User Guide

*【Executive Standard】 Q/RS 001-2021

Revision History

Revision	Content	Date	Edited by
1.0.0	Initial issue	2022-04-18	PD
1.1.0	Revise some description error Update Appendix C Dimension Update the priority for packet recording tool	2022-07-01	PD
1.2.0	Revise Chapter 1 some description error	2022-09-05	PD
1.3.0	Revise Chapter 2 Communication Protocol, IP and Port; Revise Chapter 3 State Machine and Wiring Harness Instruction Revise Appendix A RSview version and User Guide Revise Appendix B Diver and SDK	2022-12-21	PD

Table of Contents

1 Product Specifications

RS-LiDAR-M1P, adopting the MEMS solid-state LiDAR technology, has achieved long measuring distance up to 200 meters (180m @ 10%), high data rate of 750,000 points/sec (single return) and 1,500,000 points/sec (dual return) data output, a horizontal FOV of 120° (-60.0°~+60.0°), a vertical FOV of 25° (-12.5°~+12.5°).

Table 1: Product Specifications

Sensor	● Time of Flight (TOF) ranging, including reflection intensity value ● Ranging distance: 0.5m ~200m(180m@10% NIST)[1] ● Ranging Precision: ± 5cm@1 sigma[2] ● FOV(vertical): 25° (-12.5°~+12.5°)[3] ● Angular resolution(vertical): average 0.2°[4] ● FOV(horizontal): 120° (-60.0°~+60.0°) ● Angular resolution(horizontal): average 0.2°[4] ● Frame rate: 10Hz
Laser	● Class 1 eye safe ● Wavelength: 905nm
Output	● ~750,000 points/second (single return mode) ● ~1,500,000 points/second (dual return mode) ● 1000Base-T1 Gigabit Ethernet ● UDP package contains Three-dimensional space coordinates, reflection intensity, time stamp, etc.

1 The ranging capability of 180 meters is measured with the 10% NIST diffuse reflector as the target, the test results may be affected by the environment conditions, including but not limited to factors such as ambient temperature and lights;

2 The ranging precision is tested in the range of 10m~100m with 50% NIST diffuse reflector as the target. The test results may be affected by the environment conditions, including but not limited to factors such as ambient temperature and target distance. The precision value is applicable to most channels, but difference may exist between some channels.

3 The five channels of RS-LiDAR-M1P are horizontally arranged, with staggered positions vertically; The maximum envelope vertical FOV of a single channel is 25.2 °; Since the FOV of five channels are present irregularly, based on the maximum envelope principle, the vertical FOV will be calculated as 35.79 °;

4 The vertical & horizontal angular resolution is not uniform in the entire FOV, the average angular resolution is 0.2°;

Mechanical/electronic operation	● Power consumption: 15w[5] ● Working voltage: 9~16VDC ● Weight: about 0.75kg (not including data cable) ● Dimensions: Length 110mm * Width 111mm * Height 45mm ● Protection level: IP67, IP6K9K ● Operating temperature range: -40°C~85°C(Forced convection is required for long hours of work)[6] ● Storage temperature: -40°C ~105°C

5 The device power consumption is tested when the device is working stably, and the results may be affected by external environment conditions, including but not limited to factors such as ambient temperature, target distance, target reflectivity, etc.

6 The operating temperature of the device may be affected by external environment conditions, including but not limited to factors such as solar radiation, airflow changes, etc.

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2 Communication Protocol

The communication between RS-LiDAR-M1P and the computer is through Ethernet, and uses UDP protocol. There are two types of output packets: MSOP packet and DIFOP packet. All MSOP packets involved in this document are with fixed length of 1210 bytes, DIFOP packets are with fixed length of 256 bytes. In single return mode, the output data includes 6300 MSOP packets and 10 DIFOP packet, which demands the data transfer rate no less than 58.2 Mbps. In dual return mode, the rate must be no less than 116.4 Mbps. RS-LiDAR-M1P network parameters are configurable, and the factory default IP and fixed client port number are set as listed in the table below:

Table 2: Factory default network configuration

	IP Address	MSOP Port Number	DIFOP Port Number
RS-LiDAR-M1P	192.168.1.200	/	/
Computer	192.168.1.102	6699	7788

The default MAC address of the LiDAR is initially set at the factory, and the MAC address of each LiDAR is unique.

When using the LiDAR in unicast mode, you need to set the computer's IP to the same network segment as the LiDAR, for example, 192.168.1.x (the range of x is 1~254), and the subnet mask as 255.255.255.0. If you don't know the network configuration information of the LiDAR, please set the host computer subnet mask to 0.0.0.0, connect to the LiDAR and use Wireshark to capture the LiDAR output packet for analysis.

The communication protocol between RS-LiDAR-M1P and the computer is mainly divided into two categories. See the table below for the protocol list.

- The main data stream output protocol (MSOP), encapsulates the distance, angle, reflectivity and other information measured by the LiDAR into a package and outputs it to the computer;
- LiDAR information output protocol (DIFOP), outputs various configuration information of the LiDAR currently in use to the computer.

Table 3: List of communication protocols

Protocol	Abbreviation	Function	Type	Packet size
Main Data Stream Output	MSOP	Output measured	UDP	1210 Bytes

Protocol		data		
LiDAR Information Output Protocol	DIFOP	Output device information	UDP	256 Bytes

Note: The following chapters describe and define the payload (MSOP package of 1210 bytes and DIFOP package of 256 bytes) of the protocols.

2.1 Main Data Stream Output Protocol (MSOP)

Main data Stream Output Protocol is abbreviated as MSOP.

I/O type: LiDAR output, computer analysis.

Default port number: 6699.

The MSOP packets output three-dimensional measurement related data, including laser ranging value, return reflectivity value, vertical angle, horizontal angle and time stamp. The payload length of the MSOP packet is 1210 bytes, which consists of a synchronization header of 32 bytes, a data packet of 1175 bytes (a total of 25 data blocks of 47 bytes), and a tail of 3 bytes.

The basic structure of the MSOP packet is as shown in the figure below:

MSOP Packet (1210 Bytes)

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Figure 1: MSOP Packet Structure

2.1.1 Header

The header is 32-byte long, and is used for identification of the starting position of data, packet counting, UDP communication reservation, and time stamp storage. The detailed definition is as follows:

Table 4: MSOP Header

Header（32 Bytes）				
pkt_header	pkt_psn	protocol version	wave_mode	time_sync_mode
4 Bytes	2 Bytes	2 Bytes	1 Byte	1 Byte
timestamp	reserved	lidar_type	mems_tmp	
10 Bytes	10 Bytes	1 Byte	1 Byte	

pkt_header: can be used as a packet inspection sequence, and the identification header is 0x55, 0xaa, 0x5a, 0xa5.

pkt_psn: Packets Sequence Number, packet counting in a circular counting manner, the count value of the first data packet of each frame is 1, the count value of the last data packet of each frame is the maximum value.

protocol version: version number of the UDP communication protocol

wave_mode: return mode flag, 0 means dual return mode, 1 - N/A, 2 - N/A, 3 - N/A, 4 means strongest return, 5 means last return, 6 means first return.

time_sync_mode: time synchronization mode:

0x00 currently using the LiDAR internal timing

0x01 currently using 1PPS for sub-second reset in full seconds

0x02 currently using PTP time synchronization mode

0x03 currently using gPTP time synchronization mode

Timestamp: store timestamps. The defined timestamp is used to record the system time. The high 6 bytes are the second bits, and the low 4 bytes are the microsecond bits.

reserved: reserved bit

lidar_type: the type of LiDAR, default value is 0x10

mems_tmp: mems temperature, Temp=mems_tmp-80; namely when mems_tmp value is 0, mems temperature is -80℃; when the value is 255, the temperature is 175℃.

2.1.2 Data Packet

The data packet in the MSOP packet stores the data measured by the LiDAR. It has a total of 1175 bytes consisting of 25 data blocks, each data block has 47 bytes.

In single return mode, each data block represent the complete measurement data measured by a group of 5 laser channels at one time. Each data block stores the data of one transmission in the single return mode.

In dual return mode, the odd numbered MSOP packets store the data of the first return, including 25 data blocks. The even numbered MSOP packets store the data of the second return, including 25 data blocks. The first and second returns are stored by turns in sequence. The type of returned packets could be judged according to the 'returen_seq' value in the data block, please check Table 5 for detailed definition. Every two MSOP packets form a complete measurement. The total number of data points in a dual return mode is twice that of a single return mode.

The detailed definition is as follows:

Table 5： Definition of data block in MSOP packet

data block N (47 Bytes)			
content	offset(byte)	byte	instruction
time_offset	0	1	The time offset of all points in the block relative to the timestamp of the packet, the time of this group of points equals to timestamp+time_offset
return_seq	1	1	Return sequence. In single-return mode, this flag is always 0; in dual-return mode, the first return (closer) is represented by 0x1, and the second return (further) is represented by 0x2
ch1_radius	2	2	In the polar coordinate system, the radial distance value of the channel 1 points, the distance resolution is 5mm
ch1_elevation	4	2	In the polar coordinate system, the vertical angle of the channel 1 points, the resolution is 0.01°
ch1_azimuth	6	2	In the polar coordinate system, the horizontal angle of the channel 1 points, the resolution is 0.01°

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ch1_intensity	8	1	Reflection intensity value of the channel 1 points, the value range is 0~255
resev.	9	2	Reserved bits
ch2_radius	11	2	In the polar coordinate system, the radial distance value of the channel 2 points, the distance resolution is 5mm
ch2_elevation	13	2	In the polar coordinate system, the vertical angle of the channel 2 points, the resolution is 0.01°
ch2_azimuth	15	2	In the polar coordinate system, the horizontal angle of the channel 2 points, the resolution is 0.01°
ch2_intensity	17	1	Reflection intensity value of the channel 2points, the value range is 0~255
resev.	18	2	Reserved bits
ch3_radius	20	2	In the polar coordinate system, the radial distance value of the channel 3 points, the distance resolution is 5mm
ch3_elevation	22	2	In the polar coordinate system, the vertical angle of the channel 3 points, the resolution is 0.01°
ch3_azimuth	24	2	In the polar coordinate system, the horizontal angle of the channel 3 points, the resolution is 0.01°
ch3_intensity	26	1	Reflection intensity value of the channel 3 points, the value range is 0~255
resev.	27	2	Reserved bits
ch4_radius	29	2	In the polar coordinate system, the radial distance value of the channel 4 points, the distance resolution is 5mm
ch4_elevation	31	2	In the polar coordinate system, the vertical angle of the channel 4 points, the resolution is 0.01°
ch4_azimuth	33	2	In the polar coordinate system, the horizontal angle of the channel 4 points, the resolution is 0.01°
ch4_intensity	35	1	Reflection intensity value of the channel 4 points, the value range is 0~255
resev.	36	2	Reserved bits
ch5_radius	38	2	In the polar coordinate system, the radial distance value of the channel 5 points, the distance resolution is 5mm

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ch5_elevation	40	2	In the polar coordinate system, the vertical angle of the channel 5 points, the resolution is 0.01°
ch5_azimuth	42	2	In the polar coordinate system, the horizontal angle of the channel 5 points, the resolution is 0.01°
ch5_intensity	44	1	Reflection intensity value of the channel 5 points, the value range is 0~255
resev.	45	2	Reserved bits

N is the N^{th} data block in any MSOP packet.

time_offset: the time offset of all points in the N^{th} block relative to the time stamp of the packet. The time of this group of points equals time stamp+time_offset.

return_seq: return sequence. In single-return mode, this flag is always 0; in dual-return mode, the first return (closer) is represented by 0x1, and the second return (further) is represented by 0x2

n is the n^{th} channel in the N^{th} data block, n=1, 2, 3, 4, 5, which contains data as follows:

chn_radius: the radial distance value of the points of channel n in the polar coordinate system, the resolution is 5mm.

chn_elevation: the vertical angle of the channel n points in polar coordinate system, the resolution is 0.01°

chn_azimuth: the horizontal angle of the channel n points in polar coordinate system, the resolution is 0.01°

chn_intensity: reflection intensity value of the channel n points, the value range is 0~255.

2.1.2.1 Channel Data Definition

The channel data is 9-byte long, with the radial distance of this channel occupying 2 bytes, the elevation angle occupying 2 bytes, the horizontal angle occupying 2 bytes, the reflection intensity value occupying 1 byte, and 2 bytes reserved.

Detailed definitions are as follows:

Table 6：Definition of channel data in data block

channel data（9 Bytes)			
chn_radius	chn_elevation	chn_azimuth	chn_intensity

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(2 Bytes)		(2 Bytes)		(2 bytes)		(1 Byte)
R1 [15:8]	R2 [7:0]	E1[15:8]	E2[7:0]	A1[15:8]	A2[7:0]	Intensity[7:0]
resv. (2 Bytes)						
r1 [15:8]	r2 [7:0]					

Take the radial distance calculation as an example：

Chn_radius is 2-byte long, and the resolution is 0.5 cm.

Get the hexadecimal number of the radius value of a channel in the data packet: R1 is 0x03, R2 is 0xfc

0x03 is the high digit of the distance, converted to decimal is 3, 0xfc is the low digit of the distance, converted into decimal is 252.

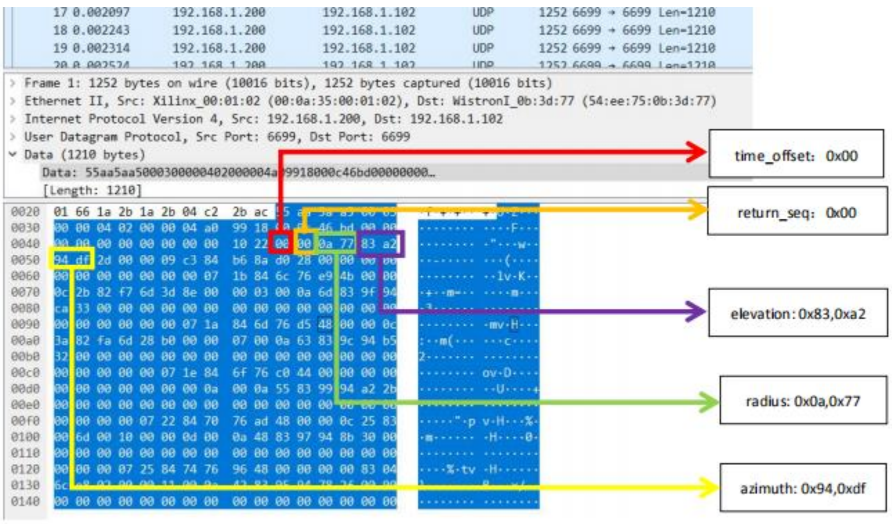
Therefore: the radial distance of this channel=R1*256+R2=3*256+252=1020.

According to the resolution of the coordinates, it is converted to meters: 1020 *0.005=5.10m.

Therefore, the radial distance of this channel in the corresponding elevation and azimuth direction is 5.1 m.

Calculation of XYZ coordinates:

Use Wireshark to capture the data packets of RS-LiDAR-M1P, as shown in the figure below:



Example of parameters calculation:

1. **time_offset:** data block time offset HEX: 0x00 -> DEC: 00 -> 0 µs

2. **return_seq:** HEX: 0x00 -> single return

3. **radius:** radial distance HEX: 0x0a,0x77 -> DEC: 10, 119

-> radius = (10 x256 + 119) x0.005 [m] = 13.395 m

4. **elevation:** vertical angle HEX: 0x83,0xa2 -> DEC: 131,162

-> elevation = ((131 x 256 + 162)-32768) x 0.01[degree] = 9.3º

5. **azimuth:** horizontal angle HEX: 0x94,0xdf -> DEC: 148,223

-> azimuth = ((148 x 256 + 223)-32768) x 0.01[degree] = 53.43º

The X, Y, Z coordinates of the point cloud can be calculated by the formula below:

$$\begin{cases} X = radius \bullet \cos(evelation) \bullet \cos(azimuth) \\ Y = radius \bullet \cos(evelation) \bullet \sin(azimuth) \\ Z = radius \bullet \sin(evelation) \end{cases}$$

$$\begin{cases} X = 13.395m \bullet \cos(9.3^\circ) \bullet \cos(53.43^\circ) \\ Y = 13.395m \bullet \cos(9.3^\circ) \bullet \sin(53.43^\circ) \\ Z = 13.395m \bullet \sin(9.3^\circ) \end{cases}$$

Thus, the X, Y, Z coordinates of the point cloud of one transmitting in the single return mode of this channel is (7.88m,10.62m,2.17m)。

2.1.3 Tail

The Tail contains 3 bytes and are reserved bits.

2.2 LiDAR Information Output Protocol (DIFOP)

LiDAR Information Output Protocol is abbreviated as DIFOP

I/O type: LiDAR output, computer read.

Default port number: 7788.

DIFOP is an "output-only" protocol to periodically send the LiDAR serial number (S/N), firmware version information, host computer driver compatibility information, network configuration information, calibration information, operating status, and fault diagnosis information to users. By reading DIFOP, users can learn specific information of various parameters of the LiDAR currently in use.

A complete DIFOP packet consists of a synchronization header, reserved bytes and a data packet. Each DIFOP Packet is 256-byte long, including an 8-byte long synchronization header, 1 reserved byte and a 247-byte long data packet.

The basic structure of the DIFOP packet is as shown in the table below.

Table 7: Definition of DIFOP packet

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DIFOP 256Byte					
Catalogue	No.	Type	Details	Offset	Byte
Header	1	DIFOP_Header	DIFOP_Header	0	8
Data	2	Reserve		8	1
	3	Frequency	Frequecy_Setting	9	1
	4	Ethernet	Source_IP	10	4
			Destination_IP	14	4
			MAC_Address	18	6
			MSOP_Port	24	2
			DIFOP_Port	26	2
	5	FW	Mian_Board_PL_PN	28	5
			Main_Board_PS_PN	33	5
	6	Reserve		38	16
	7	Wave	Return_Mode	54	1
	8	Time	Timesync_Mode	55	1
			Timesync_Status	56	1
			Time_Status	57	10
	9	Volt	Battery_Volt	67	2
	10	Reserve		69	67
	11	Diagnosis	Lidar fault status	136	1
	12	Reserve		137	118

Note:

1. The Header (DIFOP identification header) in the table is 0xa5, 0xff, 0x00, 0x5a, 0x11,0x11,0x55, 0x55, which can be used as the packet inspection sequence.

2. The LSB of the horizontal FOV is 0.01°the minimum value is 0°, and the maximum value is 120°.

3. The LSB of the vertical FOV is 0.01°, the minimum value is 0°, and the maximum value is 25 °.

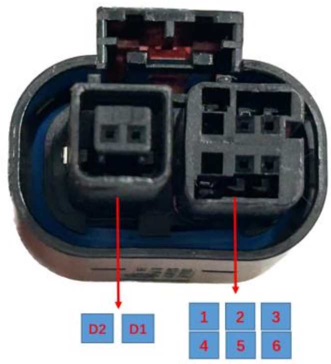
4. Return mode setting: the return mode flag, 0-dual return, 1-N/A, 2-N/A, 3-N/A, 4- strongest return, 5-last return, 6-The first return.

5. Time synchronization mode setting: the default value is 0x03. 0x00 means currently using the LiDAR internal timing, 0x01 means that the 1PPS is currently used for sub-second reset in full seconds, 0x02 means currently using PTP time synchronization mode, 0x03 means currently using gPTP time synchronization mode.

6. Time synchronization status: status of synchronization success. 0-unsuccess syn, 1-syn Success, 2-Time out.

3 Interface Box Connection and State Machine

3.1 The Instruction of Wiring Harness

<table>
<tr><th>Item</th><th>Photograph</th><th>Terminal</th><th colspan="2">Signal Type</th></tr>
<tr><td rowspan="13">Auto-motive Ethernet and Power Harness</td><td rowspan="13"></td><td rowspan="8">Terminal：a</td><td>D2</td><td>1000Base T1 P</td></tr>
<tr><td>D1</td><td>1000Base T1 N</td></tr>
<tr><td>1</td><td>GND</td></tr>
<tr><td>2</td><td>Wakeup</td></tr>
<tr><td>3</td><td>/</td></tr>
<tr><td>4</td><td>Battery+</td></tr>
<tr><td>5</td><td>/</td></tr>
<tr><td>6</td><td>/</td></tr>
<tr><td rowspan="3">Terminal：b</td><td>1</td><td>GND</td></tr>
<tr><td>2</td><td>Wakeup</td></tr>
<tr><td>4</td><td>Battery+</td></tr>
<tr><td rowspan="2">Terminal：c</td><td>D2</td><td>1000Base T1 P</td></tr>
<tr><td>D1</td><td>1000Base T1 N</td></tr>
</table>

<table>
<tr><td>AC Power Harness</td><td></td><td rowspan="4">Interface Box</td><td>d</td><td>AC Power (female)</td></tr>
<tr><td rowspan="2">AC Power Adaptor</td><td rowspan="2"></td><td>e</td><td>AC Power (male)</td></tr>
<tr><td>f</td><td>Interface Box Power Supply</td></tr>
<tr><td>Gigabit Ethernet Cable</td><td></td><td>g/h</td><td>Gigabit Ethernet</td></tr>
</table>

3.2 The Connection of Interface Box

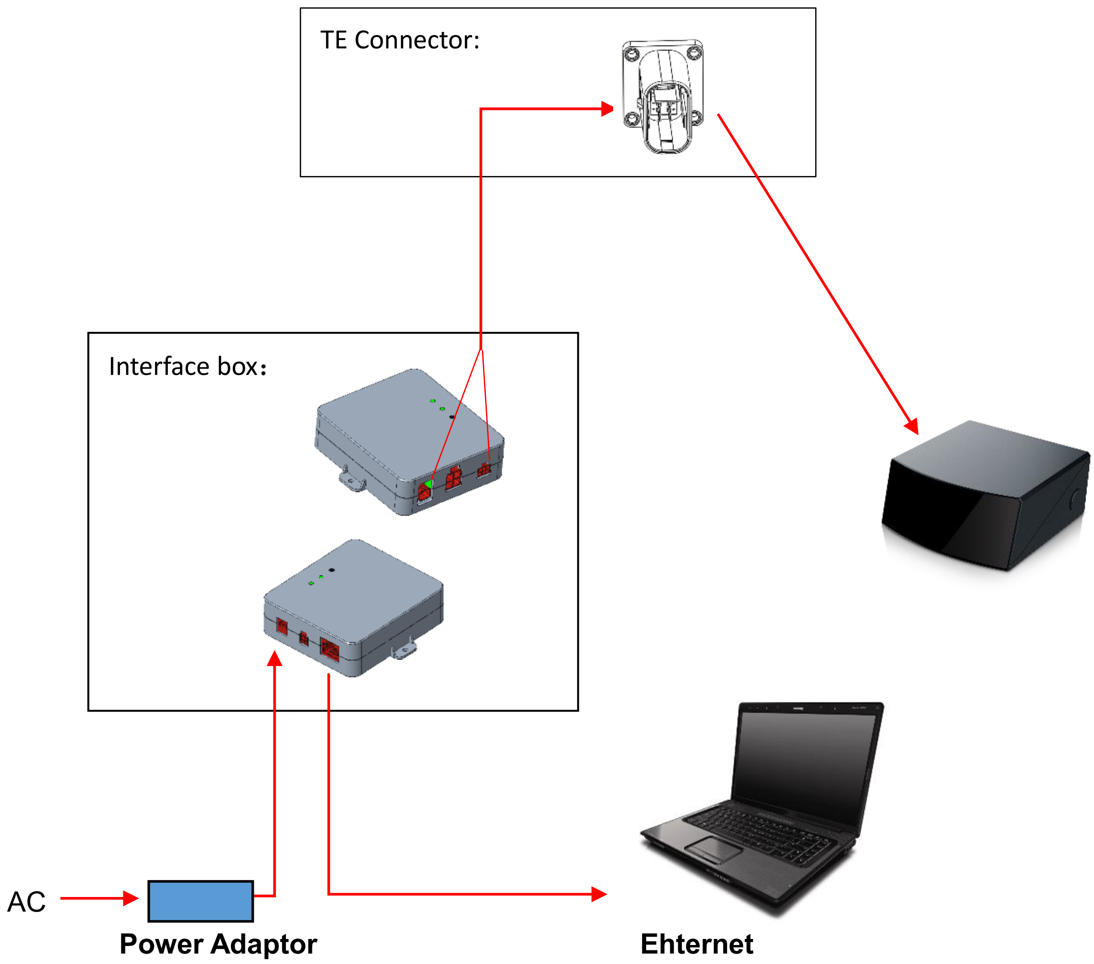
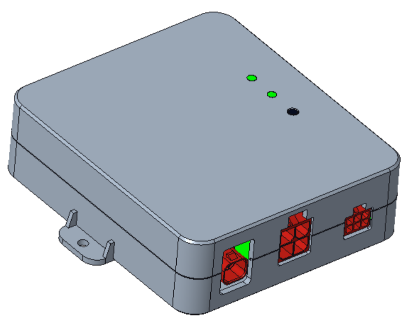
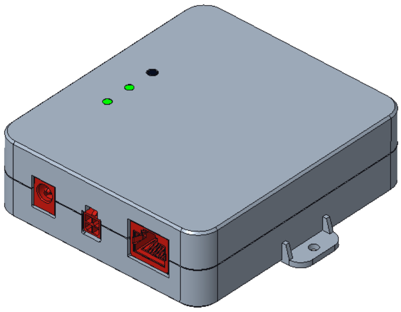


Figure 2: Image for topology of LiDAR and PC

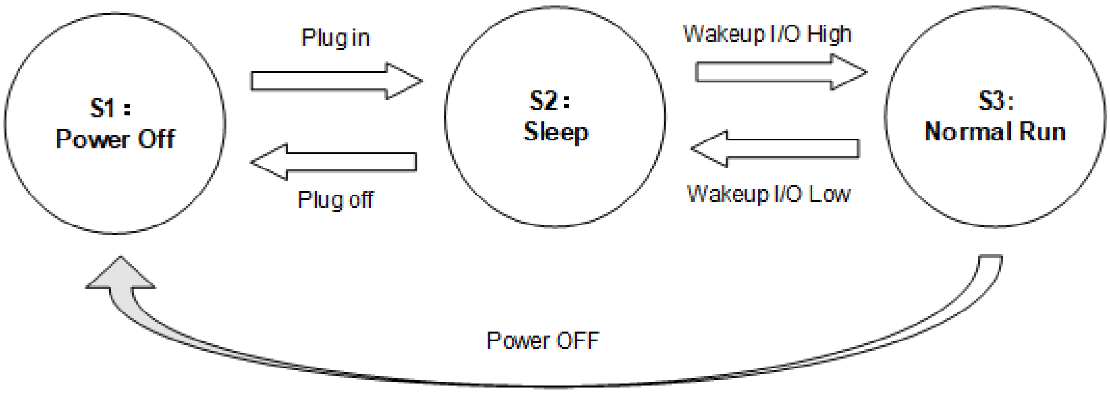
Note：

Figure 2 shows the topology of connection of Interface Box (TE).

Connection	Interface Box (TE)
Connecting to LiDAR	

Connecting to Power Adaptor and Host Computer	

3.3 State Machine of LiDAR



Wakeup I/O Definition

Item	Wakeup I/O Voltage Range	Note
Wakeup I/O High	7V~16V	DC High-Level signal
Wakeup I/O Low	0V~2V	DC Low-Level signal

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4 Time Synchronization

RS-LiDAR-M1P default firmware supports gPTP (IEEE 802.1AS) time synchronization method. Therefore, only gPTP is supported by default. If users want to apply PTP (IEEE 1588v2)time synchronization method, please contact RoboSense technical team for support.

4.1 Precision Time Protocol

4.1.1 Time Synchronization Introduction

PTP is defined as a time-synchronization protocol. It is mainly used to achieve high-precision time synchronization between different devices through network communication, and can also be used for frequency synchronization. Compared to the existing time synchronization mechanisms, PTP has the following advantages:

1) Compared to Network Time Protocol (NTP), PTP can fulfill the requirement of time synchronization with higher precision. Generally, NTP can only achieve the sub-second level of time synchronization precision, while PTP can support sub-microsecond level.

2) Compared to Global Positioning System (GPS), PTP has advantages of lower construction and maintenance costs. Meanwhile, it also has significant meanings in national security due to independence on GPS.

PTP supports different communication protocols (CAN, Ethernet, etc.). PTP can apply two mechanisms for synchronous: end-to-end (E2E) or peer-to-peer network (P2P):

E2E mode: apply Request Response Mechanism

P2P mode: apply a peer delay mechanism (Peer Delay Mechanism).

Note: The PTP protocol provided by RoboSense only supports the L2 layer of Ethernet protocol, E2E mode.

gPTP (general precise time protocol) is a derivative protocol of PTP in Time-Sensitive Networking. gPTP shares the same synchronization mechanism with PTP -- Peer Delay Mechanism, and it applies the L2 layer of Ethernet for communication. Unlike PTP, hardware timestamps are required for gPTP, which results in stricter requirements for the switch and Master clock.

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4.1.2 gPTP Wiring Connection

To initialize gPTP synchronization procedure, users need to prepare the following devices and finish wiring connection according to the topology below:

1) a gPTP Grand Master (plug-and-play without additional configuration);

2) Ethernet switch;

3) Slave devices supporting gPTP (RS-LiDAR-M1P and others);

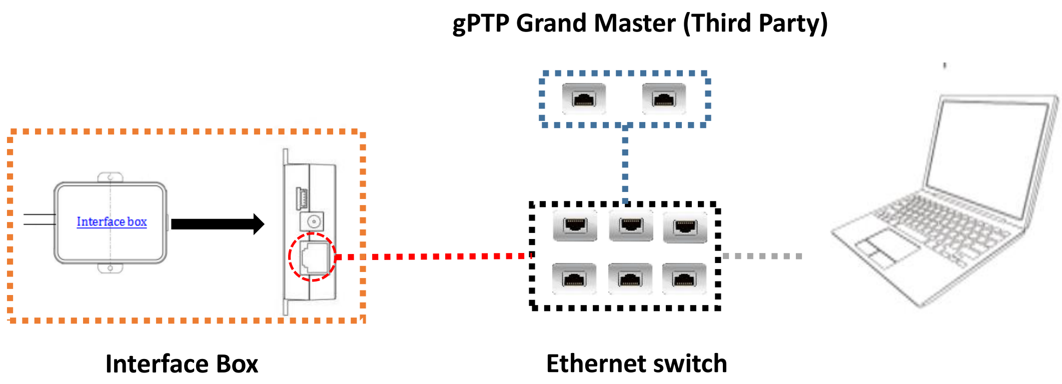

Figure 3：Topology of gPTP time synchronization

Note：

1. gPTP Grand Master device belongs to the third party, which is not included in our packing list. Users need to purchase that by themselves in advance;

2. As a Slave terminal, RS-LiDAR-M1P only obtains the time from gPTP Grand Master device with no hesitation about the accuracy of the master clock by principle. If the timestamp of LiDAR point cloud deviates from the real-time, please check whether gPTP Grand Master clock is accurate;

3. When time synchronization has been run on RS-LiDAR-M1P, in case that the gPTP Grand Master is disconnected suddenly, the time stamp of LiDAR data packet will continue to stack according to LiDAR internal clock. The time of RS-LiDAR-M1P will not be reset until powered off and restarted.

4.2 Use Linuxptp tool to verify time synchronization

Please connect RS-LiDAR-M1P power cable and network cable to the Interface Box, and then to Host Computer. The Host Computer operating system (OS) must be Linux. We take Ubuntu as an example below:

1. Use the command $ifconfig to check the network card name. The name of the network

card is enp2s0 below.

```
sti@sti:~$ ifconfig
enp2s0    Link encap:Ethernet  HWaddr 54:ee:75:f0:7b:9f
          UP BROADCAST MULTICAST  MTU:1500  Metric:1
          RX packets:1148564 errors:0 dropped:0 overruns:0 frame:0
          TX packets:2786 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:1436527228 (1.4 GB)  TX bytes:309309 (309.3 KB)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          inet6 addr: ::1/128 Scope:Host
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:138110 errors:0 dropped:0 overruns:0 frame:0
          TX packets:138110 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:48448646 (48.4 MB)  TX bytes:48448646 (48.4 MB)
```

Figure 4: Find network card name

2. Use the command $ethtool - T enp2s0 (network card's name) to check whether the network card supports PTP hardware. For gPTP synchronization, hardware support is required, PTP Hardware Clock should not be none.

```
sti@sti:~$ ethtool -T enp2s0
Time stamping parameters for enp2s0:
Capabilities:
        software-transmit     (SOF_TIMESTAMPING_TX_SOFTWARE)
        software-receive      (SOF_TIMESTAMPING_RX_SOFTWARE)
        software-system-clock (SOF_TIMESTAMPING_SOFTWARE)
PTP Hardware Clock: none
Hardware Transmit Timestamp Modes: none
Hardware Receive Filter Modes: none
```

Figure 5: Check PTP hardware supporting status

3. Download and install the Linuxptp tool.

$sudo git clone git://git.code.sf.net/p/linuxptp/code linuxptp

$cd linuxptp

$sudo make

$sudo make install

$reboot

4. Use ptp4l command.

Ptp4l command options:

Delay mechanism options

-A Automatic mode, E2E mode is selected automatically, and switch to P2P mode when peer to peer delay request is received

-E E2E mode, request-response delay mechanism (default)

·

-P P2P mode, peer delay mechanism

Network transmission options

-2 IEEE 802.3

-4 UDP IPV4 (default)

-6 UDP IPV6

Timestamp options

-H Hardware timestamp (default)

-S Software simulation timestamp

-L Former hardware timestamp, LEGACY HW needs to be used with PHC equipment

Other options

-f [file] Reads the configuration info from the specified file. By default, no configuration info is read.

-i [dev] Select a PTP interface device, such as eth0 (which can be specified more than once), you must specify at least one port using this option or configuration file.

-p [dev] This option is used to specify the PHC device (such as: dev / ptp0 clock device) to be used on the former Linux kernel. The default is auto, ignoring the software / LEGACY HW timestamp (this option is not recommended)

-s Slave-Only-mode, slave clock mode (override profile)

-t Transparent clock mode

-l [num] Set the logging level to 'num' and the default is 6

-m Print the message to stdout

-q Do not print messages to syslog

-v Print software version and exit

-h Help command

Use command to synchronize RS-LiDAR-M1P:

(1) PTP E2E (L2 layer) command:

$sudo ptp4l -E -S -2 -m -i enp2s0 (network card name)

If PTP Hardware Clock is not none (hardware supported), you can use -H instead of -S

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(2) gPTP command:

$sudo ptp4l -i enp4s0 -m -H -2 -f gptp-master.cfg

PTP Hardware Clock should not be none(hardware supported). Special note: Devices without hardware support can use -S instead of -H for gPTP synchronization simulation, and its synchronization accuracy cannot be guaranteed. And gptp-master.cfg is the gPTP master clock configuration file.

Create a new gptp-master.cfg file on the host, copy the following content in this file, and save the file:

```
# 802.1AS example configuration containing those attributes which
# differ from the defaults.    See the file, default.cfg, for the
# complete list of available options.
[global]
domainNumber            0
logSyncInterval         -3
syncReceiptTimeout      3
neighborPropDelayThresh     800
path_trace_enabled      1
follow_up_info          1
transportSpecific   0x1
ptp_dst_mac         01:80:C2:00:00:0E
#p2p_dst_mac        01:1B:19:00:00:00
network_transport L2
delay_mechanism         P2P
masterOnly          1
BMCA                noop
asCapable                       true
inhibit_announce    1
inhibit_delay_req   1
```

4.3 GPS Time Synchronization

In case that users would like to synchronize RS-LiDAR-M1P with GPS module, it is necessary for gPTP Grand Master to receive GPS timing service at first. Please consult gPTP Grand Master device provider for the specific connectors and GPS timing service guidance. Robosense will not provide technical support except for special cases.

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Figure 6: Topology of GPS Timing service synchronization

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Appendix A RSView

This appendix explains how to use RSView to record, visualize, save and review of the data from RS-LiDAR-M1P.

The original sensor data can be also captured and examined by using other free of charge tools, such as Wireshark or tcp-dump. But visualization of the 3D data through using RSView is easy to realize. User may contact RoboSense technical support for the specific RSview Version.

A.1 Software Features

RSView supports real-time visualization of 3D coordinate data from RS-LiDAR-M1P. RSView also supports review of the pre-recorded data stored in “pcap” (Packet Capture) files, however, RSView doesn’t support direct importing of “.pcapng” files at the moment.

RSView displays directly the point cloud that is exchanged from the measured distance from RS-LiDAR-M1P. It supports changing the display mode of point cloud according to XYZ coordinates, distance, pitch(elevation) and yaw(azimuth), etc.

Function and features of RSView are as shown below:

- Online visualization of sensor data over Ethernet
- Record of real-time data into pcap files
- Review of the recorded point cloud from pcap files
- Different visualization mode based on distance, pitch(elevation) and yaw(azimuth), etc.
- Tabular display of point cloud data
- Tool for measuring distance from visualized cloud point

A.2 Install RSView

Installation packet of RSView is suited for Windows 64-bit system and it requires no other dependent software packets. Unzip the compressed packet of RSView, the RSView.exe executable file can be found in the /bin folder.

A.3 Set Up Network

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In Unicast mode，the sensor has set the default IP address to computer at factory, therefore, the default IP address of the computer should be set as 192.168.1.102, sub-net mask as 255.255.255.0. Besides, users should make sure that the RSView doesn't be blocked by any firewall or third party security software.

A.4 Visualization of Point Cloud

1. Connect the RS-LiDAR-M1P 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** (Fig A-1).

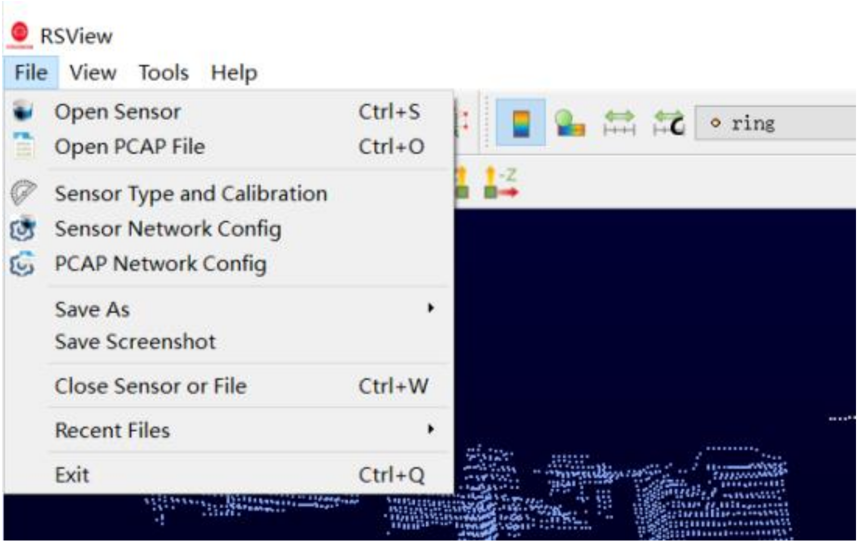

Fig A-1：Open the Sensor Stream in RSView.

4. After finishing the above 3 steps, the dialogue box "**Sensor Type and Configuration**" shows up. Please Choose RSM1 in the Drop-Down menu to fit RS-LiDAR-M1P. In this dialogue box, the **Sensor Calibration** default contains the configuration folder named MEMSCorrectionFile_3V, directly click **Add** and then click the **OK** button (as shown in Fig A-2). The original point cloud data output from the RS-LiDAR-M1P is already calibrated point cloud data, therefore the value in this parameter file is void.

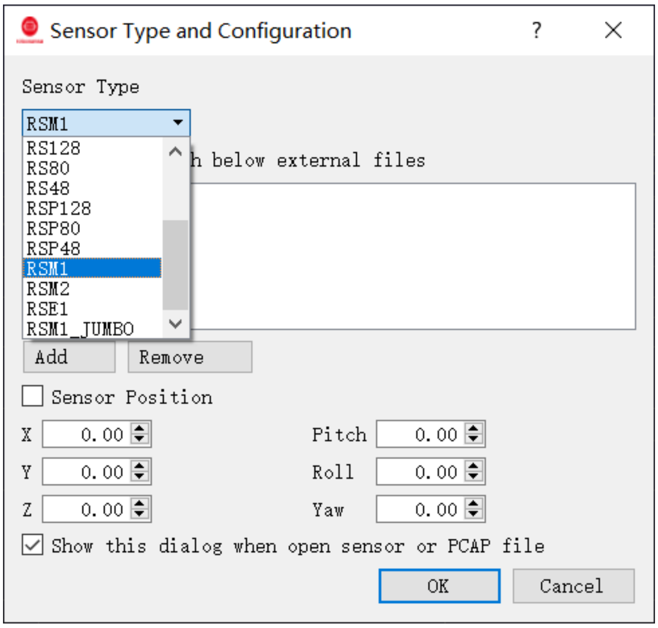

Figure A-2：Select the parameter configuration file of RS-LiDAR- M1

5. Check the MSOP and DIFOP port number: Sensor Network Configuration, input the correct MSOP and DIFOP port number

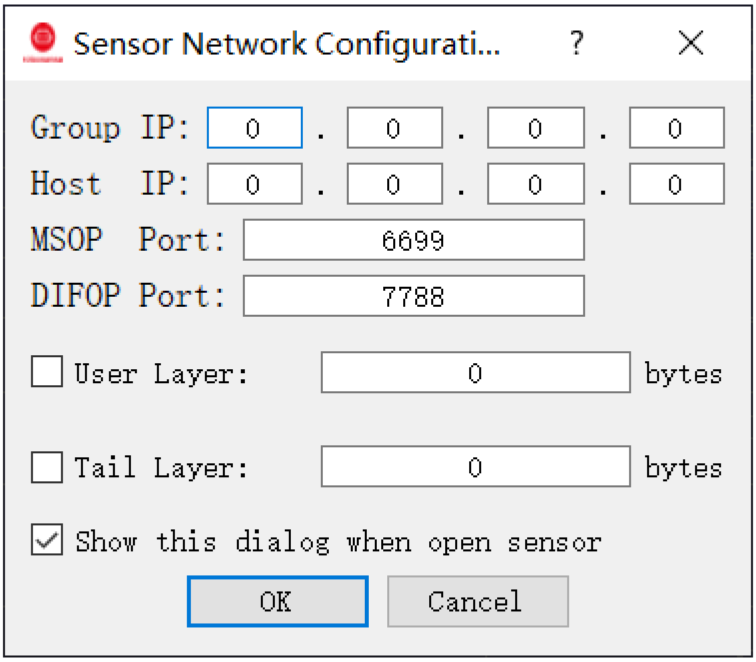

Figure A-3: RSView data port setting

6. RSView begins displaying the colored point cloud from capturing the sensor data stream from LiDAR (as shown in Fig. A-4). The stream can be paused by pressing the **Play** button, click again, the stream continues.

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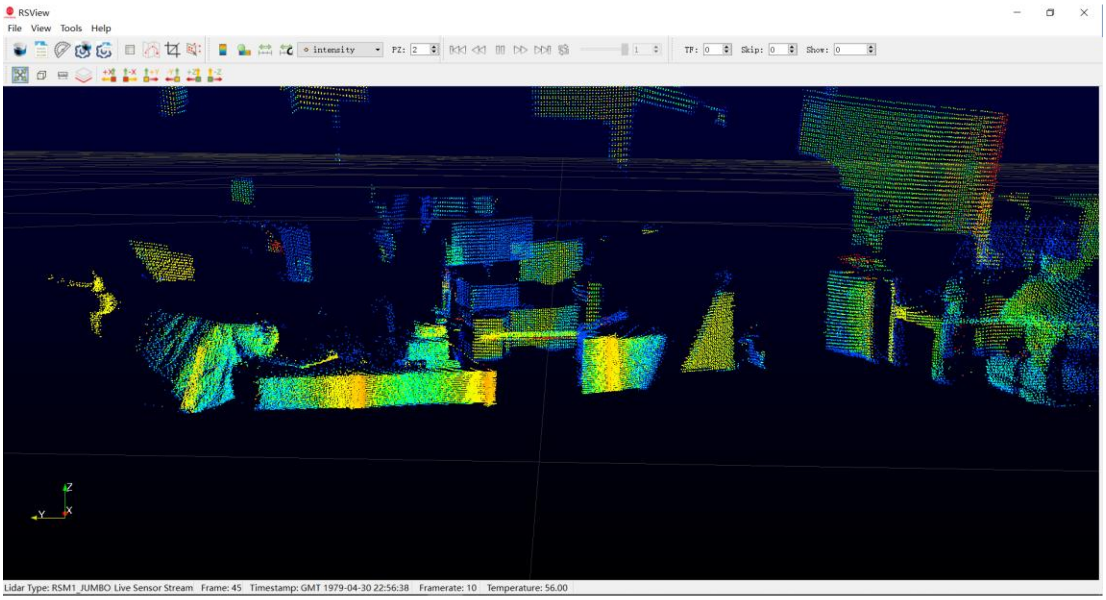

Figure A-4：RS-LiDAR-M1P Sensor Stream display

7. If there is no point cloud display, please click **Tools** and check if the MSOP and DIFOP port number are correctly set in the **Data Port Setting** window.

A.5 Save Streaming Sensor Data into PCAP File

Use Wireshark as the packet recording tool:

1. Download and install the wireshark software.

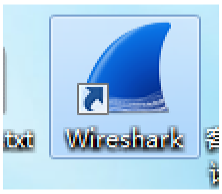

Figure A-5：Wireshark icon

2. Double click to start the wireshark application, select the name of the network card currently connected to the LiDAR and double-click it.

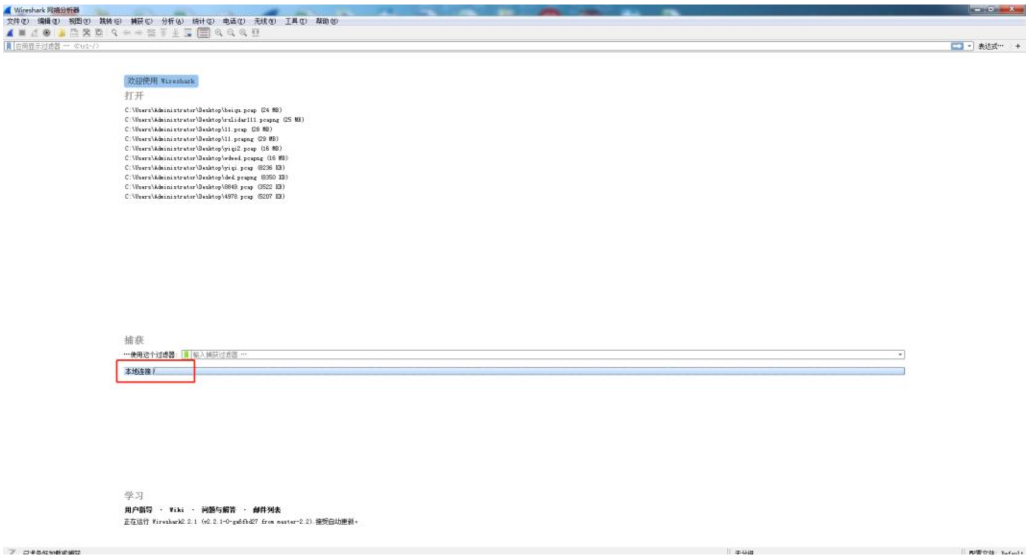

Figure A-6：Start Wireshark

3. If the figure below shows up, the connection to the LiDAR is normal. The data in the red boxes represent "LiDAR IP", "PC IP", "MSOP port number", and "DIFOP packet port number" respectively.

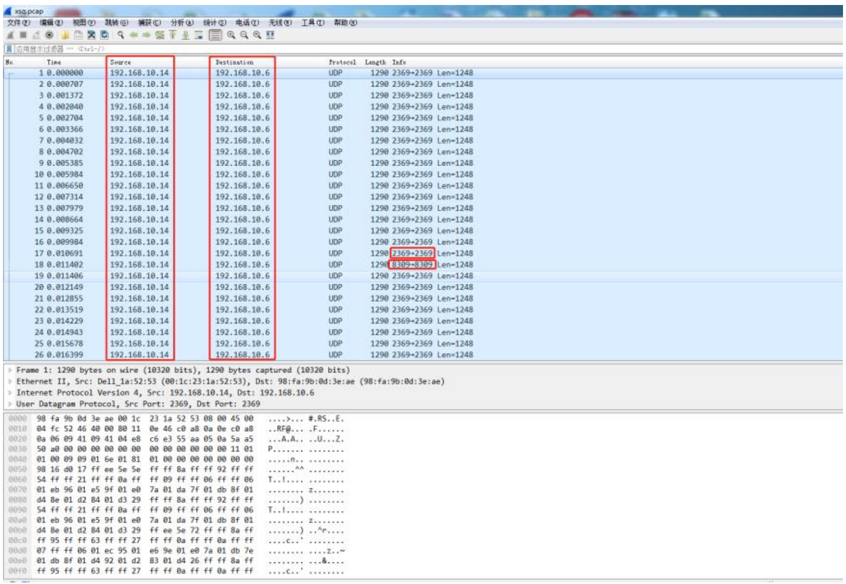

Figure A-7：Wireshark at work

4. Click **File** at the up left corner of the window, and click **Save** to save the data.

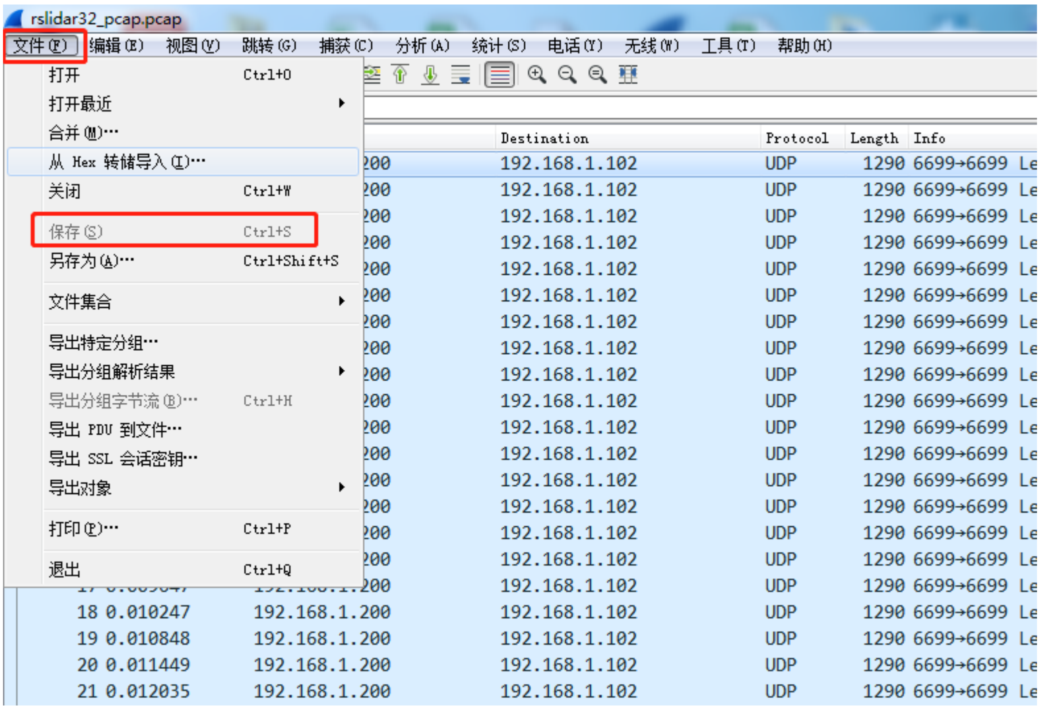

Figure A-8：Wireshark data saving

5. Enter the file name in the pop-up dialog box and select .pcap as the data format to save.

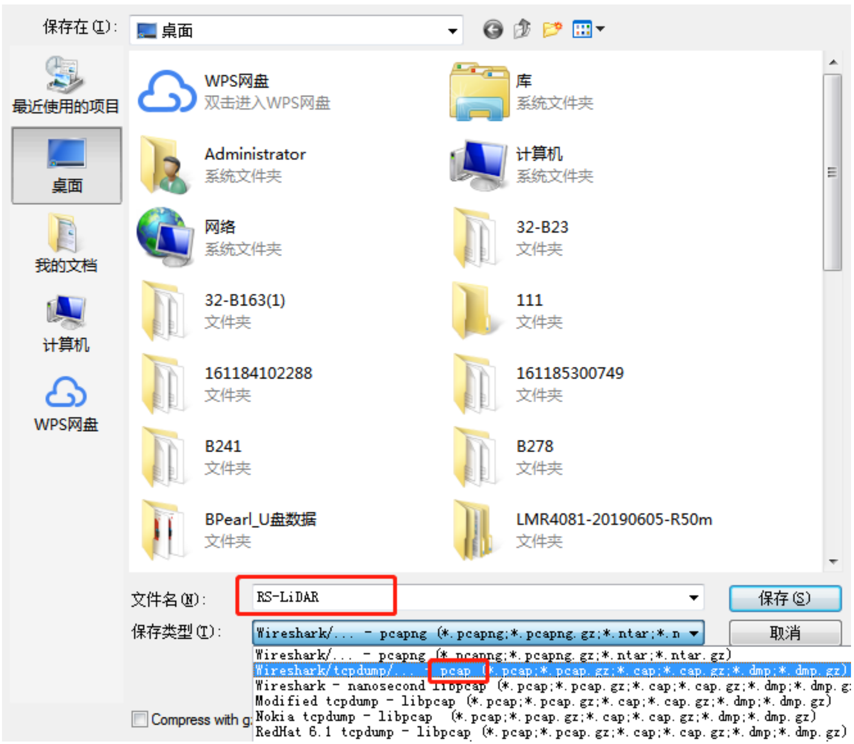

Figure A-9：Wireshark data saving

6. Now, the corresponding files can be found in the specified folder directory and you can use the RSView software or driver to view the point cloud (please refer to the product user

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manual for the RSView operation guide).

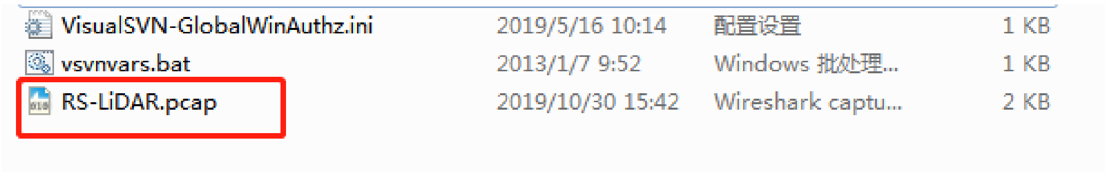

Figure A-10 Wireshark data saving

A.6 Replay Recorded Sensor Data from PCAP Files

The pcap file can be replayed or examined through RSView. User can press the **Play** button to play or pause the data play, and can also scrub the time slider to check the data at a certain time point. User can also use a mouse to click and select part of the point cloud and check them in the pop-up table. Save path of pcap file should not contain any Chinese characters.

1. Click **File -> Open PCAP File.**

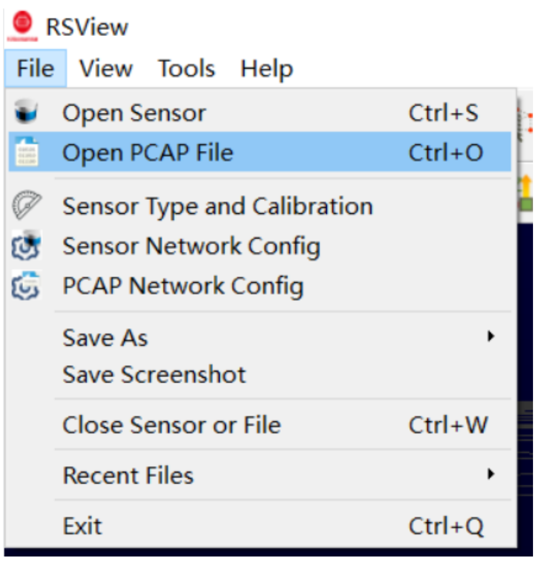

Figure A-11 RSView Open capture file

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

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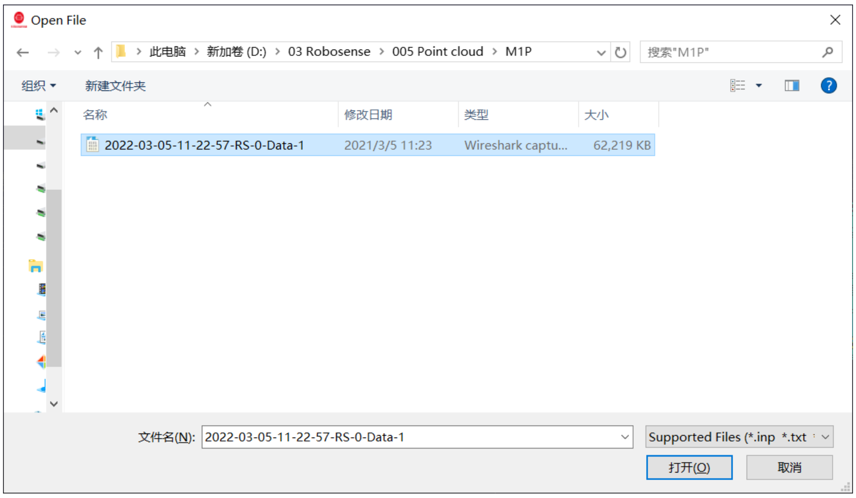


Figure A-12 Import PCAP File

3. In the dialogue box **Sensor Type and Configuration**, add and select the right configuration file of RS-LiDAR-M1P, then click **OK** button. Then input the correct MSOP and DIFOP port in the dialogue box **PCAP Network Configuration**

4. Click **Play** button to play or pause 3D point cloud data streaming. Using the Scrub tool to select the interested frame. (Fig. A-13).

Figure A-13 RSView **Play** button and **Scrub** tool

5. In order to inspect partial relevant point cloud data from a closer aspect, please scrub to an interested frame and click the **Spreadsheet** button (Fig A-16). A data table will be displayed on the right side. It displays all data points in the frame.

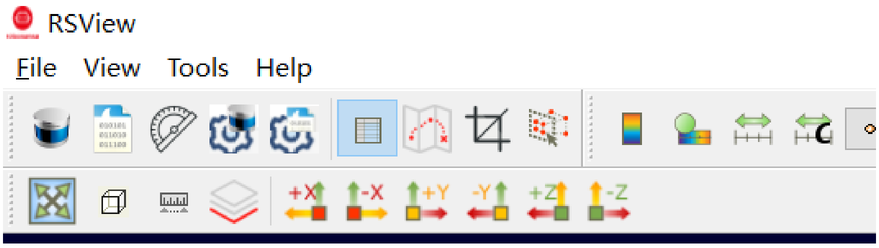


Figure A-14 RSView Spreadsheet

6. You can adjust the width of each column of the table, or sort for clearer inspection.

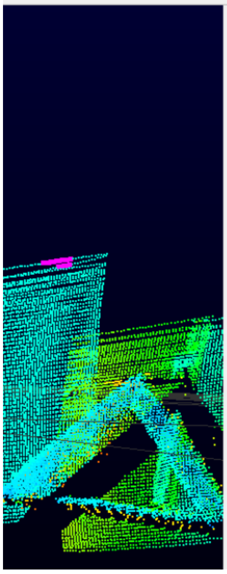
Showing Data Attribute: Point Data Precision: 3

	Point ID	Point_X	Point_Y	Point_Z	distance	intensity	pitch	ring	timestamp	yaw
0	0	1.556	2.870	0.578	3.315	33	1005	0	15062685...	6154
1	1	3.192	2.367	0.858	4.065	39	1219	1	15062685...	3656
2	2	3.184	0.679	0.698	3.330	39	1210	2	15062685...	1204
3	3	2.415	-0.539	0.448	2.515	34	1025	3	15062685...	-1259
4	4	3.143	-2.300	0.400	3.915	76	586	4	15062685...	-3619
5	5	1.565	2.859	0.577	3.310	33	1004	0	15062685...	6131
6	6	3.193	2.349	0.857	4.055	39	1220	1	15062685...	3634
7	7	3.187	0.666	0.700	3.330	38	1213	2	15062685...	1181
8	8	2.403	-0.547	0.448	2.505	35	1030	3	15062685...	-1282
9	9	3.130	-2.309	0.403	3.910	81	592	4	15062685...	-3642
10	10	1.587	2.875	0.581	3.335	34	1003	0	15062685...	6110
11	11	3.189	2.328	0.854	4.040	40	1221	1	15062685...	3613
12	12	3.179	0.653	0.699	3.320	39	1216	2	15062685...	1161
13	13	2.401	-0.556	0.450	2.505	34	1035	3	15062685...	-1303
14	14	3.128	-2.327	0.408	3.920	78	597	4	15062685...	-3664
15	15	1.603	2.878	0.581	3.345	33	1000	0	15062685...	6089
16	16	3.193	2.314	0.853	4.035	39	1221	1	15062685...	3593
17	17	3.181	0.641	0.700	3.320	38	1217	2	15062685...	1140
18	18	2.408	-0.567	0.453	2.515	34	1038	3	15062685...	-1324
19	19	3.135	-2.350	0.413	3.940	76	601	4	15062685...	-3685
20	20	1.616	2.877	0.580	3.350	34	997	0	15062685...	6068
21	21	3.182	2.288	0.847	4.010	39	1219	1	15062685...	3572
22	22	3.184	0.630	0.700	3.320	39	1217	2	15062685...	1119
23	23	2.411	-0.577	0.454	2.520	35	1039	3	15062685...	-1345
24	24	3.138	-2.371	0.415	3.955	77	603	4	15062685...	-3707
25	25	1.628	2.876	0.580	3.355	34	995	0	15062685...	6049
26	26	3.182	2.272	0.844	4.000	39	1218	1	15062685...	3553

Figure A-15 RSView Spreadsheet display

7. Click **Show only selected elements** in the spreadsheet, only the data of selected points will be displayed. If no point is selected, there will be no data shown in table (Fig. A-18).

sity PZ: 2 79 TF: 0 Skip: 0 Show: 0



Showing Data Attribute: Point Data Precision: 3

	Point ID	Point_X	Point_Y	Point_Z	distance	intensity	Show only selected elements.		mestamp
0	508	3.140	-2.089	0.824	3.860	37	1232	3	15062685...
1	513	3.132	-2.100	0.825	3.860	37	1234	3	15062685...
2	518	3.132	-2.117	0.829	3.870	37	1237	3	15062685...
3	523	3.132	-2.134	0.833	3.880	37	1239	3	15062685...
4	528	3.132	-2.151	0.836	3.890	36	1241	3	15062685...
5	533	3.136	-2.170	0.839	3.905	37	1241	3	15062685...
6	538	3.132	-2.184	0.842	3.910	37	1244	3	15062685...
7	543	3.144	-2.209	0.849	3.935	37	1246	3	15062685...
8	548	3.135	-2.221	0.850	3.935	37	1248	3	15062685...
9	553	3.127	-2.231	0.852	3.935	38	1250	3	15062685...
10	558	3.131	-2.251	0.857	3.950	37	1253	3	15062685...
11	693	3.130	-2.247	0.822	3.940	37	1204	3	15062685...
12	698	3.134	-2.233	0.819	3.935	37	1202	3	15062685...
13	703	3.136	-2.215	0.815	3.925	37	1198	3	15062685...
14	708	3.136	-2.200	0.810	3.915	37	1194	3	15062685...
15	713	3.136	-2.183	0.807	3.905	37	1192	3	15062685...

Figure A-16 RSView **show only selected elements** tool

8. Click the **Select All Points** tool, your mouse will turn into a data point selection tool (Figure A-17).

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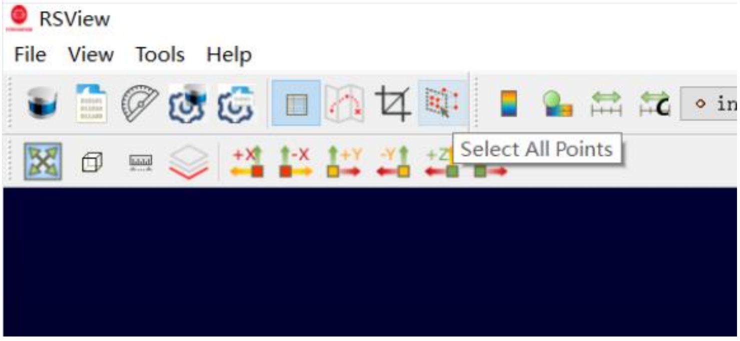

Figure A-17 RSView Select All Points tool

9. In the 3D point cloud display space, use the mouse to draw a rectangle to frame some data points. The data of these points will be displayed in the **Spreadsheet** and these points will turn pink in the point cloud display space (Figure A-18).

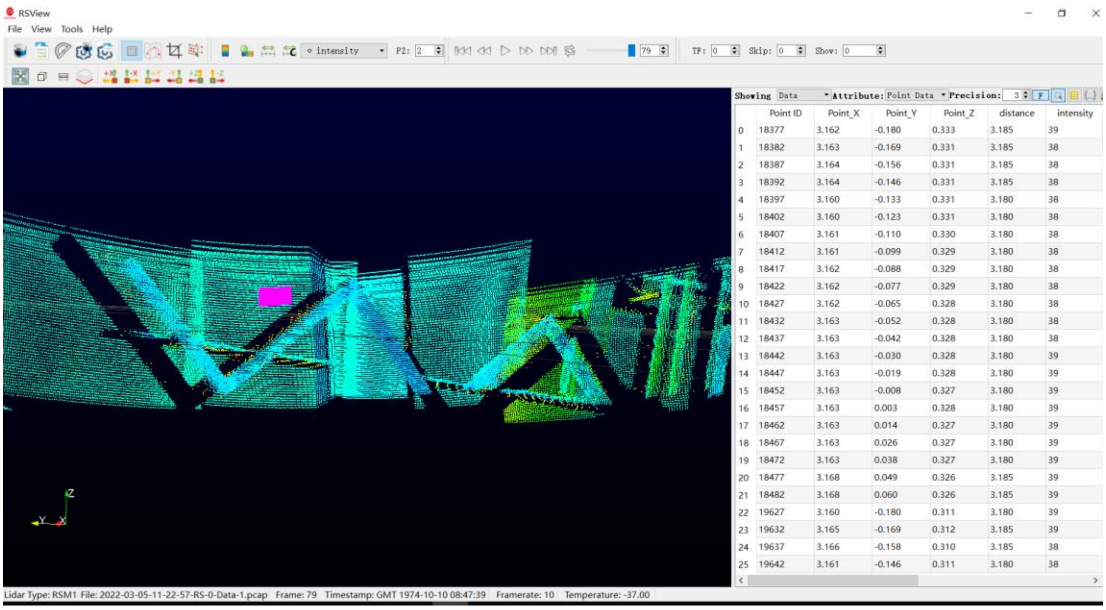

Figure A-18 RSView List Selected Points

10. Any selected point can be saved through the **output csv data** tool at the Spreadsheet toolbar (see Figure A-19).

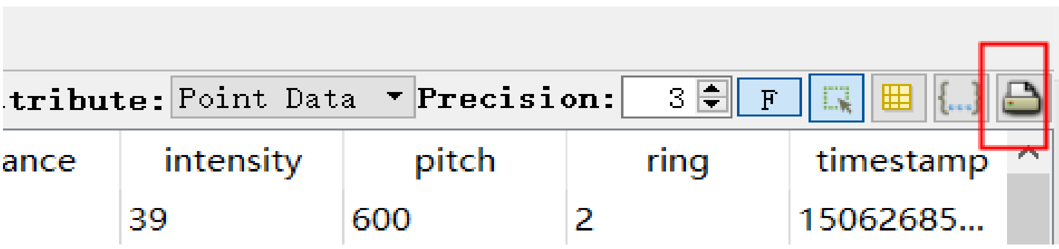

Figure A-19 RSView export selected points to csv file

Appendix B Driver & SDK

To download the latest version and guidebook of RS-LiDAR-M1P Driver & SDK, Please refer to the following link: *https://github.com/RoboSense-LiDAR/rslidar_sdk*

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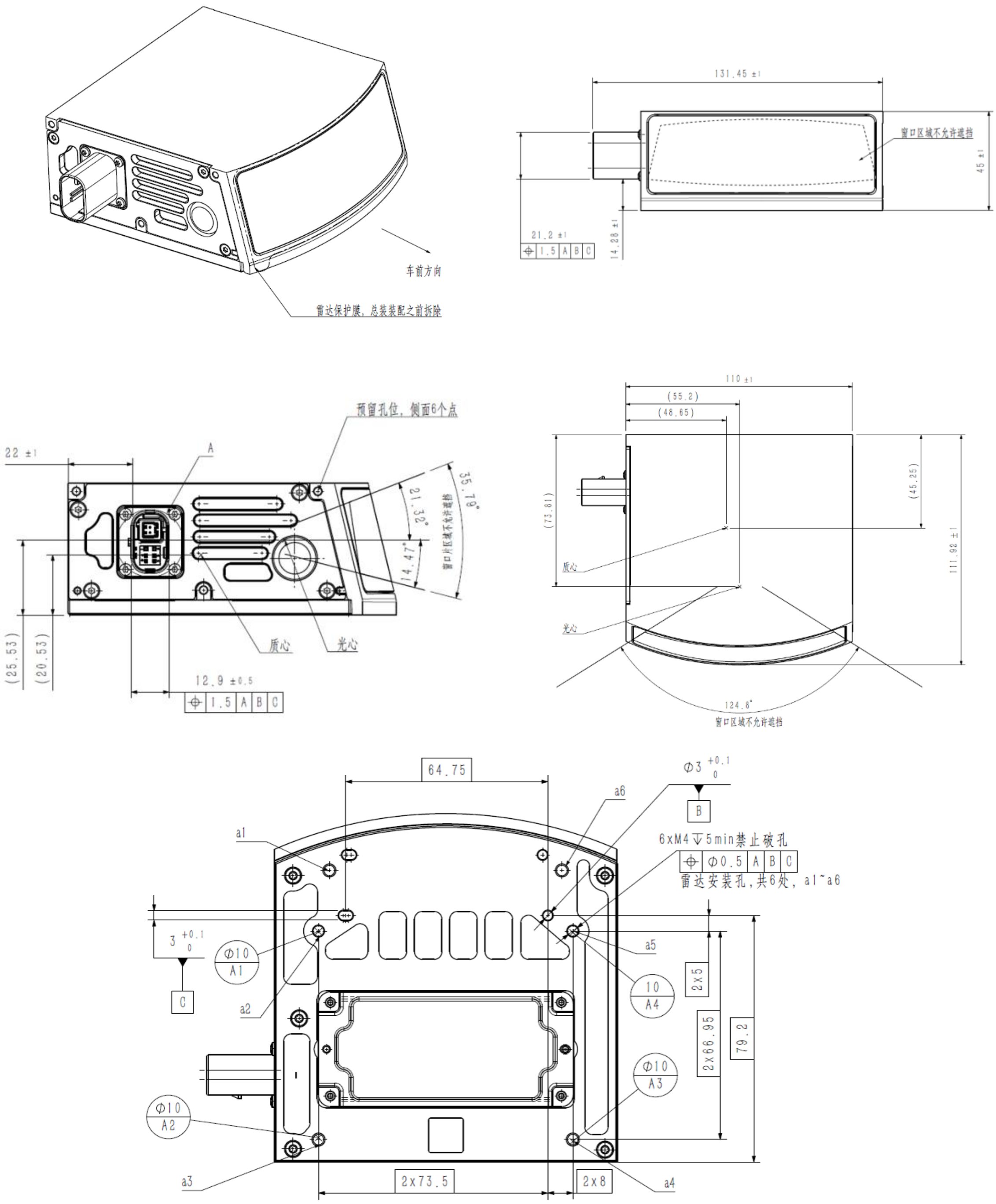
Appendix C Dimension

Drawing of LiDAR with TE Connector:



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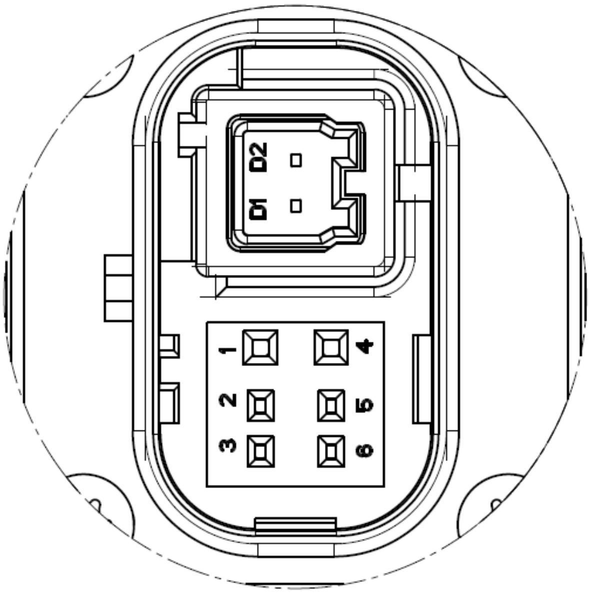
Definition of TE-Pins:



NO.	Pin Definition	Connector PN
1	GND	TE 2387351-1
2	Wakeup(KL15)	
3	/	
4	Battery+	
5	/	
6	/	
D1	TRX_N(1000Base-T1)	
D2	TRX_P(1000Base-T1)	

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