LiDAR, as shown in Table 6.

Temp: the temperature of device;

Time: it is used to save the timestamp. In the defined timestamp the system time is recorded, resolution is 1us, the definition of time can be found in the appendix B.11.

Resv: those bytes are reserved.

5.1.2 Data Field

The value of measurement result is saved in the data field, in total 976 byte. It consists of 4 data blocks, the length of each data block is 244 bytes. Each block stands for a complete round of distance measuring for all 80 channels. The definition is shown as follow:

Table 5: Data Block Definition.

Data block n (244bytes)					
Symbol	Ret_id	Azimuth	Channel1_data	...	Channel80_data
1byte	1byte	2bytes	3bytes	...	3bytes

Symbol: identification bit, default value: 0xFE;

Ret_id: it is used to represent which echo measurement is for this block, the relationship between Wave_mode and Ret_id is shown in Table 6;

Azimuth: the information of horizontal rotation angle. This angle information will be used to calculate the 3D coordinate with all following 80-channel data in the same block. In following section, it will be completely explained.

Channel data: the length of each channel data is 3 bytes, each block includes 80-channel data (further details could be seen in Table 7). (The relationship between the number of channel and vertical angle can be found in chapter 8.)

Table 6: The Map List between Wave_mode and Ret_id.

The Map between Wave_mode and Ret_id		
Item / Mode	Wave_mode	Ret_id
Strongest Return Mode	1	1
Last Return Mode	2	2
Dual Return Mode	3	1,2; 1,2 …

5.1.2.1 Calculation of the Azimuth

In each data block the value of azimuth is measured once and this azimuth corresponds to the first position of the first laser emission (the first channel data in this block). The rotation angle is recorded by angle encoder. The zero position of angle encoder is the zero degree of azimuth. The resolution of angle is 0.01°.

For instance, in Figure 6, the azimuth value is calculated as follow:

Get azimuth values (HEX): 0x59, 0x39

Combine to a 16-bit, unsigned integer (HEX): 0x 5939

Convert the value to decimal (DEC): 22841

Divided by 100 (DEC): 228.41°

Hence, the angle value in this block is 228.41°.

Notice: the 0°axis of azimuth is co-axis and same positive direction with the Y axis in Figure 12.

5.1.2.2 Channel Data

Channel data is 3 bytes. The higher 2 bytes of them are used to save the distance information. The lower one byte stands for reflectivity.

Table 7: The Format of Channel Data.

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

Distance is 2 bytes, resolution: 0.5 cm.

For instance, in Figure 6, the explanation of Channel data is as follow:

Get the higher 2 bytes(HEX): 0x08 (Distance 1), 0x4b (Distance 2).

Combine to a 16-bit unsigned integer (HEX):0x084b

Convert the value to decimal (DEC):2123

*According to the resolution 0.5 cm, change to meter: 2123 * 0.005 = 10.615 m*

Hence, the distance between sensor and measurement object is 10.615 m.

Reflectivity is a relative value, please find the concrete definition in "chapter 9 Reflectivity", Reflectivity could show energy of the light return from measuring object in the real circumstance. Through analytic of reflectivity, the object of different materials can be distinguished.

5.1.3 Tail

The 4-byte Tail is reserved as the checksum.

5.1.4 MSOP Data Package

The following figure shows the format of MSOP data packet and relevant parsing processes in next page.

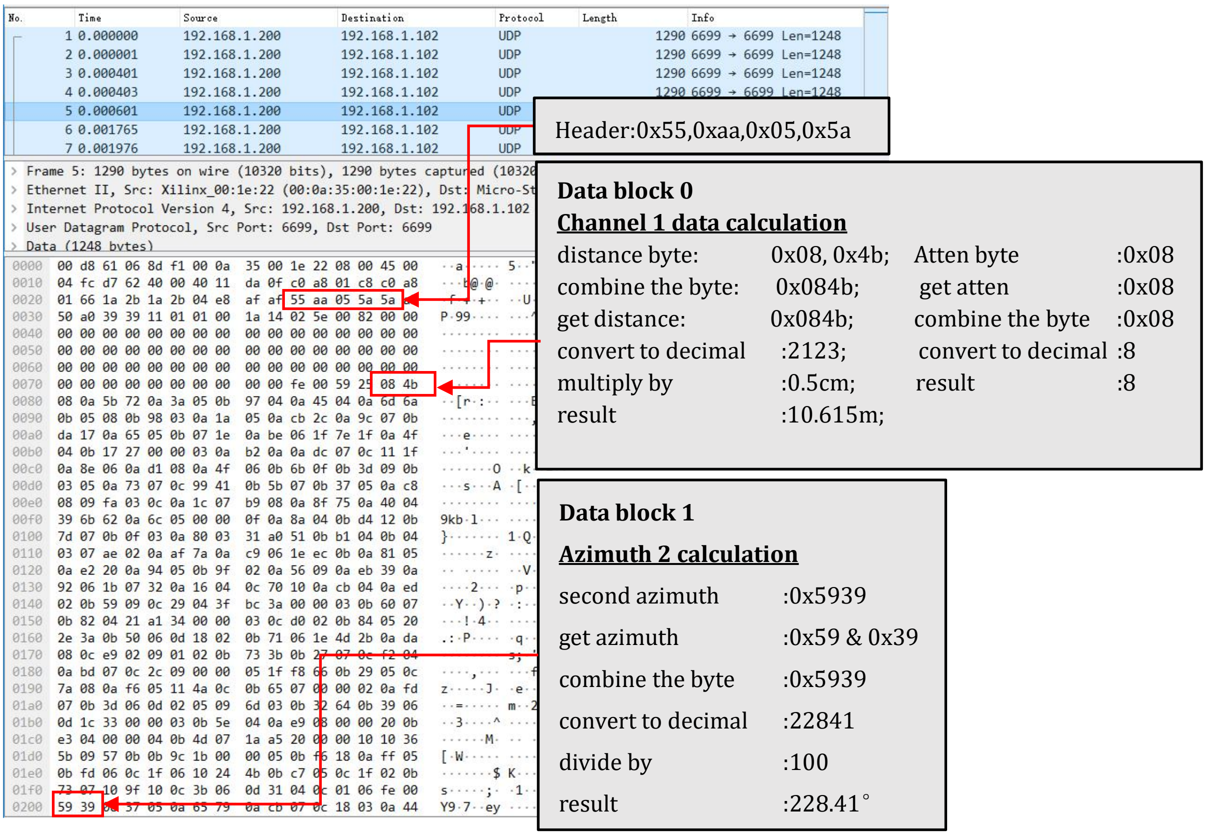


Figure 6: MSOP Packet of RS-Ruby Lite in Single Return Mode.

5.2 DIFOP

Device Info Output Protocol, abbreviation: DIFOP
I/O Type: output from device, input to PC
Default port number: 7788
DIFOP is a protocol that reports and outputs device information including the device serial number (S/N), firmware version, internet setting, calibration data, electrical machine setting and operation status, fault detection information. The UDP packet of DIFOP is sent to PC from LiDAR in a confirm time interval. It is a viewer for users to get comprehensive details about the device.
Each DIFOP packet is 1248 byte long, and comprises an 8-byte Header, a 1238-byte data field, and a 2-byte Tail.

Table 8: Data Format of DIFOP Packet.

	No.	Information	Offset	Length(byte)
Header	0	DIFOP header	0	8
Data	1	Motor rotation speed	8	2
	2	Source IP Address (LiDAR IP)	10	4
		Destination IP Address	14	4
		LiDAR MAC Address	18	6

		Port Number of MSOP	24	2
		Reserved	26	2
		Port Number of DIFOP	28	2
		Reserved	30	2
	3	FOV of start angle	32	2
		FOV of end angle	34	2
	4	Reserved	36	2
	5	Motor Phase Lock	38	2
	6	Top Board Firmware Version	40	5
		Bottom Board Firmware Version	45	5
		Bottom Board Software Version	50	5
		Electrical Motor Firmware Version	55	5
		LiDAR Hardware Version	60	3
	7	Reserved	63	229
	8	S/N	292	6
	9	Correction Value of Zero Angle	298	2
	10	Return mode	300	1
	11	Time Synchronization Mode	301	1
		Time Synchronization Status	302	1
		UTC time	303	10
	12	Operation Status	313	24
	13	Reserved	337	5
	14	Reserve for Fault Diagnose	342	9
		Number of Start	351	2
		SER (symbol error rate) of Magnetic Ring	353	4
		GPS Status	357	1
		Temperature Detection	358	10
		Reserved	368	3
		Real-time Phase	371	2
		Real-time Rotation Speed	373	2
		Reserved	375	7
	15	GPRMC	382	86
	16	Horizontal Angle Correction	468	384
		Vertical Angle Correction	852	384
	17	Reserved	1236	10
Tail	18	Tail	1246	2

Note: The Header (the DIFOP identifier) in the table above is 0xA5, 0xFF, 0x00, 0x5A, 0x11, 0x11, 0x55, 0x55. This sequence can be used to identify the packet.

The tail is 0x0F,0xF0.

For definition of information registers as well as their usage, please check more details in Appendix B of this manual.

6 Time Synchronization

RS-Ruby Lite supports two time synchronization modes, one is external GPS + PPS and the other is PTP. Mode switching can be realized through using web application(please refer to Appendix A.2).

6.1 GPS Synchronization

The time of RS-Ruby Lite can be synchronized with GPS module from external.

6.1.1 Principle of GPS Synchronization

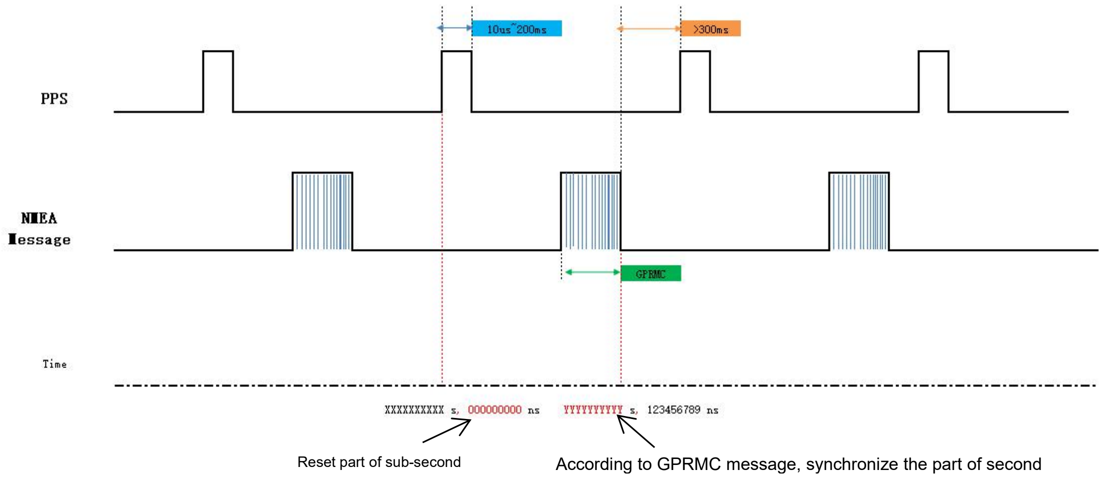


Figure 7: Timing Sequence Diagram of GPS Synchronization.

The GPS module keeps generating synchronization Pulse Per Second (PPS) signal, GPRMC messages and sends them to the sensor. The pulse width of the PPS should be between 10us to 200ms, and the GPRMC message should be received within 500ms after this rising edge of this PPS signal.

6.1.2 GPS Usage

GPS_REC receives the signal from GPS module with standard serial RS232 communication protocol. The interface format of GPS_REC is SH1.0-6 female connector, the pin definition can be referred in Figure 3.

GPS PULSE receives the positive PPS signal from the GPS module and requests voltage between 3.0 V ~ 15.0 V.

PIN +5V of GPS interface can supply power to GPS module. (If GPS module is only allowed to use +3.3V as power supply, please do not use this +5V PIN on Interface Box. Please exchange the +5V to +3.3V)

PIN GND is connected to ground wire of the GPS module.

The GPS module should be set to 9600bps baud rate, 8-bit data bit, no parity and 1 stop bit. RS-LiDAR-Ruby only reads the GPRMC message from GPS module., the GPSMRC message format is shown as below:

$GPRMC, <1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,<10>,<11>,<12>*hh
<1>UTC time
<2>validity-A-ok, V-invalid
<3>Latitude
<4>North/South
<5>Longitude
<6>East/West
<7>Ground speed
<8>True course
<9>UTC date
<10>Variation
<11>East/West
<12>Mode(A/D/E/N=)
hh checksum from $ to

Notice:

1. The interval of 1PPS pulse must be controlled within 1s ±100μs;
2. In GPRMC message, the status bit (<12>Mode>) must be A, otherwise, synchronization timing cannot be given;
3. The different GPS module could send out different GPRMC message length, the RS-Ruby Lite could be compatible with the most GPS modules on the market. Please contact RoboSense of technical support when it is incompatible.

6.2 Precision Time Protocol (PTP)

6.2.1 Principle of PTP

PTP (Precision Time Protocol) defines a protocol enabling precise synchronization of clocks in measurement and control systems, also used in different devices. Compared with other synchronization mechanisms, PTP has many advantages:

1) In comparison with NTP (Network Time Protocol), PTP could meet much higher demand of time synchronization. NTP could only satisfy the sub-second-level synchronization. However, the synchronization accuracy of PTP is sub-microsecond.
2) In comparison with GPS (Global Positioning System), the cost of purchase and maintenance of PTP is much lower.

6.2.2 Topology of PTP

The setup steps of PTP:

1)In web application, the PTP Mode should be chosen (referring to A.2 Web configuration);
2)Prepare a PTP Master ;
3)Ethernet Switch;
4)The device supporting PTP.
5)The Topology is shown as below:

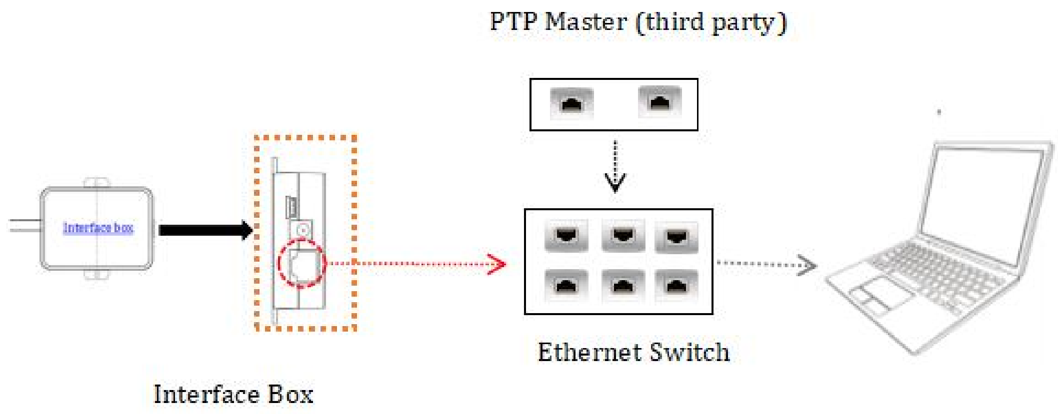


Figure 8: Topology of LiDAR, PC and PTP Master.

Notice:

1. PTP Master is a third-party device that is not included in accessories while shipment. It needs to be bought by user.
2. Our product is only as a PTP Slave that gets the synchronized time from PTP Master. The synchronization accuracy cannot be examined by LiDAR. If there is deviation between LiDAR time and real time, please check the accuracy of Master Clock.
3. If the connectivity is interrupted after synchronization, the LiDAR time will continue counting based on the clock inside of LiDAR. The LiDAR time will be reset until the LiDAR is powered up again.

6.2.3 Time Calculation

In MSOP packet, it includes time stamp information. When the external synchronization is not active, the internal timing will start from a default origin.

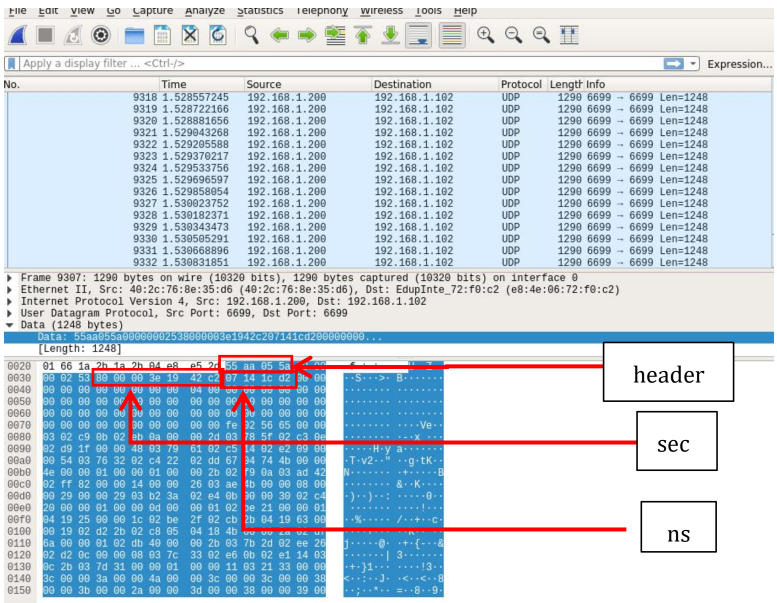


Figure 9: the Data Format of PTP.

(1) The time stamps are divided into second part and nanosecond part. The second part shown in Figure 9 is 0x00003e1942c2(1041842882); the nanosecond part is

0x07141cde(118758610)

(2) The second part is UTC timestamp, which indicates the incremental count of seconds from 0:00 (London time) on January 1, 1970 to the current time. Figure 9 shows the identification of London time 2003/01/06 09:48:02;

(3) The maximum value of the nanosecond part is 0x3B9AC9FF(99999999), after the maximum value is increased by 1, the nanosecond returns to zero and the second will be added to 1, as shown in Figure 9 is 118758610 nanosecond;

(4) Most PC development environments have time conversion functions, such as including system library < time.h >, time.gmtime (&t) function can convert timestamp to London time.

7 Key Specifications

7.1 Return Mode

7.1.1 The Principle of Return Mode

Due to laser divergence, laser pulse could hit more than one object after one single emission. The strongest return indicates the return signal that owns the strongest energy. The last return indicates the return signal that lastly comes back to sensor. For the dual return, both the two return signals are received by sensor.

There are three return modes on RS-Ruby Lite: Strongest Return, Last Return and Dual Return Mode. If return mode is set up to the strongest return mode, only the strongest return signal is seen as available signal in distance calculation. Similarly, if the setting is the last return mode, only the last return signal is used to calculate distance. Dual return mode includes the distances of both the two return modes mentioned before.

Notice: only if the distance of two different objects is larger than 1m, those cannot be distinguished in the dual return.

7.1.2 Strongest Return

When the laser pulse hits on a near object, this return signal could be considered as strongest return signal.

7.1.3 Strongest, Last and Dual Return Signal

After the laser pulse hits two flat walls at different distance, two return signal will appear in dual return mode. There will be two consequences:

1) The strongest return signal is not last return signal, it will return strongest and last signal.

2) The strongest return signal is the last return signal, it will return a sub-strongest signal and the strongest return signal.

7.1.4 Return Mode Flag

The factory default setting of return mode on RS-Ruby Lite is Last Return Mode. The relative return mode setting refers to "Return Mode" in appendix A. In DIFO packet, the 300th. Byte indicates the return mode flag:

Table 9: Flag and Return Mode.

Flag	Return Mode
03	Dual Return Mode
02	Last Return Mode
01	Strongest Return Mode

7.2 Phase Lock

The Phase Lock feature can be used to make the sensor rotating to the specific position when the PPS signal is triggered. To operate correctly, the PPS signal must be present and locked stable.

In Figure 10 different Phase Lock is shown as red arrow. When PPS is triggered, sensor can rotate to the 0°, 135°or 270°.

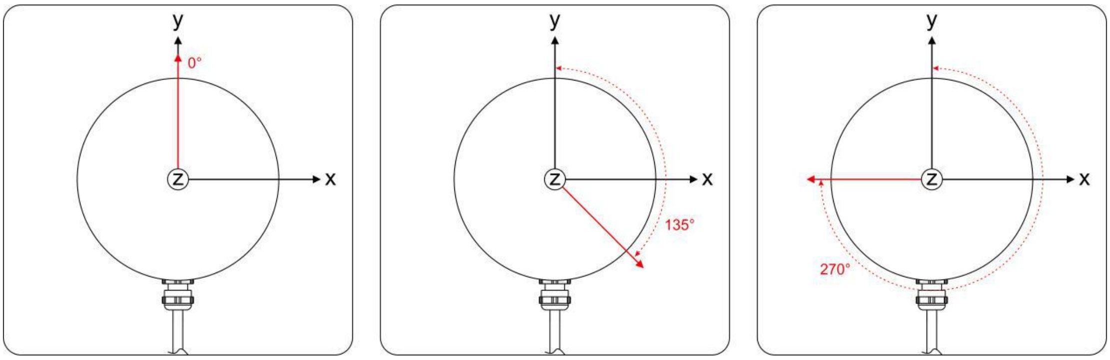


Figure 10:Different phase lock angles 0°/135°/270°.

In Web sever -> Option "Setting" -> **Phase Lock Setting**, the angle of phase lock can be set in the interval [0°~ 360°], refer to section A.2.

8 Point Cloud

8.1 Coordinating Mapping

In data packet including the measured azimuth and distance, in order to calculating the point cloud, the coordinate in polar coordinate system should be transferred to the 3D XYZ coordinates in Cartesian Coordinate System, as shown in Figure 11. The function of how to transfer the information is as shown below:

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

Here r is the reported distance, ω is the vertical angle/elevation of the laser (which is fixed and is given by the Laser ID), and α is the horizontal angle/azimuth reported at the beginning of every other firing sequence. δ is the angle offset of the azimuth. x, y, z values are the projection of the polar coordinates on the XYZ Cartesian Coordinate System.

The value of ω and δ can be exported per RSView in angle.csv.

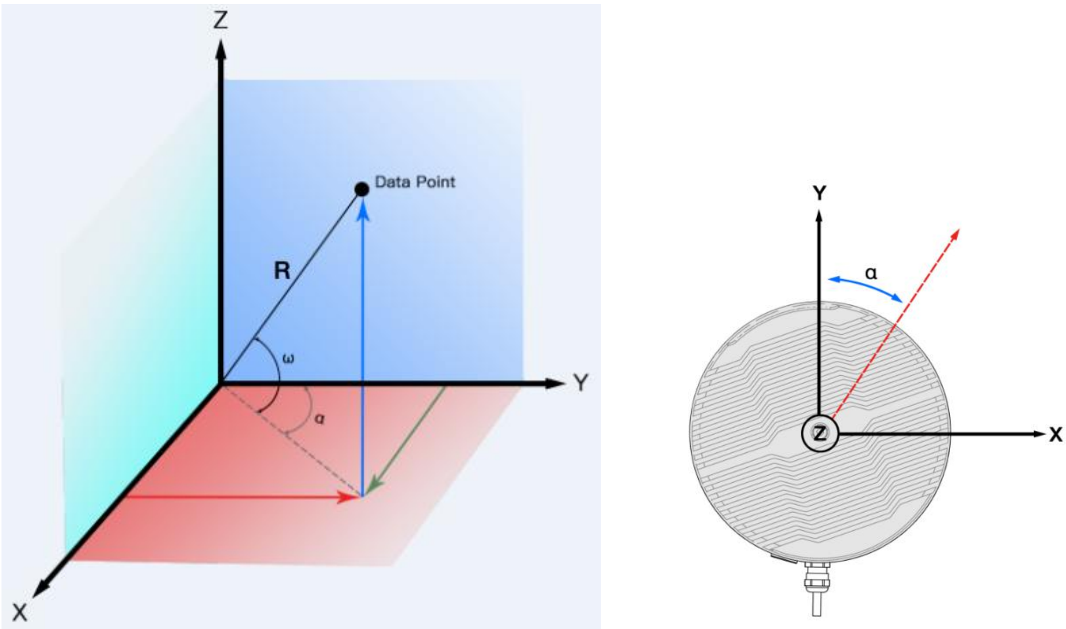


Figure 11: Coordinate system mapping between polar system and XYZ system.

Note 1: In the RS-Ruby Lite ROS package, the coordinate system must be transferred to the ROS right-hand Coordinate system.

The ROS-X axis is co-axis with the Y-axis and with same direction as Figure 11.

The ROS-Y axis is co-axis with the X-axis but the positive direction is reverse as Figure 11.

The Z axis is same before and after transformation.

Note 2: The origin of the LiDAR coordinate is defined at the center of the LiDAR structure, with 68 mm high to the bottom of the LiDAR.

8.2 Laser Channel in Spatial Distribution

80 lasers in RS-Ruby Lite are defined as 80 channels. The vertical angles of those lasers are distributed in the range of -25°~+15°. The distribution of the angles is non-uniform. According to table 9, the corresponding channel and vertical angle are as follow.

Table 10: Serial number of laser channel and corresponding horizontal angles.

Channel No.	Vertical Angle	Horizontal Offset Angle
1	-13.565	5.95
2	-1.09	4.25
3	-4.39	2.55
4	-0.29	4.25
5	-3.59	2.55
6	-5.79	5.95
7	0.51	4.25
8	-2.79	2.55
9	3.51	0.85
10	-4.99	5.95
11	-1.99	2.55
12	5.06	0.85
13	-4.19	5.95
14	-19.582	2.55
15	-1.29	0.85
16	-3.39	5.95
17	-7.15	2.55
18	-0.49	0.85
19	-2.59	5.95
20	-5.99	2.55
21	0.31	0.85
22	-1.79	5.95
23	-5.19	2.55
24	-0.99	5.95
25	-25	0.85
26	-0.19	5.95
27	-7.65	0.85
28	0.61	5.95
29	-2.69	4.25
30	1.41	5.95
31	-1.89	4.25
32	-16.042	4.25
33	-1.19	2.55

34	-6.85	4.25
35	-0.39	2.55
36	0.41	2.55
37	-2.89	0.85
38	6.56	5.95
39	1.21	2.55
40	-2.09	0.85
41	-8.352	-0.85
42	-0.69	-2.55
43	-3.99	-4.25
44	-6.19	-0.85
45	0.11	-2.55
46	-3.19	-4.25
47	-5.39	-0.85
48	0.91	-2.55
49	-2.39	-4.25
50	-4.59	-0.85
51	-1.59	-4.25
52	-3.79	-0.85
53	2.51	-2.55
54	-10.346	-4.25
55	-0.89	-5.95
56	-2.99	-0.85
57	-0.09	-5.95
58	-2.19	-0.85
59	-5.59	-4.25
60	0.71	-5.95
61	-1.39	-0.85
62	11.5	-2.55
63	-4.79	-4.25
64	-0.59	-0.85
65	-11.742	-5.95
66	0.21	-0.85
67	-6.5	-5.95
68	1.01	-0.85
69	-2.29	-2.55
70	1.81	-0.85
71	-1.49	-2.55
72	9	-4.25

73	-9.244	-2.55
74	-0.79	-4.25
75	0.01	-4.25
76	0.81	-4.25
77	-2.49	-5.95
78	15	-0.85
79	1.61	-4.25
80	-1.69	-5.95

9 Reflectivity

The reflectivity is included in the data field of MSOP packet. Reflectivity is a scale to evaluate the ability of the object in reflection of light. This value is highly related to the material of measured object. Hence, the character can be used to distinguish the different materials.
RS-Ruby Lite reports reflectivity values from 0 to 255 with 255 being the reported reflectivity for an ideal reflector. Diffuse reflection reports values from 0 to 100, with the weakest reflectivity reported from black objects and strongest reflectivity reported from white objects. Retro-reflector reports values from 101 to 255, the ideal retro-reflector is near to 255.

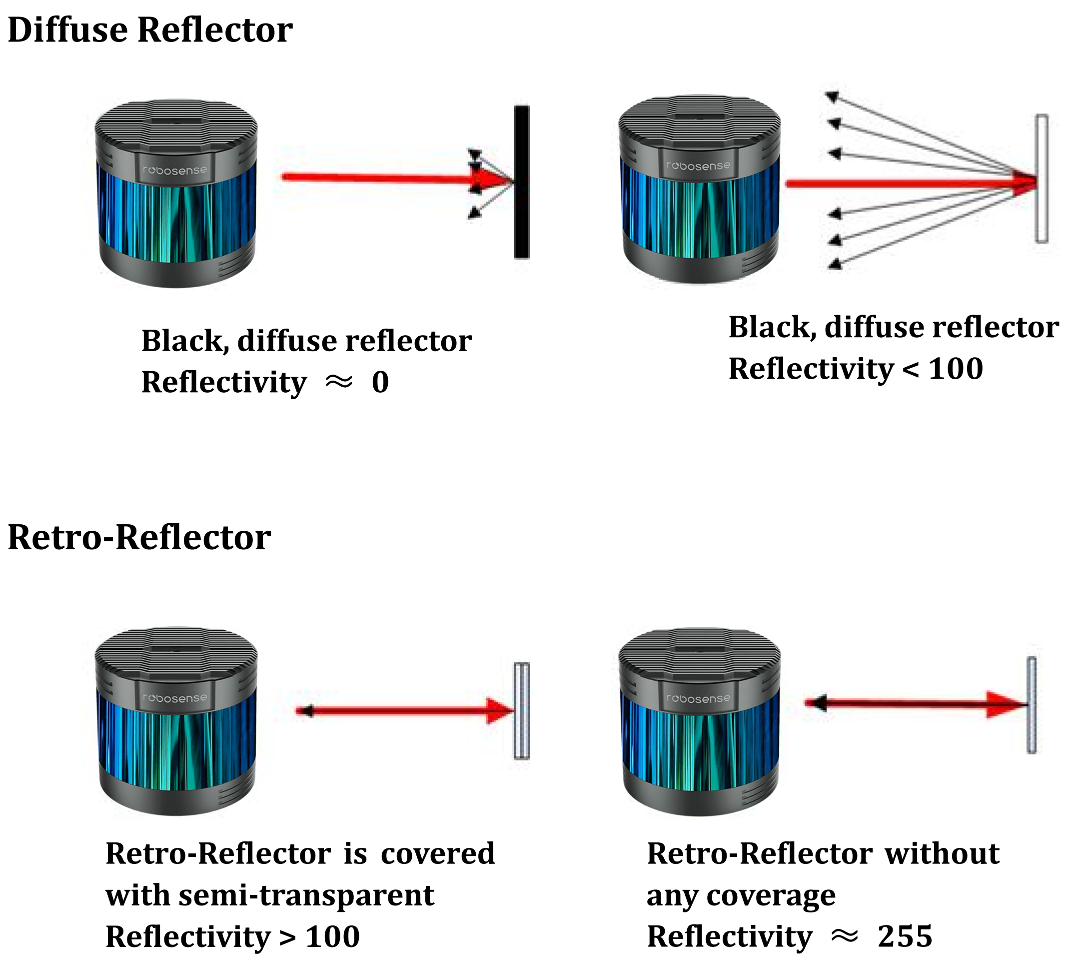


Figure 12: Calibration of reflectivity.

The value of reflectivity is already encapsulated in MSOP. It means that the reflectivity can be directly read.

10 Troubleshooting

This section provides detail on how to troubleshoot your sensor.

Problem	Resolution
Red LED on Interface BOX doesn't light or blink	● Verify the power connection and polarity ● Verify if the power supply satisfy the requirement (at least 4A @ 19V)
Red LED on Interface BOX lights on, when GPS module is connected. But green LED doesn't light or blink	● Verify if the connection between Interface BOX and GPS module is solid.
Rotor doesn't spin	● Verify if the Interface BOX LEDs is okay ● Verify if the connection between Interface BOX and LiDAR is solid.
Reboot at the boot time	● Verify the power connection and polarity ● Verify if the power supply satisfy the requirement (at least 4A @ 19V) ● Check if the LiDAR mounting plane is level or if the LiDAR bottom fixing screws are too tight.
Unit spin but no data	● Verify if the network wiring is functional. ● Verify receiving computer's network settings. ● Verify packet output using another application (e.g. Wireshark) ● Verify if no security software is installed which may block Ethernet broadcasts. ● Verify if input voltage and current draw are in proper range
Can see data in Wireshark but not RSVIEW	● Check if no firewall is active on receiving computer. ● Check if the receiving computer's IP address is the same as LiDAR destination IP address. ● Check the RSVIEW Data Port setting. ● Check if the RSVIEW installation path and LiDAR configuration files path both do not contain any Chinese characters. ● Check if the Wireshark receive the MSOP packets.
Data dropouts	● This is nearly always an issue with the network and/or user computer. ● Check the following: ● Is there is excessive traffic and/or collisions on network?

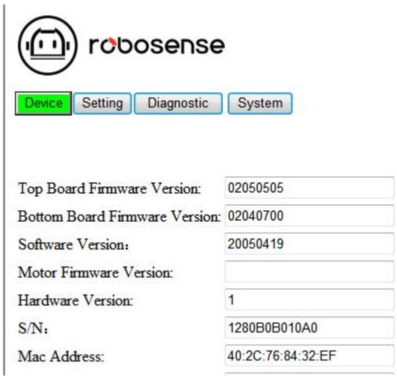
	● Are excessive broadcast packets from another service being received by the sensor? This can slow the sensor down. ● Is the computer fast enough to keep up with the packet flow coming from the sensor? ● Remove all network devices and test with a computer directly connected to the sensor.
GPS not synchronizing	● Check is the baud rate is 9600 and serial port set to 8N1 (8 bits, no parity, 1 stop bit). ● Check if the signal level is RS232 level ● Check if electrical continuity of PPS and serial wiring ● Check incorrect construction of NMEA sentence ● Check if the GPS and Interface BOX are connected to the same GND ● Check if the GPS receive the valid data
No data via router	● Close the DHCP function in router or set the Sensor IP in router configuration
Sensor point cloud data distortion	● Check if the configuration files is right
A blank region rotates in the cloud data when using ROS driver	● This is the normal phenomenon as the ROS driver use fixed packets quantity to divide display frame. The blank region data will output in the next frame.
Point cloud data to be a radial	● If the computer is windows 10 OS, then run the RSVIEW with windows 7 OS compatible mode.

Appendix A Websever

RS-Ruby Lite supports websever. In the webpage, we can execute the parameters, device information or status monitoring and firmware update for RS-Ruby Lite.
The IP of websever is always same as the device IP, default IP is 192.168.1.200. If the default IP is changed, the websever IP will also turn into the new IP of device.

A.1 Visiting Websever

After correctly connecting the RS-Ruby Lite with PC and configuring them, use a web browser to visit the device IP (default device ip: 192.168.1.200) to enter into the Homepage including version of Top Board Firmware, Bottom Board Firmware, Software, Motor Firmware, Hardware, serial number, Mac Address and Model, as the Figure A-1 shown:



1.Top Board

2.Bottom Board

3.Software Version

4.S/N

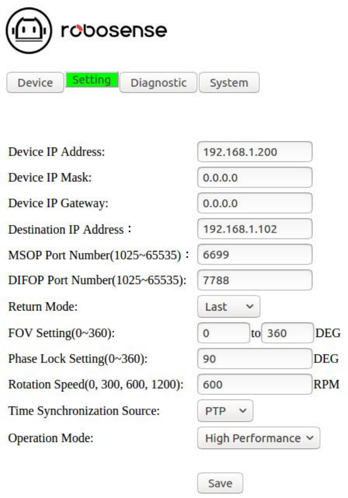
5.Model

6.Web App Version

Figure A - 1: Information on the Homepage of Websever.

A.2 Parameter Setting

In the option "Setting", the Device IP, Port Number, Return Mode, Rotate Speed can be set. The concrete functions are shown in Figure A-2 as below:



1. RS-Ruby Lite supports unicast (default)/ boardcast mode. If set Destination IP to 255.255.255.255, boardcast mode will be active. The default IP is 192.168.1.102;
2. The port number of MSOP and DIFOP could be set inside of an interval [1025 ~ 65535];
3. Return Mode: Last (default)/ Strongest/ Dual;
4. FOV could be set to an arbitrary subregion between [0°~360°]. After setting FOV to a fixed region, only the cloud points within this region cloud be shown.
5. Rotate Speed: 300rpm, 600rpm(default), 1200rpm;
6. Time Synchronization Source: PTP(default)/ GPS;
7. Operation Mode: Stand by/ High Performance (default)/ Balance. When "stand by" is chosen, electrical motor and laser diode won't work.

Figure A - 2: Parameter Setting in "Setting".

Notice:

1. Device IP and Destination IP must be set to the same network segment. Otherwise, the connectivity may not be established;
2. The port number of MSOP and DIFOP could not be set to any value, only from 1025 to 65535;
3. After every change, the "Save" button must be clicked. If a message box with "success" shows up, it means those parameter values have been successfully changed.

A.3 Device Diagnose/ Operating Status

In option "Diagnose", the LiDAR operating status including Voltage, Current, Real-time Rotate Speed, Operating Duration and Operating Temperature is shown in following Figure A-3:

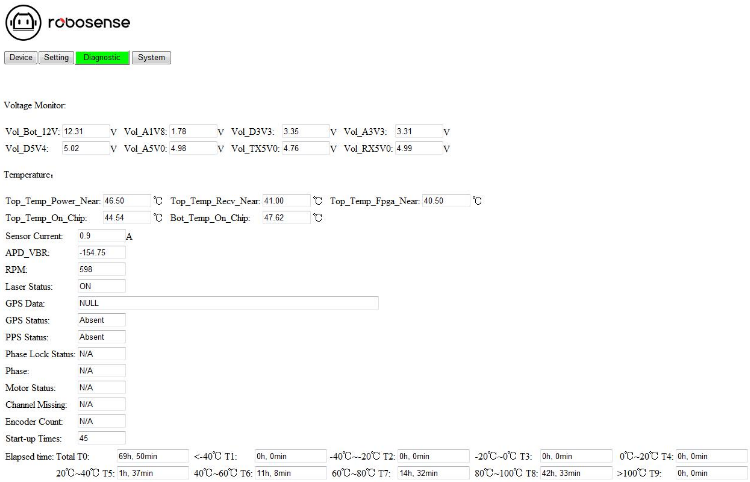


Figure A - 3: Operating Status and Error Diagnose in Websever.

Interpretation:

1. In Voltage Monitor, the box field will turn to red (cannot be edited), when Operation Mode is "Standby".
2. The operating temperature can be viewed in Temperature .
3. RPM shows the real-time rotate speed.
4. Laser Status is always "On" (default), but it is Off, when Standby is active.
5. In "Start Times", the total times of "power on" is recorded.
6. In "Elapsed time Total T0", the operating duration on different operating temperatures is recorded.

Notice:

1. The refresh rate of web page is 1 Hz;
2. N/A indicates that the items is disabled now.
3. If the box field of Voltage/Current is red, please check whether the device stays at "Standby" mode. If not, please check the operating status of device.
4. The Start-up Times is refreshed after 1 minute from power on. The operating duration is recorded every 1minute.

A.4 Firmware Update

In the option "System", the update of top board firmware, bottom board firmware, software and motor firmware can be updated. Manipulation is shown as below:

1. Prepare the firmware needed to update and click Button "Browse" to locate it under a directory.

Figure A - 4: Click Browser to search "Firmware".that needs to be updated.

2. Select firmware and click Button "Open".

Figure A - 5: Select and Import Firmware to update.

3. Click Button "Update" to finish the update.

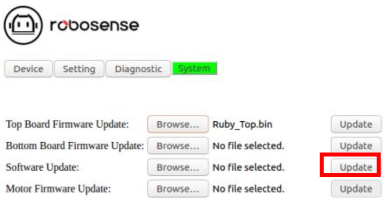


Figure A - 6: Click Button "Update".

4. When the indication "Successful!" shows up, the update process is done. Device will reboot, and please check again whether the version of firmware is updated.

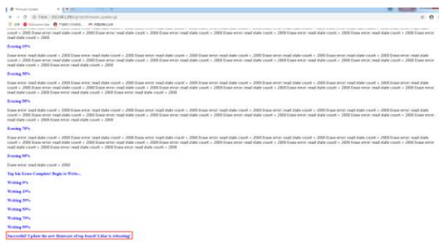


Figure A - 7: Indication while successful update.

Appendix B The Format of all Register

Here are definitions and more details on information registers as mentioned in Chapter 5.

B.1 Motor Speed (MOT_SPD)

Motor Speed (2 bytes in total)						
Byte No.	byte1	byte2				
Function	MOTOR_SPD					

Register description:

(1)This register is used to set the rotation direction and rotation speed.

(2)The data storage format adopts big endian format.

(3)Supported rotation speed:

(byte1==0x04) && (byte2==0xB0) speed 1200rpm, clockwise rotation;

(byte1==0x02) && (byte2==0x58) speed 600rpm, clockwise rotation;

(byte1==0x01) &&(byte2==0x2C) speed 300rpm, clockwise rotation;

If set with data other than the above described, the rotation speed of the motor is 0.

B.2 Ethernet (ETH)

Ethernet (22 bytes in total)								
Byte No.	byte1	byte2	byte3	byte4	byte5	byte6	byte7	byte8
Function	LIDAR_IP				DEST_PC_IP			
Byte No.	byte9	byte10	byte11	byte12	byte13	byte14	byte15	byte16
Function	MAC_ADDR						port1	
Byte No.	byte17	byte18	byte19	byte20	byte21	byte22		
Function	Resv.		port3		Resv.			

Register description:

(1)LIDAR_IP is the LiDAR source IP address, it takes 4 bytes.

(2)DEST_PC_IP is the destination PC IP address, it takes 4 bytes.

(3)MAC_ADDR is the LiDAR MAC Address.

(4)port1~port4 signals the number of ports. Port1 is the MSOP packet port, Port2 is the DIFOP packet port. Port 2 and 4 are reserved. The default port number of PC and LiDAR are the same.

B.3 FOV Setting (FOV SET)

FOV Setting (4bytes in total)						
Byte No.	byte1	byte2	byte3	byte4		
Function	FOV_START		FOV_END			

Register Description:

Set the horizontal angle range of the device for outputting valid data, FOV_START and FOV_END adjustment range 0~36000, corresponding angle 0~360°, the data storage format adopts big endian format. For example: byte1=0x5d, byte2=0xc0, byte3=0x1f, byte4=0x40, so:

FOV_START = 93*256+192=24000

FOV_END = 31*256+64=8000

Indicates that the valid data output has a horizontal angle ranging from 240.00°to 80.00°.

Note: In all above calculation, bytes have been transformed to decimal.

B.4 Motor Phase Offset (MOT_PHASE)

Motor Phase Offset (2bytes in total)						
Byte No.	byte1	byte2				
Function	MOT_PHASE					

B.5 Top Board Firmware (TOP_FRM)

Top Board Firmware (5bytes in total)						
Byte No.	byte1	byte2	byte3	byte4	byte5	
Function	TOP_FRM					

Register description:

If our top board firmware revision is 02050700, then TOP_FRM will output 00 02 05 07 00.

B.6 Bottom Board Firmware (BOT_FRM)

Bottom Board Firmware (5bytes in total)						
Byte No.	byte1	byte2	Byte3	Byte4	Byte5	
Function	BOT_FRM					

Register description:

If our top board firmware revision is 02040A00, then BOT_FRM will output 02 04 0A 00.

B.7 Software Version (SOF_FRM)

Software Version (5 bytes in total)						
Byte No.	byte1	byte2	Byte3	Byte4	Byte5	
Function	SOF_FRM					

Register description:

If our top board firmware revision is 20053019, then BOT_FRM will output 00 20 05 30 19.

B.8 Corrected Vertical Angle (COR_VERT_ANG)

Corrected Vertical Angle (384bytes)									
Byte No.	byte1	byte2	byte3	byte4	byte5	byte6	byte7	byte8	byte9
Function	Channel 1 COR_VERT_ANG			Channel 2 COR_VERT_ANG			Channel 3 COR_VERT_ANG		
Byte No.	byte10	byte11	byte12	byte13	byte14	byte15	byte16	byte17	byte18
Function	Channel 4 COR_VERT_ANG			Channel 5 COR_VERT_ANG			Channel 6 COR_VERT_ANG		
Byte No.	byte19	byte20	byte21	byte22	byte23	byte24	byte25	byte26	byte27
Function	Channel 7 COR_VERT_ANG			Channel 8 COR_VERT_ANG			Channel 9 COR_VERT_ANG		
Byte No.	byte28	byte29	byte30	byte31	byte32	byte33	byte34	byte35	byte36
Function	Channel 10 COR_VERT_ANG			Channel 11 COR_VERT_ANG			Channel 12 COR_VERT_ANG		
Byte No.	byte37	byte38	byte39	byte40	byte41	byte42	byte43	byte44	byte45
Function	Channel 13 COR_VERT_ANG			Channel 14 COR_VERT_ANG			Channel 15 COR_VERT_ANG		
Byte No.	byte46	byte47	byte48	byte49	byte50	byte51	byte52	byte53	byte54
Function	Channel 16 COR_VERT_ANG			Channel 17 COR_VERT_ANG			Channel 18 COR_VERT_ANG		
Byte No.	byte55	byte56	byte57	byte58	byte59	byte60	byte61	byte62	byte63
Function	Channel 19 COR_VERT_ANG			Channel 20 COR_VERT_ANG			Channel 21 COR_VERT_ANG		
Byte No.	byte64	byte65	byte66	byte67	byte68	byte69	byte70	byte71	byte72
Function	...			..			..		
Byte No.	...	...	...	...	...	...	...	...	...
Function	...			...			...		
Byte No.	Byte223	Byte224	Byte225	Byte226	Byte227	Byte228	Byte229	Byte230	Byte231
Function	Channel 75 COR_VERT_ANG			Channel 76 COR_VERT_ANG			Channel 77 COR_VERT_ANG		
Byte No.	byte232	byte233	byte234	byte235	byte236	byte237	byte238	byte239	byte240
Function	Channel 78 COR_VERT_ANG			Channel 79 COR_VERT_ANG			Channel 80 COR_VERT_ANG		
Byte No.	byte241	byte242	byte243	....			Byte382	Byte383	Byte384
Function	Reserved								

Register description:

(1) The angle value is signed integer, vertical angle for each channel consists of 3 bytes, while the first byte represents the sign, the second byte and the third byte represent the value for the angle.

(2) The first byte 0x00 represents positive while 0x01 represents negative.

(3) LBS=0.01;

(4) For example, the register for vertical angle of Channel 1 is as below: byte1=0x01, byte2=0x05 convert to decimal is 5, byte3=0x4c convert to decimal is 76, so the vertical angle of Channel 1 is:

$$- (5*256+76)*0.01 = -13.56$$

Note: total number of vertical angle is 384 bytes, for now, 240 bytes are used, remain 144 bytes are reserved.

B.9 Corrected Horizontal Offset Angle (COR_HOR_ANG)

Corrected Vertical Angle (384bytes)									
Byte No.	byte1	byte2	byte3	byte4	byte5	byte6	byte7	byte8	byte9
Function	Channel 1 COR_HOR_ANG			Channel 2 COR_HOR_ANG			Channel 3 COR_HOR_ANG		
Byte No.	byte10	byte11	byte12	byte13	byte14	byte15	byte16	byte17	byte18
Function	Channel 4 COR_HOR_ANG			Channel 5 COR_HOR_ANG			Channel 6 COR_HOR_ANG		
Byte No.	byte19	byte20	byte21	byte22	byte23	byte24	byte25	byte26	byte27
Function	Channel 7 COR_HOR_ANG			Channel 8 COR_HOR_ANG			Channel 9 COR_HOR_ANG		
Byte No.	byte28	byte29	byte30	byte31	byte32	byte33	byte34	byte35	byte36
Function	Channel 10 COR_HOR_ANG			Channel 11 COR_HOR_ANG			Channel 12 COR_HOR_ANG		
Byte No.	byte37	byte38	byte39	byte40	byte41	byte42	byte43	byte44	byte45
Function	Channel 13 COR_HOR_ANG			Channel 14 COR_HOR_ANG			Channel 15 COR_HOR_ANG		
Byte No.	byte46	byte47	byte48	byte49	byte50	byte51	byte52	byte53	byte54
Function	Channel 16 COR_HOR_ANG			Channel 17 COR_HOR_ANG			Channel 18 COR_HOR_ANG		
Byte No.	byte55	byte56	byte57	byte58	byte59	byte60	byte61	byte62	byte63
Function	Channel 19 COR_HOR_ANG			Channel 20 COR_HOR_ANG			Channel 21 COR_HOR_ANG		
Byte No.	byte64	byte65	byte66	byte67	byte68	byte69	byte70	byte71	byte72
Function	...			..			..		
Byte No.	...	...	...	...	...	...	...	...	...
Function	...			...			...		
Byte No.	Byte223	Byte224	Byte225	Byte226	Byte227	Byte228	Byte229	Byte230	Byte231
Function	Channel 75 COR_HOR_ANG			Channel 76 COR_HOR_ANG			Channel 77 COR_HOR_ANG		
Byte No.	byte232	byte233	byte234	byte235	byte236	byte237	byte238	byte239	byte240
Function	Channel 78 COR_HOR_ANG			Channel 79 COR_HOR_ANG			Channel 80 COR_HOR_ANG		
Byte No.	byte241	byte242	byte243	....			Byte382	Byte383	Byte384
Function	Reserved								

Register description:

(1) The angle value is a signed integer, vertical angle for each channel consists of 3 bytes, while the first byte represents the sign, the second byte and the third byte represent the value for the angle.

(2) The first byte 0x00 represents positive while 0x01 represents negative.

(3) LBS=0.01;

(4) For example, the register for vertical angle of Channel 1 is as below: byte1=0x01, byte2=0x02 convert to decimal is 2, byte3=0x53 convert to decimal is 83, so the vertical angle of Channel 1 is:

$$(2*256+83)*0.01 = 5.95$$

Note: total number of vertical angle is 384 bytes, for now, 240 bytes are used, remain 144 bytes are reserved.

B.10 Serial Number (SN)

SN (6 bytes in total)						
Byte No.	byte1	byte2	byte3	byte4	byte5	byte6
Function	SN					

Similar to MAC address, 6-byte hexadecimal value to identify device.

B.11 Time (UTC_TIME)

Time Register (10bytes in Total)								
Byte No.	byte1	byte2	byte3	byte4	byte5	byte6	byte7	byte8
Function	sec						ns	
Byte No.	byte9	byte10						
Function	ns							

Note: ns is in a range [0~999999999].

B.12 ASCII code in GPSRMC Packet

GPSRMC register reserve 86 bytes, it can store the whole GPSRMC message from GPS module in to the register in ASCII code.

Appendix C Timestamp Calculation of Point Cloud

In each MSOP packet, there are 4 blocks, each block has one sequence for the whole 80 laser firings, so in a MOSP packet, there are 4 groups for the whole 80 laser firings. It will cost 55.552μs, that all of the 80 lasers fires and recharges. Each time offset in one complete 128 firings is shown in Table C-1.
The formula of Time_offset Calculation:

Exact_point_time = Timestamp + Time_offset

The exact timestamp of all laser firing Exact_point_time:

Table C - 1: The Map between Channel_ID and ideal Vertical Angle, ideal horizontal angle and Exact Timestamp of each Point Cloud.

Channel_ID	Ideal Vertical Angle	Ideal Horizontal Angle	MSOP Packet			
			Data Block 1	Data Block 2	Data Block 3	Data Block 4
1	-13.565	5.95	0	55.552	111.104	166.656
2	-1.09	4.25	0	55.552	111.104	166.656
3	-4.39	2.55	0	55.552	111.104	166.656
4	-0.29	4.25	3.236	58.788	114.34	169.892
5	-3.59	2.55	3.236	58.788	114.34	169.892
6	-5.79	5.95	6.472	62.024	117.576	173.128
7	0.51	4.25	6.472	62.024	117.576	173.128
8	-2.79	2.55	6.472	62.024	117.576	173.128
9	3.51	0.85	6.472	62.024	117.576	173.128
10	-4.99	5.95	9.708	65.26	120.812	176.364
11	-1.99	2.55	9.708	65.26	120.812	176.364
12	5.06	0.85	9.708	65.26	120.812	176.364
13	-4.19	5.95	12.944	68.496	124.048	179.6
14	-19.582	2.55	12.944	68.496	124.048	179.6
15	-1.29	0.85	12.944	68.496	124.048	179.6
16	-3.39	5.95	16.18	71.732	127.284	182.836
17	-7.15	2.55	16.18	71.732	127.284	182.836
18	-0.49	0.85	16.18	71.732	127.284	182.836
19	-2.59	5.95	19.416	74.968	130.52	186.072
20	-5.99	2.55	19.416	74.968	130.52	186.072
21	0.31	0.85	19.416	74.968	130.52	186.072
22	-1.79	5.95	22.652	78.204	133.756	189.308
23	-5.19	2.55	22.652	78.204	133.756	189.308
24	-0.99	5.95	25.888	81.44	136.992	192.544
25	-25	0.85	25.888	81.44	136.992	192.544

26	-0.19	5.95	29.124	84.676	140.228	195.78
27	-7.65	0.85	29.124	84.676	140.228	195.78
28	0.61	5.95	32.36	87.912	143.464	199.016
29	-2.69	4.25	32.36	87.912	143.464	199.016
30	1.41	5.95	35.596	91.148	146.7	202.252
31	-1.89	4.25	35.596	91.148	146.7	202.252
32	-16.042	4.25	38.832	94.384	149.936	205.488
33	-1.19	2.55	38.832	94.384	149.936	205.488
34	-6.85	4.25	42.068	97.62	153.172	208.724
35	-0.39	2.55	42.068	97.62	153.172	208.724
36	0.41	2.55	45.304	100.856	156.408	211.96
37	-2.89	0.85	45.304	100.856	156.408	211.96
38	6.56	5.95	48.54	104.092	159.644	215.196
39	1.21	2.55	48.54	104.092	159.644	215.196
40	-2.09	0.85	48.54	104.092	159.644	215.196
41	-8.352	-0.85	0	55.552	111.104	166.656
42	-0.69	-2.55	0	55.552	111.104	166.656
43	-3.99	-4.25	0	55.552	111.104	166.656
44	-6.19	-0.85	3.236	58.788	114.34	169.892
45	0.11	-2.55	3.236	58.788	114.34	169.892
46	-3.19	-4.25	3.236	58.788	114.34	169.892
47	-5.39	-0.85	6.472	62.024	117.576	173.128
48	0.91	-2.55	6.472	62.024	117.576	173.128
49	-2.39	-4.25	6.472	62.024	117.576	173.128
50	-4.59	-0.85	9.708	65.26	120.812	176.364
51	-1.59	-4.25	9.708	65.26	120.812	176.364
52	-3.79	-0.85	12.944	68.496	124.048	179.6
53	2.51	-2.55	12.944	68.496	124.048	179.6
54	-10.346	-4.25	12.944	68.496	124.048	179.6
55	-0.89	-5.95	12.944	68.496	124.048	179.6
56	-2.99	-0.85	16.18	71.732	127.284	182.836
57	-0.09	-5.95	16.18	71.732	127.284	182.836
58	-2.19	-0.85	19.416	74.968	130.52	186.072
59	-5.59	-4.25	19.416	74.968	130.52	186.072
60	0.71	-5.95	19.416	74.968	130.52	186.072
61	-1.39	-0.85	22.652	78.204	133.756	189.308
62	11.5	-2.55	22.652	78.204	133.756	189.308
63	-4.79	-4.25	22.652	78.204	133.756	189.308
64	-0.59	-0.85	25.888	81.44	136.992	192.544

65	-11.742	-5.95	25.888	81.44	136.992	192.544
66	0.21	-0.85	29.124	84.676	140.228	195.78
67	-6.5	-5.95	29.124	84.676	140.228	195.78
68	1.01	-0.85	32.36	87.912	143.464	199.016
69	-2.29	-2.55	32.36	87.912	143.464	199.016
70	1.81	-0.85	35.596	91.148	146.7	202.252
71	-1.49	-2.55	35.596	91.148	146.7	202.252
72	9	-4.25	35.596	91.148	146.7	202.252
73	-9.244	-2.55	38.832	94.384	149.936	205.488
74	-0.79	-4.25	38.832	94.384	149.936	205.488
75	0.01	-4.25	42.068	97.62	153.172	208.724
76	0.81	-4.25	45.304	100.856	156.408	211.96
77	-2.49	-5.95	45.304	100.856	156.408	211.96
78	15	-0.85	48.54	104.092	159.644	215.196
79	1.61	-4.25	48.54	104.092	159.644	215.196
80	-1.69	-5.95	48.54	104.092	159.644	215.196

Appendix D RSView

In this appendix, the record, visualization, save and review of the data from RS-Ruby Lite will be interpreted with using RSView. The original sensor data can be also captured and examined by using other free tools, such as Wireshark or TCP-Dump. But visualization of the 3D data through using RSView is easy to realize. RS-Ruby Lite is used with RSView vision 3.1.5. or above

D.1 Software Features

RSView can provide real-time visualization of 3D coordinate data from RS-Ruby Lite. RSView can also review the pre-recorded data stored in “pcap” (Packet Capture) files, but RSView still doesn’t support directly importing “pcapng” files.

RSView displays directly the point cloud that is exchanged from the measured distance from RS-Ruby Lite. It supports changing the display mode of point cloud as user wishes, according to Reflectivity, timestamp, distance, azimuth, and laser channel. The data can be exported as XYZ coordinate data in CSV format or LAS format. RSView does not support generating point cloud files in XYZ, or PLY formats.

Function and features of RSView are shown as follow:

- Online visualization of sensor data over Ethernet
- Record of real-time data into pcap files
- Review of the collected point cloud from pcap files
- Different visualization mode based on distance, timestamp, azimuth, laser ID, etc.
- Tabular inspection of point cloud data
- Exporting the point cloud data into CSV format
- Tool for measuring distance from visualized cloud point
- Simultaneously display of multiple continuous frames (Trailing frames)
- Display or hide subsets of lasers
- Crop tool to show partial point cloud

D.2 Installation of RSView

Installation packet of RSView is suited for Windows 64-bit system and it has no need for other dependent software packets. The latest version of RSView can be downloaded from RoboSense website (http://www.robosense.ai/resource). Launch the installation packet and follow the instructions to complete the installation. The installation path should not contain any Chinese characters.

D.3 Network Setup

As mentioned in Chapter 5, the default IP address of the computer should be set as 192.168.1.102, sub-net mask should be 255.255.255.0. You should make sure RSView not be blocked by firewall in PC.

D.4 Visualization of point cloud

1. Connect the RS-Ruby Lite to PC over Ethernet cables and power supply.
2. Right Click to start the RSView application with Run as administrator.
3. Click on the "**File**"-> **Open** -> **Sensor Stream** (Figure D-1).

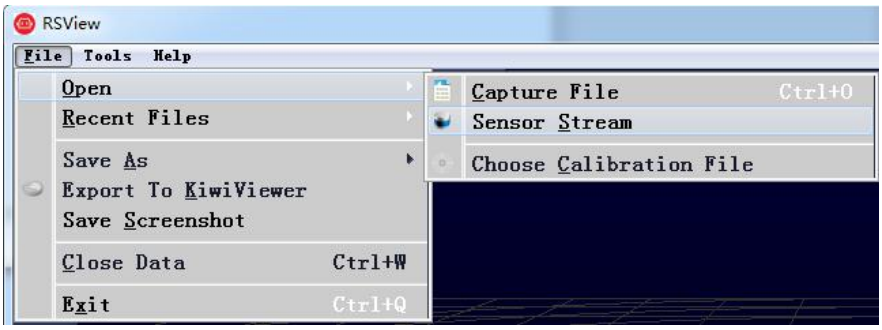


Figure D - 1: Open sensor stream in RSView.

4. After finishing the above 3 steps, the dialogue box "**Sensor Configuration**" shows up. In this dialogue box, the default configuration folder of RS-Ruby Lite calibration is already contained and the folder is already chosen. If there is chaos while displaying in RSView, please check and add the right configuration files folder. Click Add button then select corresponding file, and at last click the OK button (as shown in Figure D-2).

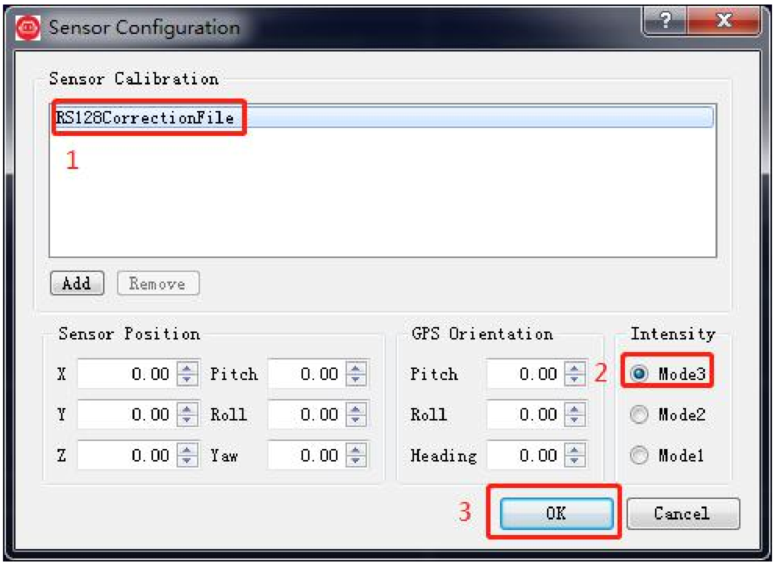


Figure D - 2: RSView Select Sensor Correction File.

5. RSView begins displaying the colored point cloud from capturing the sensor data stream from LiDAR (as shown in Figure D-3). The stream can be paused by pressing the **Play/Pause** button.

Figure D - 3: RSView Sensor Stream Display.

D.5 Save Streaming Sensor Data into PCAP File

1. Click the **Record** button during real-time display (Figure D-4).

Figure D - 4: RSView Record Button.

2. In the dialogue box "**Choose Output File**", the save path and file name of pcap file can be set up. (Figure D-5). After clicking "save" button, RSView begins writing data into pcap file. (Note: RS-Ruby Lite will generate enormous measuring data. So, it is best to use a fast, local HDD or SSD, not to use a slow subsystem, such as USB storage device or network drive.)

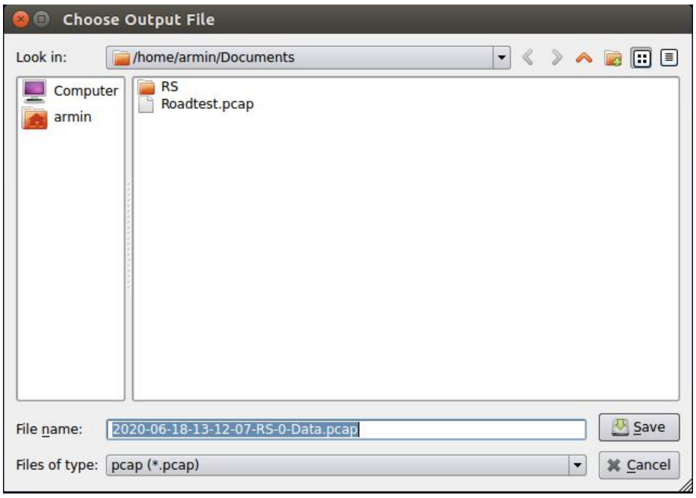


Figure D - 5: RSView Record Saving Dialog.

3. Click "**Record**" Button will finish record and save all the recorded data into this pcap file.

D.6 Replay Recorded Sensor Data from PCAP Files

In order to replaying (or examining) a pcap file, please import it into RSView. Then press **Play/Pause** button to let it play or scrub the time slider to a certain time point as user wishes. When only a part of 3D point cloud is concerned, it can be selected out by mouse. Then point cloud data of this part can be shown in table.

1. Click **File -> Open** then select **Capture File**.

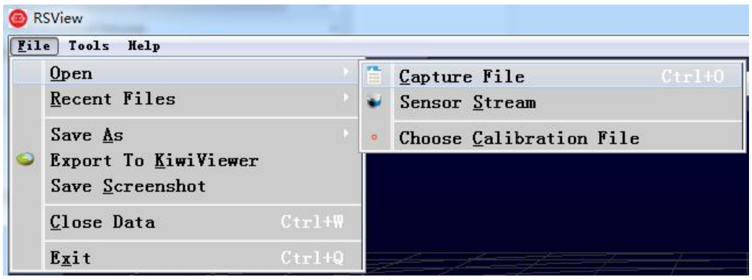


Figure D - 6: RSView Open Capture File.

2. Dialogue box "Open File" appears.
3. In dialogue box "Open File", please import a recorded pcap file then click **"Open (O)"** button.

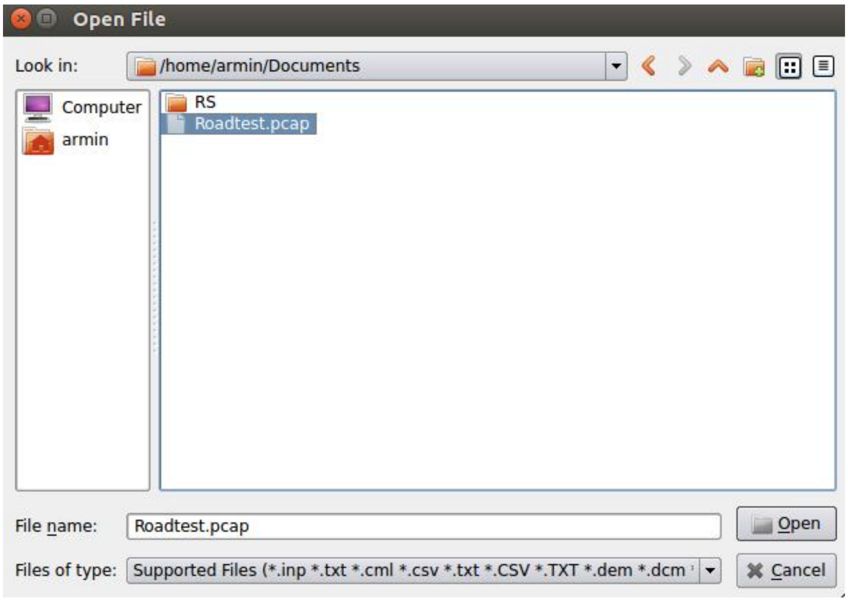


Figure D - 7: Select the PCAP File.

4. In dialogue box "Sensor Configuration", please add and select the right configuration file of RS-Ruby Lite, then click **OK**.
5. Clicking **Play/Pause** button can make 3D point cloud stream play and pause. Using the **Scrub** tool can select the interested frame. (Figure D-8)

Figure D - 8: RSView Play Button and Scrub slide tool.

6. In order to inspecting partial relevant point cloud data from a closer aspect, please scrub to an interested frame and click the **Spreadsheet** button (Figure D-9). A data table will be displayed on the right side. It contains all displayed data points in the frame.

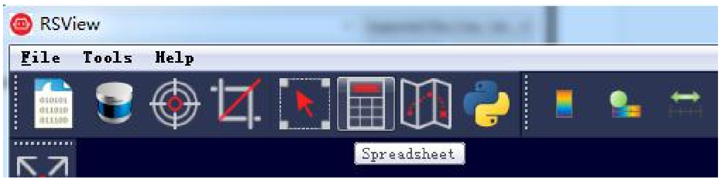


Figure D - 9: RSView Spreadsheet tool.

7. The dimension and the sort of data in this table are adjustable, which can make the display more obvious. (Figure D -10)

Showing: Data | Attribute: Point Data | Precision: 3

	Point ID	Points	adjustedtime	azimuth	distance_m	intensity	laser_id	timestamp
0	739	1.776···	998301570.000	993	10.380	5	11	998301570
1	752	1.814···	998301620.000	1011	10.415	6	11	998301620
2	753	1.820···	998301623.000	1012	10.390	25	12	998301623
3	754	1.829···	998301626.000	1013	10.390	13	13	998301626
4	766	1.846···	998301670.000	1029	10.415	6	11	998301670
5	767	1.861···	998301673.000	1030	10.440	25	12	998301673
6	768	1.861···	998301676.000	1031	10.390	13	13	998301676
7	769	1.871···	998301679.000	1032	10.410	33	14	998301679
8	780	1.877···	998301720.000	1047	10.410	6	11	998301720
9	781	1.893···	998301723.000	1048	10.440	25	12	998301723
10	782	1.896···	998301726.000	1049	10.405	13	13	998301726
11	783	1.906···	998301729.000	1050	10.425	40	14	998301729

Figure D - 10: RSView Data Point Table.

8. Click "**Show only selected elements**" in spreadsheet can acquire corresponding data, certainly there is no data shown in table, if no one point is selected. (Figure D-11)

Showing: Data | Attribute: Point Data | Precision: 3

	Point ID	Points	adjustedtime	azimuth	distance_m	intensi[Show only selected elements.]	[Show only selected elements.]stamp
0	739	1.776···	998301570.000	993	10.380	5	11	998301570
1	752	1.814···	998301620.000	1011	10.415	6	11	998301620

Figure D - 11: RSView Show Only Selected Elements.

9. By using "**Select All Points**" Tool, the arbitrary point can be selected. (as shown in Figure D-12)

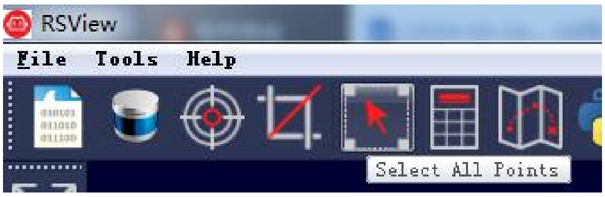


Figure D - 12: RSView Select All Points.

10. In the 3D rendered data pane using mouse to draw a rectangle around a small number of points. The values of them can be immediately shown in the table (Figure D -13).

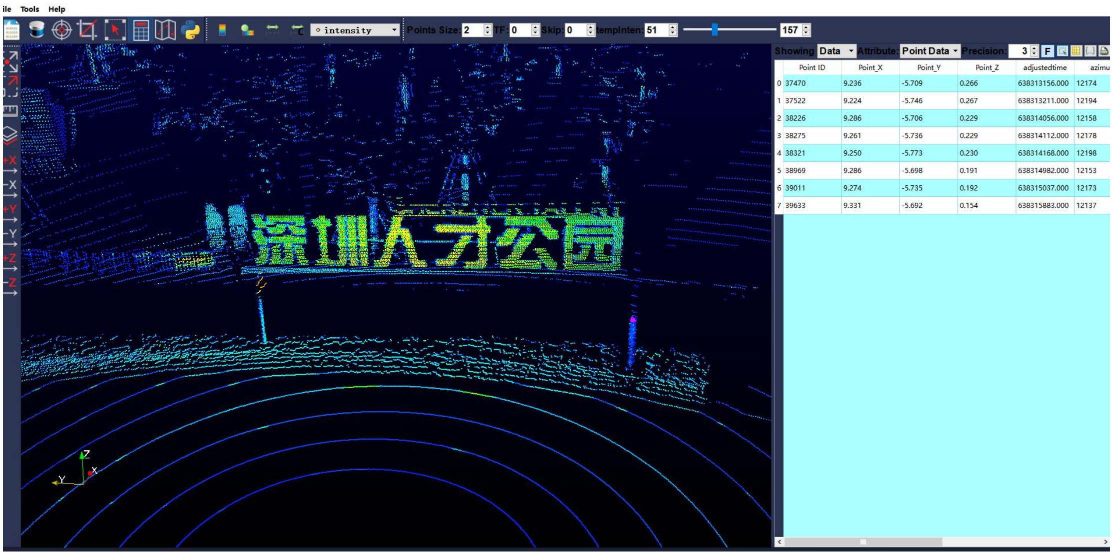


Figure D - 13: RSView Selected Points.

11. Any selected point can be saved by doing S**preadsheet > Output csv data > Select Frames**.

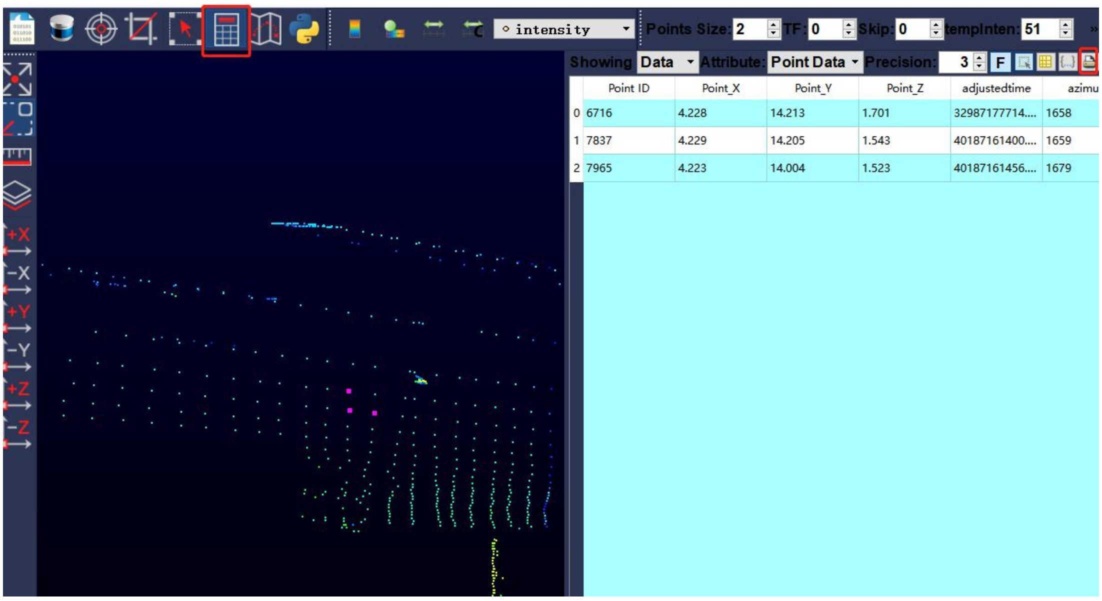


Figure D - 14: RSView Point Cloud Save.

Appendix E RS-Ruby Lite ROS&ROS2 Package

This appendix describes how to use Ubuntu +ROS or Ubuntu + ROS2 to acquire and visualize the measuring data from RS-Ruby Lite.

E .1 Software Installation

1. Download and Install Ubuntu 16.04 or Ubuntu18.04 OS.(ROS2 can be used on Ubuntu18.04)
2. For ROS: Please refer to the link (http://wiki.ros.org/kinetic/Installation/Ubuntu) to install the ROS Kinetic . (For user of Ubuntu18.04, please install ROS-melodic)
FOR ROS2: Please refer to the link (https://index.ros.org/doc/ros2/Installation/Eloquent/) to install the ROS2 Eloquent.
3. Download and install libpcap-dev.

E.2 Download & Compile RS-Ruby Lite ROS Package

The LiDAR driver can be downloaded in https://github.com/RoboSense-LiDAR/rslidar_sdk or contact RoboSense technical support. After download, **please read the README in driver packet carefully**, it can lead user to know how to compile and use LiDAR driver.
rslidar_sdk is the newest LiDAR driver, it supports our 5 mechanical LiDARs (RS-16, RS-32, RS-Bp, RS-Ruby, RS-Ruby Lite) at this moment. There are 3 compile modes:

1. Directly compile

Enter the main directory of rslidar_sdk packet, then create a build folder to compile complete project.

```
mkdir build
cd build
cmake .. && make
./rslidar_sdk_node
```

2. ROS compile environment

Create a workspace for ROS:

```
cd ~
mkdir -p catkin_ws/src
```

Copy the corresponding rslidar_sdk into the ROS workspace under the path: ~/catkin_ws/src. Open file CMakeLists.txt, then modify the set(COMPILE_METHOD ORIGINAL) on the top of document to set(COMPILE_METHOD CATKIN). Meanwhile, rename the package_ros1.xml to package.xml.

In terminal, build the project:

```
cd ~/catkin_ws
catkin_make
```

3. ROS2 compile environment

Create ros2 workspace:

```
cd ~
mkdir -p catkin_ws/src
```

Copy the corresponding rslidar_sdk into the ROS2 workspace under the path: ~/catkin_ws/src. Open file CMakeLists.txt, then modify the set(COMPILE_METHOD ORIGINAL) on the top of document to set(COMPILE_METHOD CATKIN). Meanwhile, rename the package_ros2.xml to package.xml.

In terminal, build the project:

```
cd ~/catkin_ws
conlcon build
```

E.3 Configure PC IP address

For the default RS-Ruby Lite firmware, static IP address of PC is configured to "192.168.1.102", submask: "255.255.255.0", gateway doesn't need configuration.
After configuring the static IP, it can be examined in Terminal with code ifconfig.

E.4 Display of the real-time data

In rslidar_sdk, there are explicitly instruction document to guide visualization of point cloud in ROS or ROS2 environment. Here, ROS environment is as the example.

1. Connect the RS-Ruby Lite to PC via twister pair wire with RJ45 connector, power on, then wait for PC to recognize LiDAR.

2. Use the launch file in rslidar_sdk to run the node of visualization, this launch file locate in rslidar_sdk/launch/start.launch. Open a terminal, Enter the commands as below:

```
cd ~/catkin_ws
source devel/setup.bash
roslaunch rslidar_sdk start.launch
```

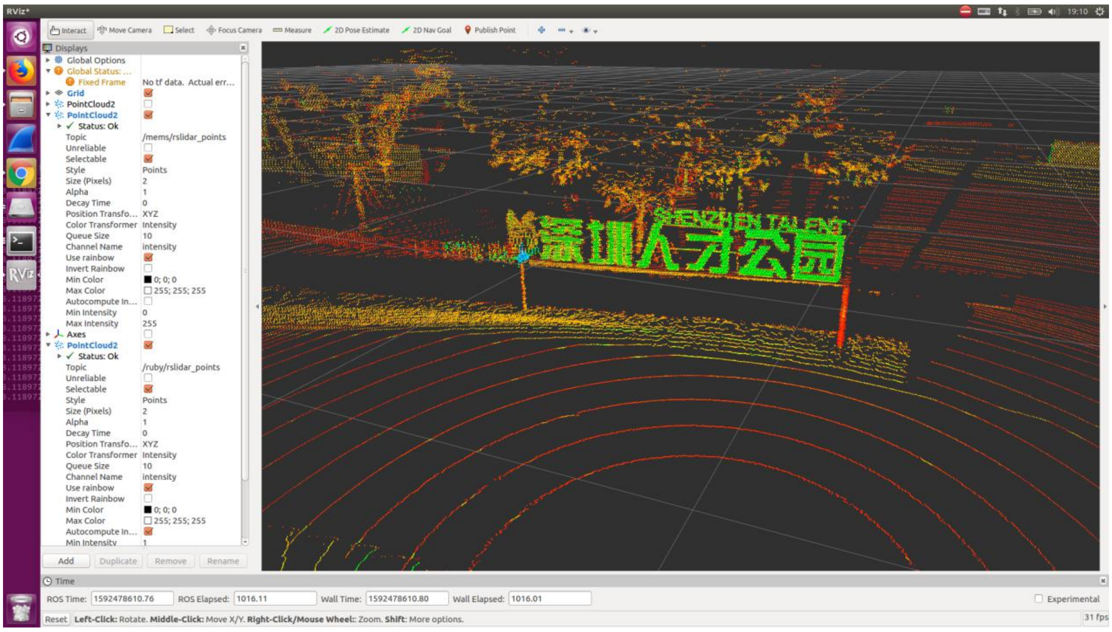


Figure E - 1: Display point cloud Data in rviz.

E.5 Display offline data

For offline data packet (rosbag or pcap) in rslidar_sdk, there is completely instructions to guide to read, parse and visualize point cloud.

1. Modify the parameters in "rslidar_sdk/config/config.yaml" file.(set *msg_source* to 3 for message from pcap and fill *pcap_directory* to the directly path to pcap (e.g. /home/robosense/80.pcap).

2. Open terminal, run the node:

```
cd ~/catkin_ws
source devel/setup.bash
roslaunch rslidar_sdk start.launch
```

Appendix F Dimension

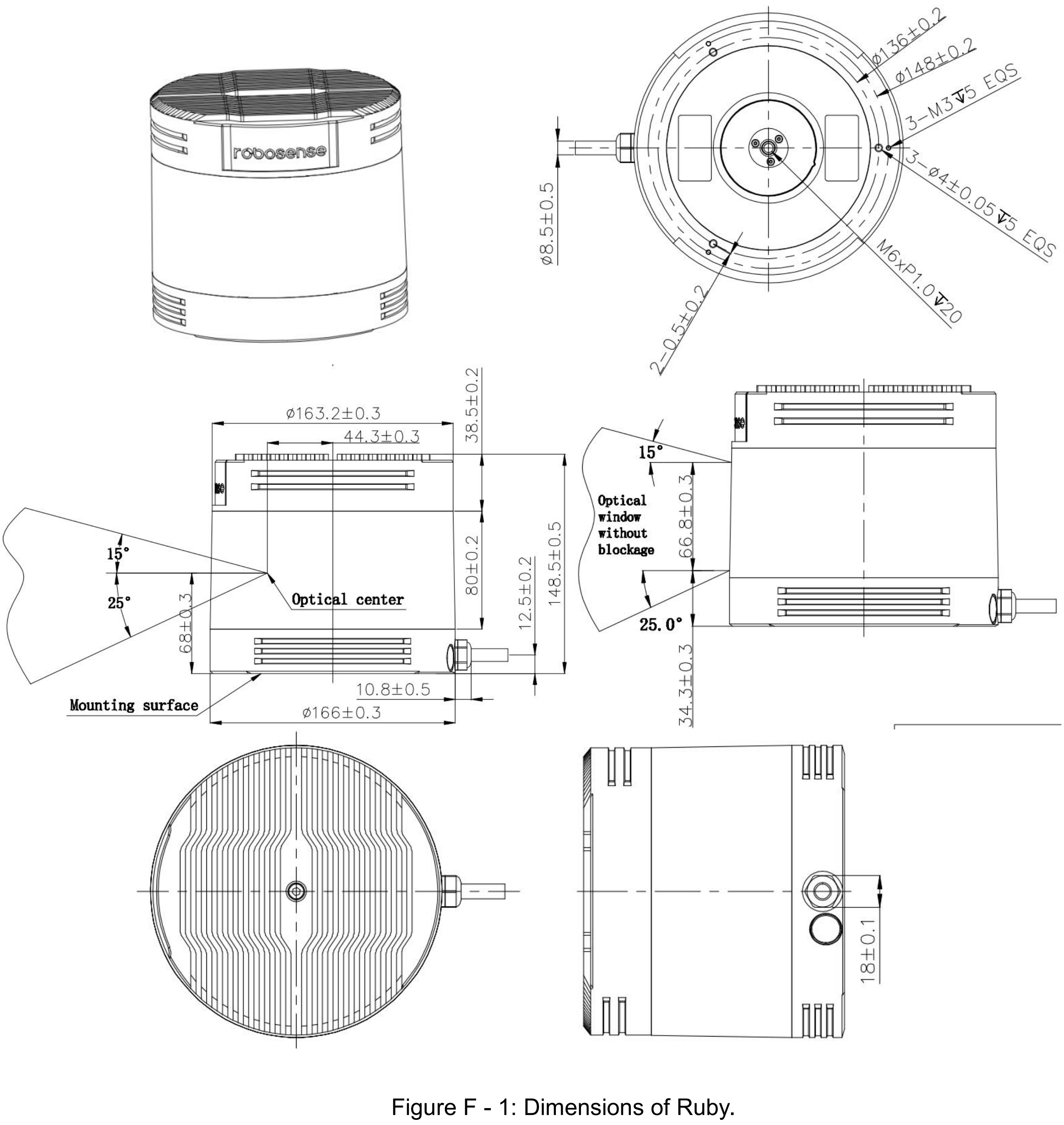


Figure F - 1: Dimensions of Ruby.

Appendix G Suggestion of Mechanical LiDAR Mount

Please make sure that the surface of platform used for mounting LiDAR is as smooth as possible.

Please make sure the locating pin on the mount surface do not exceed 4.5 mm high.

The material of the mount platform is suggested to be aluminum alloy in order to avoid thermolysis effects.

When the LiDAR is installed, if there is a mounting contact surface on the upper and bottom sides of the LiDAR, make sure that the spacing between the mounting surfaces is greater than the height of the LiDAR to avoid squeezing the LiDAR.

Please don't mount the LiDAR in a tilt position where the tilt angle exceeds 90 degrees, this will reduce the sensor life time.

When the LiDAR cable is routed in the mount device, please keep the cable a little slack, not too tense.

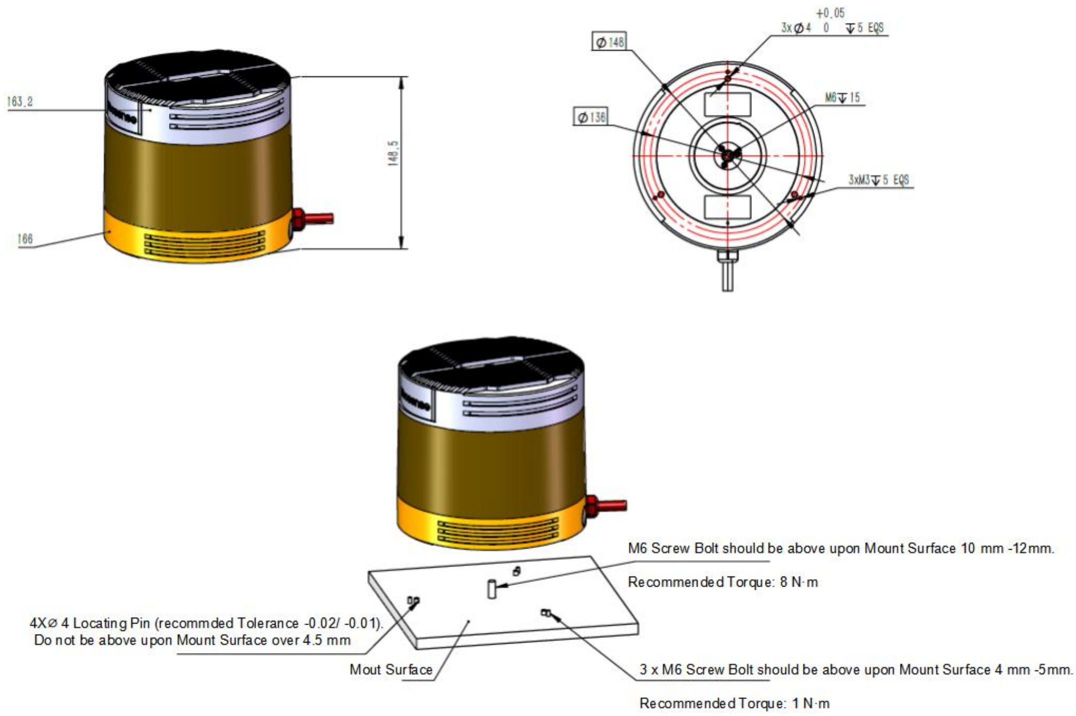


Figure G - 1: Quick Start of LiDAR Mounting.

Appendix H Cleaning of LiDAR

H.1 Attention

Before cleaning the RS-LiDAR, please read through this entire Appendix H. Otherwise, improper handling may permanently damage the LiDAR.
When the sensor is used in a harsh environment, it is necessary to clean it in time to keep its performance.

H.2 Required Materials

1. Clean microfiber cloths
2. Mild, liquid dish-washing soap
3. Spray bottle with warm, clean water
4. Solution of Isopropyl alcohol
5. Clean gloves

H.3 Cleaning Method

If the sensor is just covered by dust, use a clean microfiber cloth with a little isopropyl alcohol to clean the sensor directly, then dry with another clean microfiber cloth.
If the sensor is caked with mud or bugs: Firstly, use a spray bottle with clean, warm water to loosen any debris from it(Do not wipe dirt directly off the sensor, doing so may abrade the surface). Secondly, use warm, mildly-soapy water to gently wipe the sensor with a clean microfiber cloth(Wipe the ring lens gently along the curve of the sensor, not the top-to-bottom way). To finish, spray the sensor with clean water to rinse off any remaining soap (if necessary, use isopropyl alcohol and a clean microfiber cloth to clean any remaining dirt from the sensor), then dry with another clean microfiber cloth.

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深圳市速腾聚创科技有限公司
Shenzhen Suteng Innovation Technology Co., LTD.

Address: 深圳市南山区留仙大道 3370 号南山智园崇文园区 3 栋 10-11 层 10-11/F, Block 3, Chongwen Garden, Nanshan IPark, 3370 Liuxian Avenue, Nanshan District, Shenzhen, China

Web：www.robosense.cn Tel: 0755-8632-5830 Email: Service@sz-sti.com