LSLIDAR

The Leader In LiDAR Industry

C32-Channel LiDAR

Operation Manual V2.7

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1. LiDAR Introduction

1.1Description

(1) All the illustrations in this instruction are for reference only and shall be subject to the latest products.

(2)In order to avoid violating the warranty terms, it is not allowed to disassemble the LiDAR. For the relevant operation, please consult LeiShen Intelligent's after-sales technical staff.

1.2 Operation principles

The ranging principle of C32-channel hybrid solid-state LiDAR (hereinafter referred to asC32) is Time of flight measurement.

Time of flight(TOF): As the laser transmitter emits a laser pulse, the internal timer starts to calculate the time (t_1) and stops (t_2) when the laser receiver receives the partial energy of the laser wave bouncing off any objects

Distance = Light Speed × (t_2-t_1)/2

1.3 Product Description

Inside the LiDAR enclosure are 32 pairs of laser-emitting and receiving devices mounted on the bearings. A 360° panoramic scanning is done by rotating the internal motor at 5Hz (or 10Hz, 20Hz).

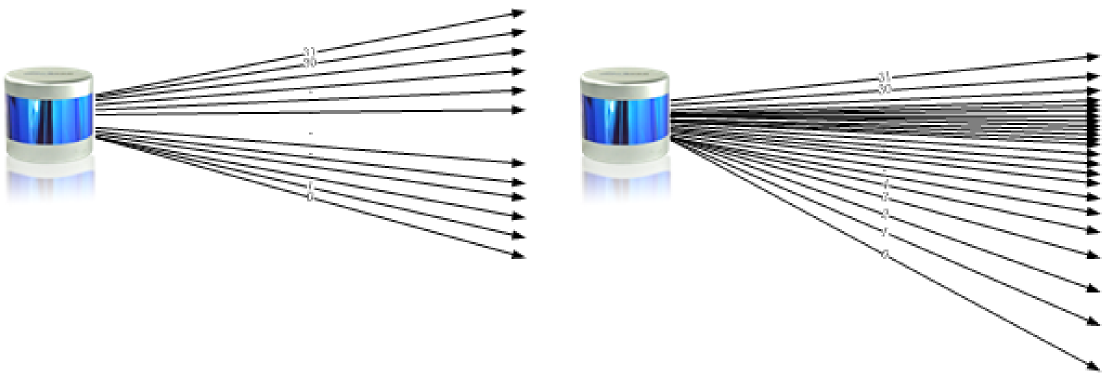


Figure 1 C32's beams distribution: 1° (Left) and 0.33° (Right)

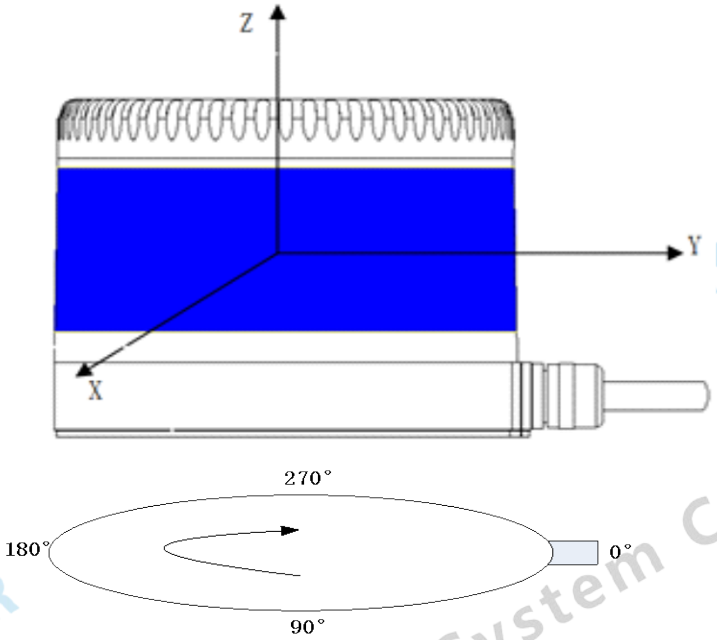


Figure 2 C32 Coordinate System and Scanning Direction

1.4Specification

Table 1 : Specifications of C32-xxxA

Model		C32-xxxA			
Detecting way		Pulsed Laser			
Laser band		905nm			
Laser class		Class 1 (eye-safe)			
Laser channel		32-channel			
Detecting range		70m	120m	150m	200m
Range accuracy		±3cm			
Data acquisition speed (Dual return mode)		640,000 pts/sec (1280,000 pts/sec)			
FOV	Vertical	-16°~+15°			
	Horizontal	360°			
Angular Resolution	Vertical	Equal1°			
	Horizontal	5Hz: 0.09º / 10Hz: 0.18º / 20Hz: 0.36º			
Scanning speed		5Hz, 10Hz, 20Hz(optional)			
Communication interface		Ethernet external communication, PPS			
Supply scope		+9V～+36VDC			
Operating temperature		-20℃～+60℃			

Storage temperature	-20℃～+85℃
Impact	500 m/sec^2, for 11 ms
Vibration	5Hz～2000Hz,3G rms
IP Grade	IP67
Dimension	Φ102mm*110mm
Weight	1600g(including 1.2m cable)/1100g(lightweight, including 1.2m cable)

Table 2: Specifications of C32-xxxC

Mode		C32-xxxC			
Detecting way		Pulsed Laser			
Laser band		905nm			
Laser class		Class 1 (eye-safe)			
Laser channel		32-channel			
Detecting range		70m	120m	150m	200m
Range accuracy		±3cm			
Data acquisition speed (Dual return mode)		640,000 pts/sec (1280,000 pts/sec)			
Viewing Angle	Vertical	-18°~+14°			
	Horizontal	360°			
Angle Resolution	Vertical	0.33°,0.66°,1°,2°,3°			
	Horizontal	5Hz: 0.09º / 10Hz: 0.18º / 20Hz: 0.36º			
Scanning speed		5Hz, 10Hz, 20Hz(optional)			
Communication interface		Ethernet external communication, PPS			
Supply scope		+9V～+36VDC			
Operating temperature		-20℃～+60℃			
Storage temperature		-20℃～+85℃			
Impact		500 m/sec^2, for 11 ms			
Vibration		5Hz～2000Hz,3G rms			
IP Grade		IP67			
Dimension		Φ102mm*110mm			
Weight		1600g(including 1.2m cable)/1100g(lightweight, including 1.2m cable)			

1.5 External Dimensions and Installation

There are 2 positioning holes and 5 screw mounting holes at the bottom of the LiDAR. The data line interface position is 0° (Or 180°, please contact sale manger)horizontal angle of the LiDAR, and the LiDAR rotates clockwise.

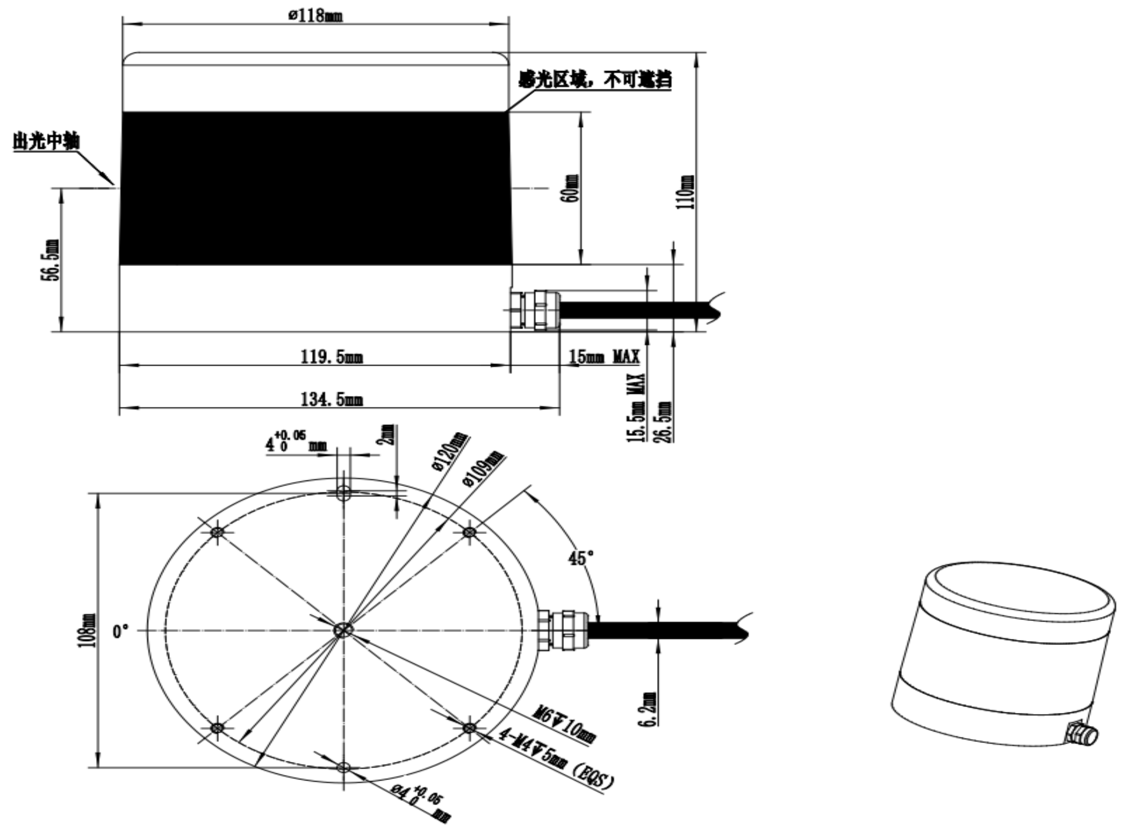


Figure 3 Structure size of C32-xxxA/C type LiDAR

1.6 Electrical Interface

1.6.1 Device Power Supply

Device power supply input range: 9VDC - 36VDC, use of input voltage 12VDC recommended.(If using other DC power supply, the recommended output voltage of the power supply: 12VDC, the maximum output current: ≥3A.

1.6.2 Definition of Device Lead Output Interface

C32 body leads cable (10-core shielded wire with serial number shown as below) from the side at the lower side.

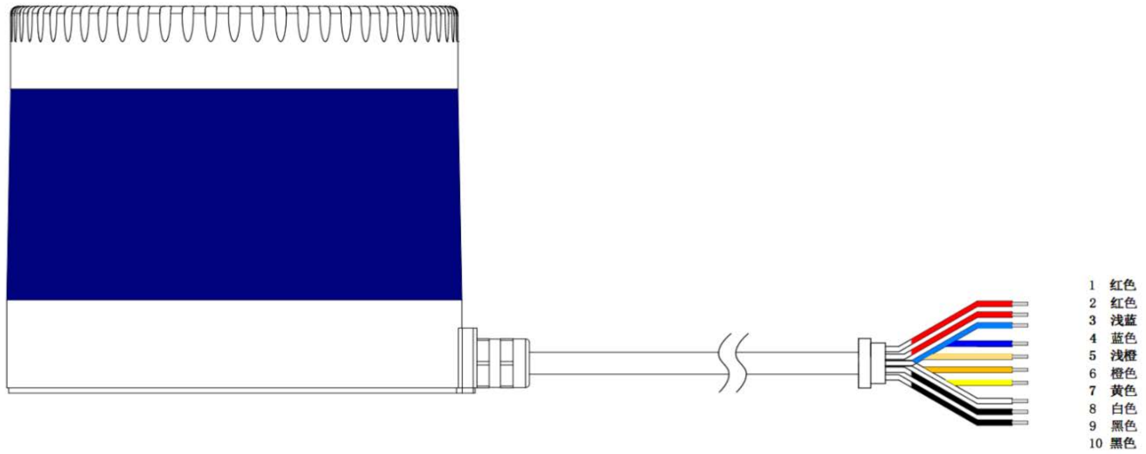


Table310 core cable defined as follows：

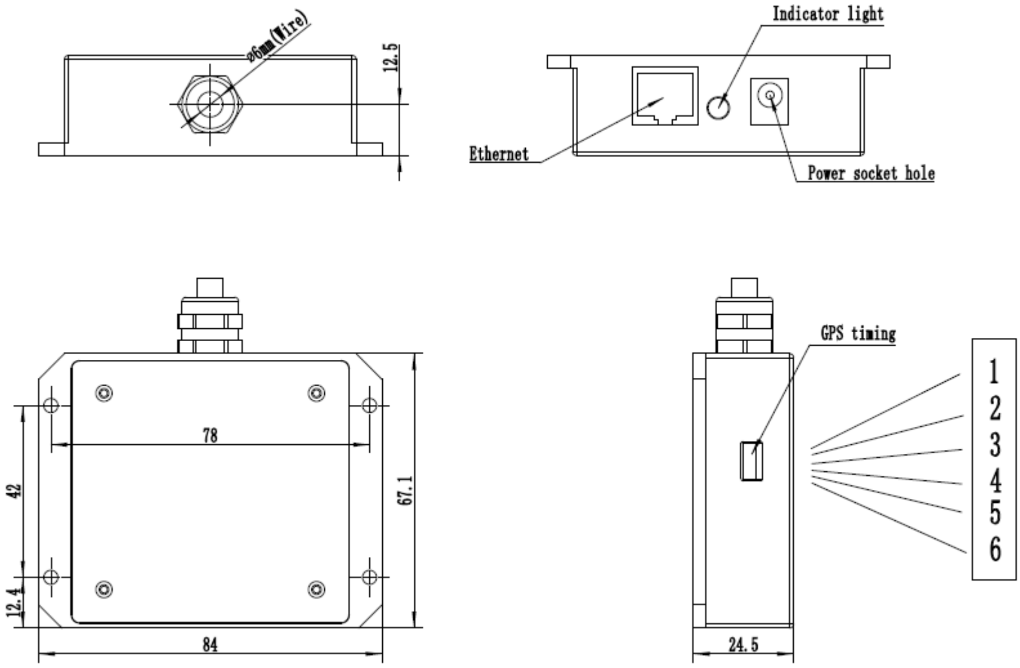
S/N	Cable color and specifications	Definition	Description
1	Red（26AWG）	VCC	Positive power supply
2	Light blue（26AWG）	TD_P	Negative Ethernet transmitter differential
3	Blue（26AWG）	TD_N	Positive Ethernet transmitter differential
4	Light orange（26AWG）	RD_P	Negative Ethernet receiver differential
5	Orange（26AWG）	RD_N	Positive Ethernet receiver differential
6	Yellow（26AWG）	GPS_PPS	GPS synchronous second
7	White（26AWG）	GPS_Rec	GPS timing receiving
8	Black（26AWG）	GND	Negative power supply (GND)
9	Red（24AWG）	VCC	Positive power supply
10	Black（24AWG）	GND	Negative power supply (GND)

Users can use the C32 to move the 10-pin terminal wire out of the junction box. The junction box provides three interfaces: power supply, Ethernet RJ45 interface and GPS device interface. Simply open the junction box housing and disconnect the soldering position of the core cable, remove the 10-pin terminal cable connector from the junction box. The purpose of the junction box is to allow the user to directly use the power adapter, Ethernet cable, and 6-pin GPS connector that comes with the LiDAR.

C32 factory default connection junction box, cable which connected to the LiDAR part of 1.5meters.

Figure 4 Connection between Adapter Box and LiDAR

The adapter box for the C32 has external interfaces including: 2.1MM DC socket, indicator, 100M Ethernet RJ45 port, and the 6-pin connector GPS timing interface.



Interface S/N	Description
1	NC
2	GND
3	GPS_REC
4	GND
5	+5V
6	GPS_PPS

Figure 5 Terminal Block Definition

1.7 Windows Software display and LiDAR Config

The pointcloud display software provides parsing data package and Device package information, and displays 3D pointcloud data. Through the visual window, users can reset LiDAR parameters. For detailed operation process, please refer to the pointcloud display software section

LiDAR IP and port:

Table 4　LiDAR Default Network Configuration

	IP Address	UDP Equipment Port	UDP Parsing Port
LiDAR	192.168.1.200	2368（Fixed unmatchable）	2369（Fixed unmatchable）
Computer	192.168.1.102	2369	2368

Note: When setting the LiDAR IP,LiDAR IP and the Computer IP cannot be set to the same IP, otherwise the LiDAR will not work properly.

When using a connecting device, it is necessary to set the computer IP to the same network segment as the device, for example, IP: 192.168.1.x, and subnet mask: 255.255.255.0. If the device’s network configuration information is unknown, wireshark is used for the connecting device to capture the device’s ARP packet for analysis after the LiDAR is powered on. For the characteristics of the ARP packet, see the figure below.

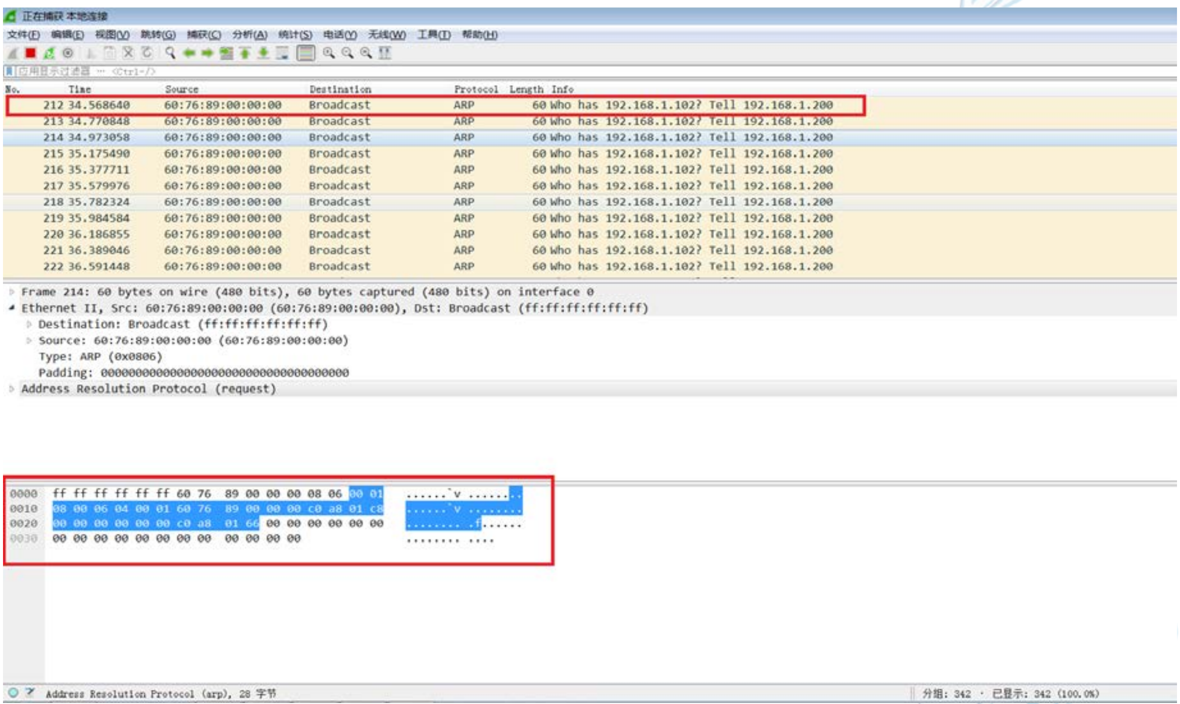


Figure 6　Wireshark ARP

Note: Wireshark software is third-party software. Copyright and commercial disputes caused by customers during use are not related to LeiShen.

2. Communication Protocol

The LiDAR data output and configuration use the 100M Ethernet UDP / IP communication protocol. There are 3 UDP packet protocols with a packet length of 1248 bytes (42 bytes Ethernet header and 1206 bytes payload). The LiDAR supports unicast, broadcast, and multicast communications.

1）**MSOP**(Main data Stream Output Protocol)，Output data include : measured distance, angle, intensity and other information；

2）**DIFOP**(Device Information Output Protocol)，Output data include:LiDAR configuration information；

3）**UCWP**(User Configuration Write Protocol)，Setting LiDAR Config parameter

Table 5　UDPprotocol

(Protocol/packet) Name	Abbreviation	Function	Type	Packet Size	Transmission Interval
Main data Stream Output Protocol	MSOP	**Outputting scanned data**	UDP	1248bytes	0.69ms/ 0.29ms
Device Information Output Protocol	DIFOP	**Outputting device information**	UDP	1248bytes	1s
User Configuration Write Protocol	UCWP	**Inputting user configured device parameters**	UDP	1248bytes	INF

2.1 MOSP Protocol

The data of the packet is little-endian mode.

MSOP Packet data format structure of the LiDAR includes frame header, sub-frame and frame tail. Each packet has 1,248byte: 42byte for UDP packet overhead, 1,200byte for sub-frame data packet interval (a total of 12 data blocks), 4byte for timestamp, and 2byte for frame tail factory.

2.1.1 MOSPformat

The C32 LiDAR data supports primary and secondary echoes.

In single-echo mode, one single-point laser emission measures one echo data. A data packet contains 12 data blocks, each data block contains a set of 32 channel data measured in the packing order, and each data block only returns an azimuth. See the figure below:

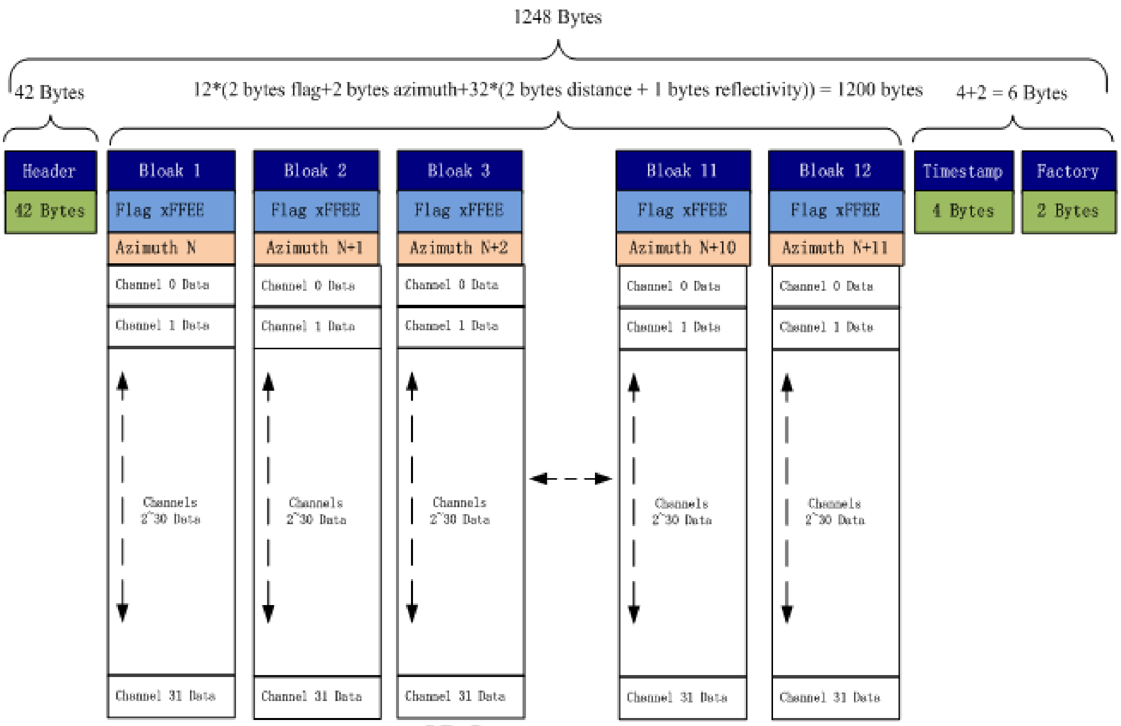


Figure 7　Single Echo Packet Data Structure Form

When using double echo mode, two echo data are returned. Information from two transmit sequences of 32 lasers is contained in one data block. The first and second data blocks (DataBlock) are two echo data of the same sequence, and so on. Each packet contains data for 12 transmit sequences. Each data block returns only one azimuth. See the picture below:

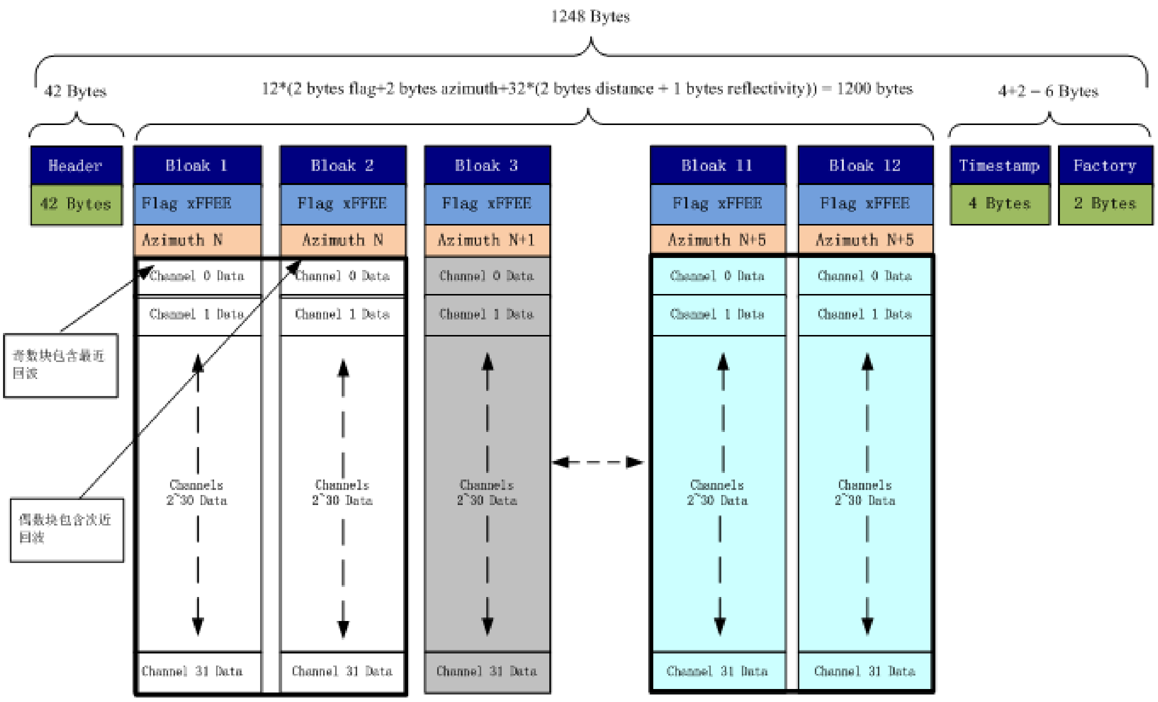


Figure 8　Second Echo Packet Data Structure Form

2.1.2 Ethernet Header

The Ethernet Header have 42byte:

Ethernet Header: 42Bytes				
NAMED	**Number**	**Information**	**Offset**	**Length（Byte）**
Ethernet II MAC	0	Destination	0	6
	1	Source	6	6
Ethernet Packet type	2	Type	12	2
Internet Protocol	3	Version, Header Length, Differentiated Services, Field, Total Length, Identification, Flags, Fragment Offset, Time to Live, Protocol, Header, Checksum	14	20
UDP Protocol port	4	LiDAR Port(0x0941, represent 2369)	34	2
	5	Computer Port(0x0940, represent 2368)	36	2
UDP Protocol Length and check	6	Length(0x04BE, represent:1214 bytes)	38	2
	7	Sum Check	40	2

2.1.3 Data Block

The measurement data is 1200 bytes in total. It consists of 12 data blocks (each block is 100 bytes)。

A data block include:

2 byte 0xffee :Fixed flag value;

2 byte Azimuth :relative horizontal angle information;

Point cloud data of 32 channels (3 bytes per channel). Each group of 32-channel channel data (UDP packet encapsulation order) corresponds to the measurement data of a LiDAR 32-channel laser at different launch times.

Note:The channel data is packed in ascending order, which is consistent with the time sequence of laser emission.(See chapter 7 Vertical angles and chapter 8 Channel luminescen times)

2.1.3.1 Azimuth

Azimuth represents the angle value when the first laser ranging of 32 laser shots is measured, that is, the angle of the first channel 0 of the data block, the unit is 0.01°, which is a relative value. To calculate the absolute horizontal angle, we need to add the horizontal correction angle values A1, A2, A3 and A4 (see device package data description). The resolution of the horizontal angle value corresponds to the motor speed (5Hz, 10Hz, 20Hz) (0.09 °, 0.18 °, 0.36 °).

2.1.3.2 Channel Data

Channel data is an unsigned integer, the upper 2 bytes are the distance, and the lower 1 byte is the intensity, as shown in the following table.

Table 6 Channel Data

Channel N data (3Bytes)		
Byte3	Byte2	Byte1
Distance	Distance	Intensity

The unit of distance is 0.25cm. The echo intensity indicates the energy reflection characteristics of the measured object, and the intensity value represents the intensity of 0-255 different reflective objects, etc.

2.1.4 Additional Information

The additional information is 6 bytes in length, including the 4-byte microsecond timestamp and the 2byte Factory.

Table 7 Additional Information

Additional Information：**6Bytes**			
Name		**Length（Byte）**	**Function**
Timestamp		4	Timestamp，Unit: us
Factory	Echo information	1	0x37Represents the strongest echo，0x38Represents the last echo，0x39 Represents the return echo
	Vendor information	1	0x10 representC16 LiDAR，0x20 represent C32 LiDAR

When the NTP service synchronous timing is enabled, the timestamp is synchronized with the NTP server time, and the range of the timestamp is 0-999999 (us).

If the NTP service synchronization time is invalid:

1) When GPS input PPS, a timestamp is generated for the periodic timing according to the PPS time, and the time stamp ranges from 0 to 999999 (us);

2) When there is an external synchronization input PPS, a time stamp is generated for the periodic timing according to the external synchronization PPS time, and the time stamp ranges from 0-999999 (us);

3) When there is no synchronous input PPS, the internal LiDAR generates a time stamp with a period of 1 hour. The time stamp ranges from 0-3599_999_999 (us).

2.2 DIFOP Protocol

DIFOP outputs read-only parameters and status information such as version number, Ethernet configuration, motor speed and running status, and fault diagnosis. The data of the DIFOP uses big-endian mode.

The device packet includes 42-byte Ethernet header and a 1206-byte payload with a length of 1248 bytes. The payload consists of an 8-byte frame header, 1196-byte data Dataand a 2-byte frametail.

Table 8　DIFOP

DIFOP: 1242Bytes				
NAMED	**Number**	**Information**	**Offset**	**Length（Byte）**
Ethernet II MAC	0	Destination	0	6
	1	Source	6	6
Ethernet	2	Type	12	2
Internet Protocol	3	Version, Header Length, Differentiated Services, Field, Total Length, Identification, Flags, Fragment Offset, Time to Live, Protocol, Header, Checksum, Source IP Address, Destination IP Address	14	20
UDP Protocol port	4	LiDAR Port(0x0941, represent2368)	34	2
	5	PC Port(0x0940, represent2369)	36	2
UDP Protocol Length and check	6	Length(0x04BE, Represent:1214 bytes)	38	2
	7	Sum Check	40	2
Payload：1206Bytes				
NAMED	**Number**	**Information**	**Offset**	**Length（Byte）**
Header	0	DIFPO identification header	0	8
Data	1	Motor speed	8	2
	2	Ethernet configuration	10	22
	3	Ethernet configuration（Network）	32	8
		rotation / stationary	40	2
	4	Device flow packet interval	42	2
	5	PPS alignment angle value	48	2
	6	PPS alignment angle error	50	2
	7	UTC TIME	52	6
	8	Latitude and longitude	58	22
	9	Horizontal correction angle A1	186	2
	10	Horizontal correction angle A3	188	2

	11	Horizontal correction angle A2	190	2
	12	Horizontal correction angle A4	192	2
	13	Version number (dd / mm / yy)	1198	4
	14	VERSION_SUBVERSION	1202	2
	15	tail	1204	2

Header is a device packet identification header, which is fixed to 0xA5,0xFF, 0x00,0x5A, 0x11,0x11,0x55,0x55, where the first 4 bytes can be used as the packet inspection sequence. The tail of the frame is fixed to 0x0F, 0xF0.

2.3 UCWP Protocol

UCWP protocol configures the LiDAR's Ethernet, PPS alignment angle, motor and other parameters. The data of the configuration packet adopts big-endian mode.

UCWP includes a 42-byte Ethernet header and a 1206-byte payload with a length of 1248 bytes. The payload consists of an 8-byte header, 1196-byte Data, and a 2-byte Tail.

Note: It is recommended that users configure the LiDAR through the Win point cloud software. It is forbidden for customers to package and configure the LiDAR parameters by themselves. Except for the Ethernet configuration, gateway, and subnet mask that require the LiDAR to restart to take effect, other configurations take effect immediately.

Table 9 UCWP Data Format

42Bytes				
NAMED	**Number**	**Information**	**Offset**	**Length（Byte）**
Ethernet II MAC	0	Destination	0	6
	1	Source	6	6
Ethernet Packet type	2	Type	12	2
Internet Protocol	3	Version, Header Length, Differentiated Services, Field, Total Length, Identification, Flags, Fragment Offset, Time to Live, Protocol, Header, Checksum, Source IP Address, Destination IP Address	14	20
UDP Protocol port	4	LiDAR Port(0x0941, represent2369)	34	2
	5	Computer Port(0x0940, represent2368)	36	2
UDP Protocol Length and check	6	Length(0x04BE, represent:1214 bytes)	38	2
	7	Sum Check	40	2
1206Bytes				
Named	**Number**	**information**	**Offset**	**Length（byte）**
Header	0	UCWP identification header	0	8
Data	1	Motor speed	8	2

	2	Ethernet configuration	10	22
	3	Reserve	32	12
	4	PPS alignment angle value	44	2
	5	LiDAR rotation / stationary	46	2
	6	Reserve	48	2
	7	Device flow packet interval	50	2
	8	Reserve	52	640
	9	Gateway address	196	4
	10	Subnet mask	200	4
	11	Reserve	204	504
Tail	12	Tail	1204	2

Header is the configuration packet identification header, fixed to 0xAA, 0x00, 0xFF, 0x11,0x22, 0x22, 0xAA, 0xAA, where the first 4 bytes are used as the packet inspection sequence. The tail of the frame is fixed to 0x0F, 0xF0.

2.3.1 Configuration Parameters and Status Description

Motor speed（2Bytes）		
Number	Byte1	Byte2
Function	Speed:5Hz/10Hz/20Hz	

Configure the motor speed, the motor rotates clockwise, you can set three kinds of speed: when set to 0x04B0, the speed is 1200rpm; when set to 0x04B0, 0x0258, the speed is 600rpm; when set to 0x012C, the speed is 300rpm. No other setting data is supported.

2.3.2Ethernet Configuration

Table 10　Ethernet Configuration

Ethernet configuration（22Bytes）								
Number	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7	Byte8
Function	IP_SRC				IP_DEST			
Number	Byte9	Byte10	Byte11	Byte12	Byte13	Byte14	Byte15	Byte16
Function	MAC_ADDR						Data port1	
Number	Byte17	Byte18	Byte19	Byte20	Byte21	Byte22		
Function	Device Port2		NTP Service Address					

LiDAR IP address IP_SRC, length 4Bytes; Computer IP address IP_DEST, length 4Bytes; each LiDAR has a fixed MAC address MAC_ADDR, which cannot be configured by the user; port1 is the UDP data port number, port2 is the UDP device port number; NTP server address, length 4Byte The internal time of the LiDAR can be synchronized from the server address through the NTP protocol.

2.3.3 PPSAlign horizontal angle

The PPS signal input from an external device controls the LiDAR to scan to a specific horizontal angle.

The configuration package sets the pps alignment angle, the unit is 0.01°.

For example, the alignment angle is 90°, the setting value is 9000, and the conversion into hexadecimal is 0x2328, corresponding to byte2 = 23h, byte1 = 28h.

PPS Angle value（2Bytes）		
Number	Byte1	Byte2
Function	Configuration PPS alignment angle	

The device package outputs the PPS synchronization time, and the unit of the alignment angle error is 0.01°. valid is 0, which means that the second pulse signal is valid; angle_err [14: 0] is the alignment angle error value, a signed integer ranging from -18000 to 18000, that is, between -180° and 180°.

Align horizontal angle error（2Bytes）		
Number	Byte1	Byte2
Function	valid	angle_err[14:0]

2.3.4Horizontal Correction Angle

DIFOP outputs horizontal correction angle A1, A2, A3, A4 value. The 32-line 1 degree lidar has two rows of transmitters, and the 0.33 degree lidar has four rows of transmitters. The horizontal correction angle defines the horizontal angle offset of the 32-wire beam, and the unit is 0.01 degrees, unsigned.

Horizontal correction angle A1（2Bytes）		
Number	Byte1	Byte2
Function	Angle correction value of the leftmost column	
Horizontal correction angle A2（2Bytes）		
Number	Byte1	Byte2
Function	Angle correction value of the rightmost column	
Horizontal correction angle A3（2Bytes）		
Number	Byte1	Byte2
Function	Angle correction value of the secondary left column (0.33°)	
Horizontal correction angle A4（2Bytes）		
Number	Byte1	Byte2
Function	Angle correction value of second right column (0.33°)	

When calculating the horizontal angle, in addition to the horizontal angle value of each channel in the data packet, the horizontal correction angle value must be added.

A1, A2, A3, A4, compensation 0.33° type lidar. A1, A2 compensation 1° type lidar.

2.3.5 UTC Time

When NTP server timing is enabled, UTC time is synchronized with NTP server time;

When NTP is turned off, the LiDAR receives GPS signals, parses $ GPRMC, and UTC time synchronizes GPS;

When there is no NTP and GPS time, UTC time is all 0.The lidar supports GPS baud rate of 9600, no parity bit, 8 data bits, and 1 stop bit.

DIFOP output UTC time, erroris 1s, GPS time data format.

UTC TIME（6Bytes）						
Number	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6
Function	**Year**	**Month**	**Day**	**Hour**	**Min**	**Sec**
	0~255correspond to 2000~2255	1~12 month	1~31 day	0~23 hour	0~59 min	0~59 sec

2.3.6LiDAR Rotation / Stationary

LiDAR rotation / stationary（2Bytes）		
Number	Byte1	Byte2
Function	0：rotation；1：stationary	

0x0000 LiDAR rotation, 0x0001 LiDAR stationary, LiDAR default is rotation scan.

2.3.7DIFOPPacket Interval

Device packet sending interval（2Byes）		
Number	Byte1	Byte2
Function	0：3 same packets per second；Other values: the same as the packet interval	

Config 0x0000 Indicates that 3 packets are sent per second. The other values are the same as the data packet interval. The default value is 0 (3 same packets per second).

2.3.8Latitude and longitude

The byte Latitude and longitude (22Bytes)								
Number	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7	Byte8
Function	remain	Latitude						
Number	Byte9	Byte10	Byte11	Byte12	Byte13	Byte14	Byte15	Byte16
Function			Longitude					
Number	Byte17	Byte18	Byte19	Byte20	Byte21	Byte22		

Function		N/S	W/E	

Latitude and longitude, output in ASCII format.

2.3.9Network Address

Network Address（4Bytes）				
Number	Byte1	Byte2	Byte3	Byte4
Function	Network Address			

2.3.10Subnet Mask

Subnet mask（4Bytes）				
Number	Byte1	Byte2	Byte3	Byte4
Function	Subnet mask			

2.4 UCWP Example

The client resets the speed, IP address, device port number, NTP server address, PPS alignment angle value, LiDAR rotation / static, etc. According to the definition of the UCWP, the payload of 1206 bytes is set as follows:

information	changed content	UCWP content	Length（byte）
Header		0xAA,0x00,0xFF,0x11, 0x22,0x22,0xAA,0xAA	8
Speed	1200rpm	0x04,0xB0	2
LiDAR IP（IP_SRC）	192.168.1.105	0xC0,0xA8,0x01,0x69	4
Computer IP（IP_DEST）	192.168.1.225	0xC0,0xA8,0x01,0xE1	4
Device（MAC_ADDR）	XXXX(read only)	0xxxxx	6
Data（port1）	XXXX	0xxxxx	2
Device（port2）	8899	0x22,0xC3	2
NTP SER Address	192.168.1.106	0xC0,0xA8,0x01,0x6A	4
Network	192.168.1.1	0xC0,0xA8,0x01,0x01	4
Subnet mask	255.255.255.0	0xFF,0xFF,0xFF,0x00	4
LiDAR rotation / static	rotation	0x00,0x00	2
Device Packet Interval	3 packs	0x00,0x00	2
PPS alignment	1.28°	0x00,0x80	2
Tail	Fixed value	0x0F,0xF0	2

Configuration package encapsulation must be completely written into the entire package of data.

3.Time Synchronization

There are 3 ways to synchronize LiDAR with external devices: GPS synchronization, NTP synchronization, and external PPS synchronization. If there is no external synchronization input, timing information is generated inside the LiDAR. The absolute precise time of the point cloud data is obtained by adding a 4-byte time stamp (accurate to microseconds) of the data packet and a 6-byte UTC time (accurate to seconds) of the device packet.

3.1GPSSynchronization

The LiDAR receiving the PPS second pulse, the LiDAR uses microsecond us as the unit, and the time value is output as the time stamp of the data packet. The LiDAR extracts UTC information from GPS's $ GPRMC information as the UTC time output of the device package, with accuracy to seconds.

3.1.1GPS

GPS timing synchronization, marking and calculating the precise emission measurement time of each pointcloud. LiDAR accurate point cloud data time can be matched with GPS / inertial measurement system's pitch, roll, yaw, latitude, longitude, and altitude.

The serial configuration baud rate of the LiDAR receiving GPS data output by default is 9600, 8N1. PPS high pulse width requirements are greater than 40ns.

The standard format of GPRMC information is as follows:

1）$GPRMC,072242,A,3027.3680,N,11423.6975,E,000.0,316.7,160617,004.1,W*67；

2）$GPRMC,065829.00,A,3121.86377,N,12114.68162,E,0.027,,160617,,,A*74。

3.2 NTP

NTP synchronization: The LiDAR periodically obtains the NTP server time ,The time is used as the timestamp of the data packet, and the extracted UTC time is output as the UTC (GMT) time of the device envelope. The LiDAR sends a time request to the NTP server every 4 seconds. After receiving the request, the server sends time information to the LiDAR according to the NTP protocol.

3.3External Synchronization

External synchronization: The LiDAR obtain PPS signal input by the external device, the LiDAR uses microsecond us as the time unit, and time is output as the time stamp of the data packet. At this time, there is no UTC time reference. If UTC time is required, it must be written through the configuration package; otherwise, the UTC time output information of the device package is invalid.

The PPS level of the external synchronization signal is 3.3 ~ 5V, which is triggered by the rising edge of the LiDAR. The PPS high pulse width is required to be greater than 40ns.

4. LiDAR data calculations of Angles and Coordinates

4.1Vertical Angle

The 32- line lidar has two different vertical angle distributions, and the data of each channel corresponds to a fixed vertical angle. See table below.

Table 10 Vertical Angle Distribution of32 1°Laser Channels

UDP Package Encapsulation SequenceChannel	Vertical Angle	Horizontal Correction Angle	UDP Package Encapsulation Sequence Channel	Vertical Angle	Horizontal Correction Angle
0	**-16°**	+A2	16	**-8°**	+A2
1	**0°**		17	**8°**	
2	**-15°**	+A1	18	**-7°**	+A1
3	**1°**		19	**9°**	
4	**-14°**	+A2	20	**-6°**	+A2
5	**2°**		21	**10°**	
6	**-13°**	+A1	22	**-5°**	+A1
7	**3°**		23	**11°**	
8	**-12°**	+A2	24	**-4°**	+A2
9	**4°**		25	**12°**	
10	**-11°**	+A1	26	**-3°**	+A1
11	**5°**		27	**13°**	
12	**-10°**	+A2	28	**-2°**	+A2
13	**6°**		29	**14°**	
14	**-9°**	+A1	30	**-1°**	+A1
15	**7°**		31	**15°**	

Table 11 Vertical Angle Distribution of 32 0.33°Laser Channels

UDP Package Encapsulation Sequence Channel	Vertical Angle	Horizontal Correction Angle	UDP Package Encapsulation Sequence Channel	Vertical Angle	Horizontal Correction Angle

0	-18°	+A2	16	-4°	+A2
1	-1°		17	-1.66°	
2	-15°	+A1	18	-3.33°	+A1
3	-0.66°		19	2°	
4	-12°	+A2	20	-3°	+A4
5	-0.33°	+A4	21	3°	+A2
6	-10°	+A1	22	-2.66°	+A3
7	0°	+A3	23	4°	+A1
8	-8°	+A2	24	-2.33°	+A2
9	0.33°		25	6°	
10	-7°	+A1	26	-2°	+A1
11	0.66°		27	8°	
12	-6°	+A2	28	-1.66°	+A4
13	1°	+A4	29	11°	+A2
14	-5°	+A1	30	-1.33°	+A3
15	-1.33°	+A3	31	14°	+A1

By querying the table above, you can get the vertical angle of the 32-channel data.

Note: The vertical angle of the uniform 1 degree lidar increases from bottom to top according to the increasing channel number, which is the same as the laser trasmitting sequence.

For example, for a 32-line 0.33 degree lidar, the fixed vertical angle of channel 18 of its data packet is 0 degrees.

In a single-echo data packet, each data block has only one horizontal angle value, which represents the horizontal angle value corresponding to channel 0 of the earliest transmission measurement of this data block. The angles corresponding to the other 31 channels need to be interpolated.

Because the lidar rotates at a constant speed, the light-emitting time interval of each channel of the data block is the same, so the two adjacent angle values (Azimuth N and Azimuth (N+1)) are interpolated, and then the data can be calculated according to the light-emitting time of each channel The horizontal angle value corresponding to the remaining 31 laser points of the block. This horizontal angle value is a relative angle, plus the horizontal correction angle value to obtain an absolute horizontal angle.

The data block structure of the 32-line single echo packet is as follows:

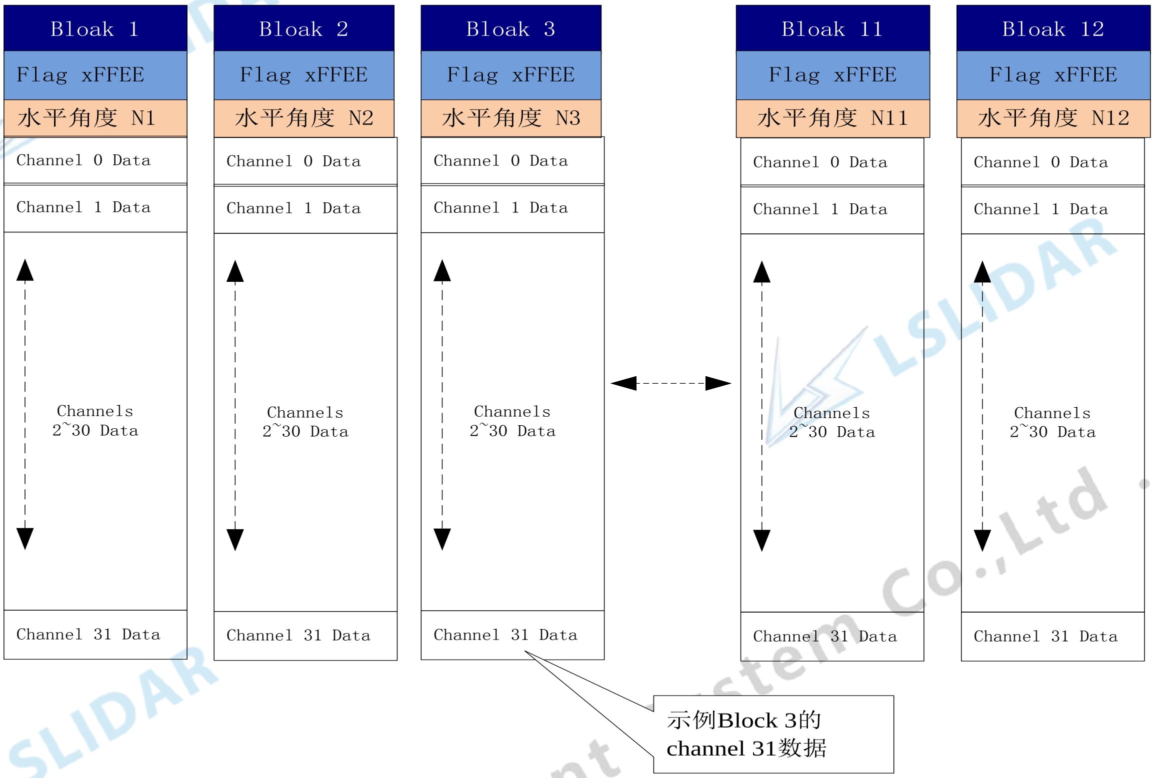


Figure 9 Single echo data block structure

Take the Channel 31 data of Block 3 of 0.33 degree lidar as an example:

1). From the angle distribution table 7.2, it can be seen that the horizontal correction angle value of Channel 31 is +A2 degrees, and the specific value of A2 unsigned number is obtained from the equipment package;

2). The horizontal angle of the starting channel of Block 3 is N3 degrees, which is the horizontal angle of Channel 0.

3). The rotation horizontal angle between each channel of Block 3 is equally spaced (N3-N2)/32 degrees;

4). From the 32-line lidar light-emitting time table 8.1, the light-emitting time of Channel 31 (T0+(T*31)) is the 31st time of Block 3, and its angular deflection relative to the light-emitting time (T0) of Channel 0 is (N3- N2)/32*31 degrees, therefore, the horizontal angle of Channel 31 = (N3+(N3-N2)/32*31) degrees;

5). Horizontal angle (absolute) = horizontal angle (relative) + horizontal correction angle value = (N3+ (N3-N2)/32*31+A2) degrees.

Horizontal angle calculation in double echo mode:

Double-echo data packet, a single-point laser emission measures two echo data. Every two data blocks contain two measurement values of the same set of 32 channel transmission sequences, and each pair of parity data blocks only returns one azimuth. The angle values provided by the Nth odd-numbered block and the even-numbered block are the horizontal angle values corresponding to channel 0 of the last transmission measurement, and the angle values corresponding to the other 31 channels need to be interpolated.

The data block structure of the 32-line duel return data packet is as follows:

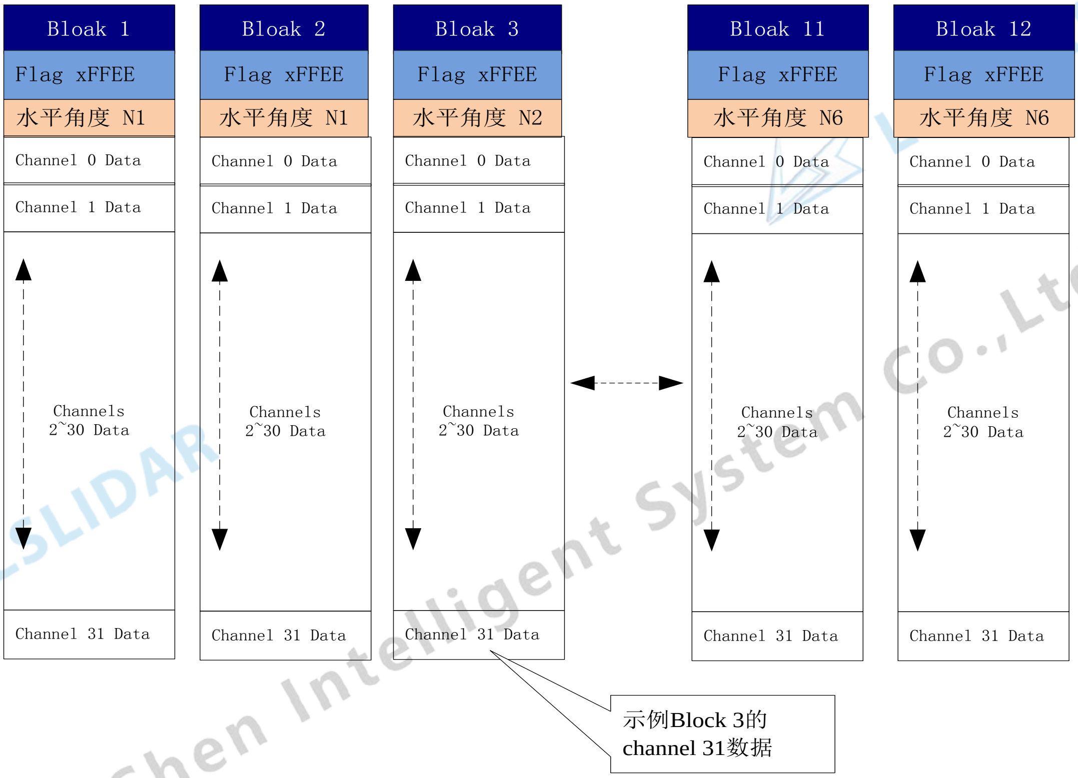


Figure10 Double return data block structure

Take the channel 31 data of Block 3 of 0.33 degree lidar as an example:

1). From the angle distribution table, it can be seen that the horizontal correction angle value of channel 31 is +A2 degrees, and the specific value of A2 unsigned number is obtained from the device package;

2). The horizontal angle of the initial luminous channel of Block 3 is N2 degrees, which is the horizontal angle of Channel 0.

3). The horizontal angle of rotation between each channel of Block 3 is equally spaced (N2-N1)/32 degrees;

4). From the 32-line lidar lighting schedule table 8.1, the lighting time of Channel 31 (T0+(T*31)) is the 31st time of Block 3, and its angular deflection relative to Channel 0 lighting time (T0) is (N2) -N1)/32*31 degrees, therefore, the horizontal angle of Channel 31 = (N2+(N2-N1)/32*31) degrees;

5). Horizontal angle (absolute) = horizontal angle (relative) + horizontal correction angle value = (N2+(N2-N1)/32*31+A2) degrees.

Distance value

Channel data distance calculation: Obtain the 2-byte channel distance in the little-endian mode of the data packet. Suppose it is (0x72,0x06), the hexadecimal number is expressed as 0x0672, and the decimal number is 1650, the unit is 0.25cm, which is 1650X0. 25cm=412.5cm.

4.2 Cartesian Coordinate Representation

Obtain the vertical angle, horizontal angle, and distance parameters of the LiDAR, and convert the angle and distance information in polar coordinates to the x, y, and z coordinates in the right-hand Cartesian coordinate system. The conversion relationship is shown in the following formula:

$$\begin{cases} x = r\cos\alpha\cos\theta; \\ y = r\cos\alpha\sin\theta; \\ \quad z = r\sin\alpha \end{cases}$$

The r is the distance, α is the vertical angle, θ is the horizontal rotation angle (the horizontal correction angle needs to be considered in the calculation), and x, y, and z are the coordinates of the polar projection onto the x, y, and z axes.

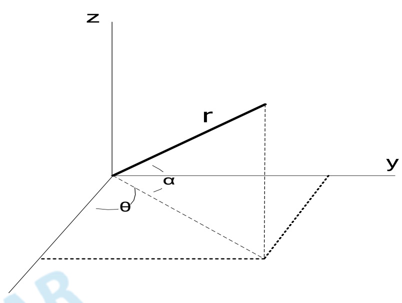


Figure 11 Coordinate

5.Pointcloud Data Time Calculation

To accurately calculate the time of point cloud data, you need to obtain the data packet timestamp and device package UTC time output by the LiDAR. The time stamp and UTC time come from the same synchronization source, such as a GPS or NTP server.

The C32 has a laser emission interval of 1.536us per channel. The data packet has 12 data blocks. One data block contains 32 channels of data. The measurement interval of each data block is 1.536us * 32 = 49.152us.

A data packet has 32 * 12 = 384 channels of data in total, and the packet packing time is about 49.152us * 12 = 0.59ms. The data rate is 1s / 0.6ms = 1694.9 data packets / second. Double-echo mode data rate doubles.

5.1GPSTime Calculation

The timestamp in the data packet is a relative time of microseconds, which is defined as the packaging time (data packet end time) of the last channel of laser measurement data in the data packet, which is less than 1 second, So to calculate the absolute time of the end of the data packet, you need to first get the 4-byte microsecond timestamp in the data packet, and then get the UTC time (greater than 1 second) from the device packet. Adding the two is the exact time at which the data packet ends.

EXACT TIME = DIFOP TIEM + MOSP TIMESTAMP

5.2Channel Data Time Calculation

Obtain the exact time of the end of the data packet. Each UDP contains 12 data blocks. And each data block contains 2 groups of 16 channels of light emitting time and the light emitting time interval of each channel. The precise measurement time of each channel data can be calculated.

5.2.1Data block time

Each data block of C32 contains 32 channel measurement data.The end time interval of each group of channels in each data block is 49.152us, each data block (single echo mode) or each parity block pair (Double echo mode) The end time interval is 49.152us. Assuming that the absolute time of the end of the data packet is TPacket_end, the steps to calculate the end time of the data block TBlock_end (N) are as follows:

a. Take Channel 3 data time T_{B3C3} for calculating Block 3 of single-echo mode as an example:

1) Calculate the end time of the packet, obtain microsecond timestamp Ttimestamp from the packet and UTC time TUTC from the device packet;Packet end time TPacket_end = TTimestamp + TUTC;

2) Calculate the end time of Block 3 TBlock_end (3) = (TPacket_end - 49.152 us *(12-3)) = (TPacket_end -442.368)us= (TTimestamp + TUTC - 442.368)us, which is the Channel 31 time of Block 3.

3) Calculate the Channel 3 time of Block 3, and query the above table 8.1. There is a T*(31-3) = 28 luminescence cycles difference between Channel 3's luminescence time (T0+(T*3)) and Channel 31's luminescence time (T0+(T*31)). Therefore, the exact time is TB3C3 = (TBlock_end(3) -28 *T) us = ((TTimestamp + TUTC -442.368) -28 *1.536)us.

b.Take Channel 3 data time T_{B3C3} for calculating dual-echo mode Block 3 as an example:

1) Calculate the end time of the packet, obtain microsecond timestampTTimestampfrom the packet and UTC time TUTC from the device packet;Packet end time TPacket_end = TTimestamp + TUTC;

2) Calculate the end time of Block 3 TBlock_end (3) = (TPacket_end - 49.152us*(6-2)) = (TPacket_end - 196.608) us= (TTimestamp + TUTC-196.608)us, which is the Channel 31 time of Block 3.

3) Calculate the Channel 3 data time of Block 3, query the above table 8.1, Channel 3's luminescence time (T0+(T*3)) andthe luminescence time of Channel 31 (T0+(T*31)) differs by T*(31-3) = 28 luminescence cycles. Therefore, the accurate time of the Channel data is obtainedTB3C3 = (TBlock_end(3) -28 *T) us = ((TTimestamp + TUTC-196.608) -28 *1.536)us

5.2.2Pointcloud Data Time Calculation

The glowing time interval of each channel of C32 lidar is fixed as: T = 49.152us / 32 = 1.536us.There is a fixed correspondence between the lighting time and the UDP packet encapsulation order. Assuming that the lighting time of Channel 0 is T0, the corresponding lighting time of 32 channels is shown in the table below:

Table 12 C32 LiDAR Channel Glowing Time

UDP Channel	Glowing moment (T=1.536us)	UDP Channel	Glowing moment (T=1.536us)
Channel 0	T_0	Channel 16	T_0+(T*16)
Channel 1	T_0+(T*1)	Channel 17	T_0+(T*17)
Channel 2	T_0+(T*2)	Channel 18	T_0+(T*18)
Channel 3	T_0+(T*3)	Channel 19	T_0+(T*19)
Channel 4	T_0+(T*4)	Channel 20	T_0+(T*20)
Channel 5	T_0+(T*5)	Channel 21	T_0+(T*21)
Channel 6	T_0+(T*6)	Channel 22	T_0+(T*22)
Channel 7	T_0+(T*7)	Channel 23	T_0+(T*23)
Channel 8	T_0+(T*8)	Channel 24	T_0+(T*24)
Channel 9	T_0+(T*9)	Channel 25	T_0+(T*25)
Channel 10	T_0+(T*10)	Channel 26	T_0+(T*26)
Channel 11	T_0+(T*11)	Channel 27	T_0+(T*27)
Channel 12	T_0+(T*12)	Channel 28	T_0+(T*28)
Channel 13	T_0+(T*13)	Channel 29	T_0+(T*29)
Channel 14	T_0+(T*14)	Channel 30	T_0+(T*30)
Channel 15	T_0+(T*15)	Channel 31	T_0+(T*31)

After the end time of each data block is obtained, the precise measurement time of the point cloud data of each channel in the data block can be calculated according to the correspondence between the channel data packing order and the light emission time in the table above.

6.Appendix

6.1Hardware Connection and Testing

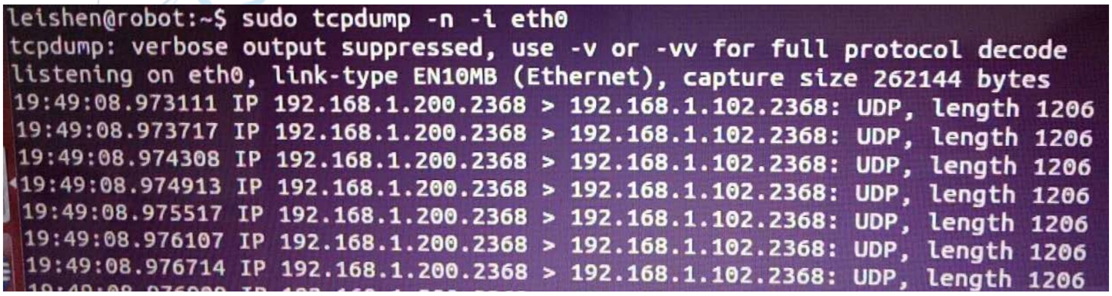
Connect LiDAR network interface and power cordSet the computer IP based on the target IP on LiDAR (use the ifconfig command to see if the computer IP has been set successfully, as shown in the target IP 192.168.1.102)

Note: LiDAR factory set IP:192.168.1.102 as original, please configure LiDAR IP according to the actual IP on the computer.

After the LiDAR is powered on, observe whether the computer's wired connection icon is connected properly or not.

Open terminal: ping LiDAR IP, test whether the hardware connection is normal. if the ping dose not show well, check the hardware connection.

You can further use: sudo tcpdump-n-i eth0, (where eth0 is the name of the wired network device.Please refer to the name of the display device which is connected by ifconfig wired) to check the LiDAR data packets (as shown in the diagram showing the LiDAR sending 1206 bytes to the destination packet which means the LiDAR data is transmitted successfully).



Note: after setting up IP for the first time, please restart the LiDAR.

6.2 Software Operation Example

1)Create a workspace and build a compilation environment

mkdir -p ~/leishen_ws/src

cd ~/leishen_ws

> Remarks:
>
> The workspace can be named arbitrarily, for example, leishen_ws can be changed to any name.

Download LiDAR drive and dependency packets

> Remarks:
>
> The driver is provided in the C16 ser package, copy the obtained rosdriver.tar to the newly created working space XXX_ws / src, and extract the .tar file.

2)Compile Package

cd ~/leishen_ws

catkin_make

3)Running Program

source ~/leishen_ws /devel/setup.bash

roslaunch lslidar_c32_decoderlslidar_c32.launch --screen

Note: if you have modified the LiDAR destination port and speed, please open the lsLiDAR_c32.launch to modify the configuration, the default port is 2368, the speed of 10hz is 2000 points.

```
process[lslidar_c16_driver_node-2]: started with pid [2805]
process[lslidar_c16_decoder_node-3]: started with pid [2806]
[ INFO] [1516783392.203906505]: Opening UDP socket: address 192.168.1.200
[ INFO] [1516783392.203990664]: Opening UDP socket: port 2368
[ INFO] [1516783392.204029421]: expected frequency: 833.333 (Hz)
[ INFO] [1516783392.205527211]: Opening UDP socket: port 2368
[ INFO] [1516783392.205580293]: Initialised lslidar c16 without error
```

Note: if the timeout indicates that the driver has no data, please check the hardware connection. Open a terminal again and execute the following command:

rosrun rviz rviz

4)Display the data detected by LiDAR in the pop-up displays window

Please change the value of "Fixed Frame" to “laser_link”, click the “add” button, and click “pointcloud2” under “by topic” to add the multi-lines point cloud.

7. Software Instructions

7.1Introduction

This document is intended to guide users and developers how to use the 32-line LiDAR of LeiShen Intelligent System Co., Ltd. and the matching 32-line LiDAR display software.

7.2 Application Scope

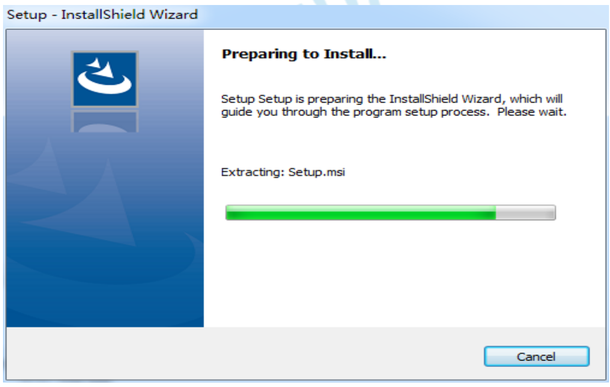
The multi-line LiDAR display software of LeiShen Intelligent is applicable for the 32-line LiDAR of LeiShen Intelligent and compatible with the related operations of 32-line single and second echo LiDAR of Velodyne.

7.3Software

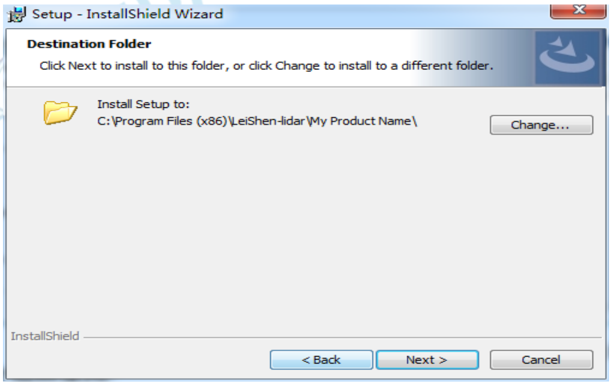
7.3.1 Installation Environment

This software is currently only applicable in the Windows x64 system operating platform. The configuration requirements for the computer installing the software are: CPU: Intel (R) Core(TM) i5 or above, GPU: NVDIA GeForce GTX750 or above (most desirable), or it may influence the software display effect. After installing Leishen's multi-lines software, it still needs to install WinPcap, from the third-party library, which is enclosed in Leishen's multi-lines software.

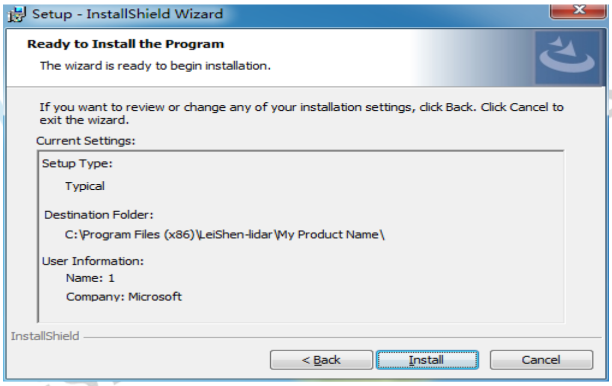
(1)Insert the CD-ROM for software installation included with the LiDAR into the CD/DVD drive. Open the CD-ROM and double-click  to install the file and the installation interface will pop up.

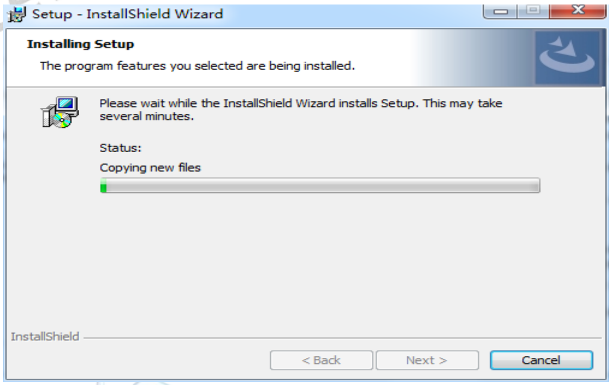


(2)Click next to enter the installation path selection interface.



(3)After customizing the installation path (do not use a path in Chinese), click next to enter the installation interface and click the install button. Wait until the installation is completed.

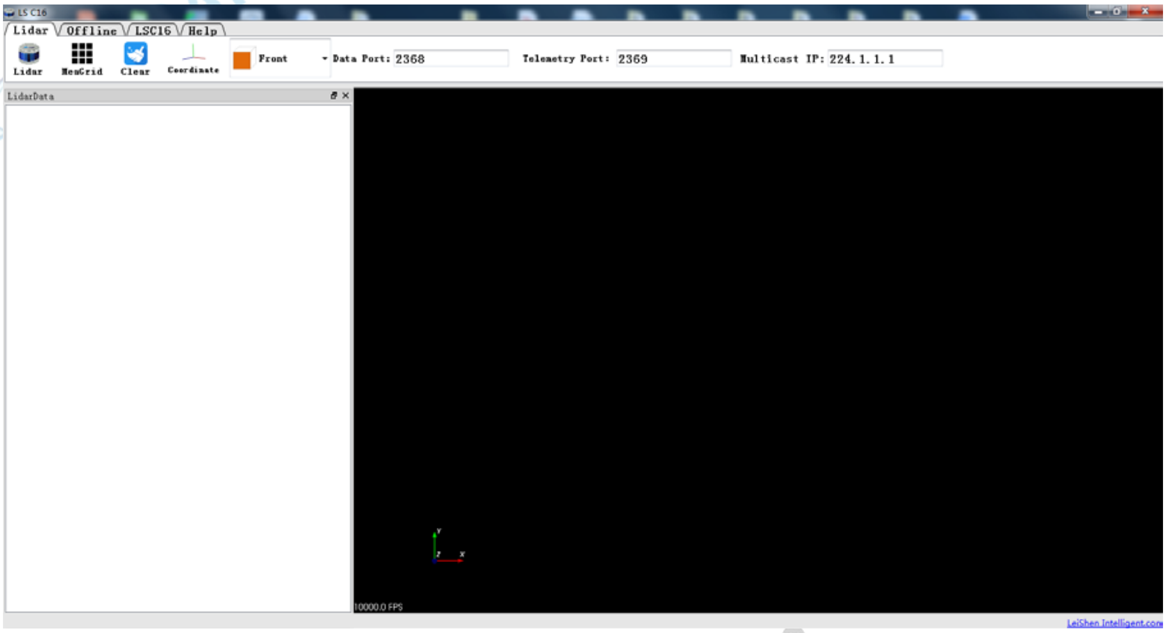




7.3.2 Introduction and Use of Related Functions

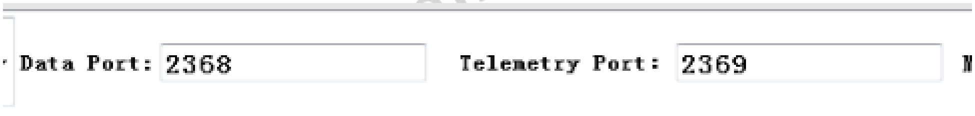
Operation of multi-line LiDAR display system of LeiShen Intelligent.

Double-click the shortcut icon on the desktop: The initial interface is shown below:

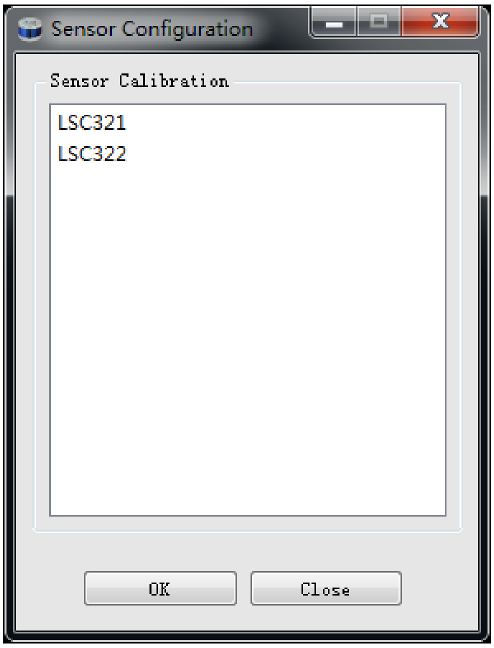


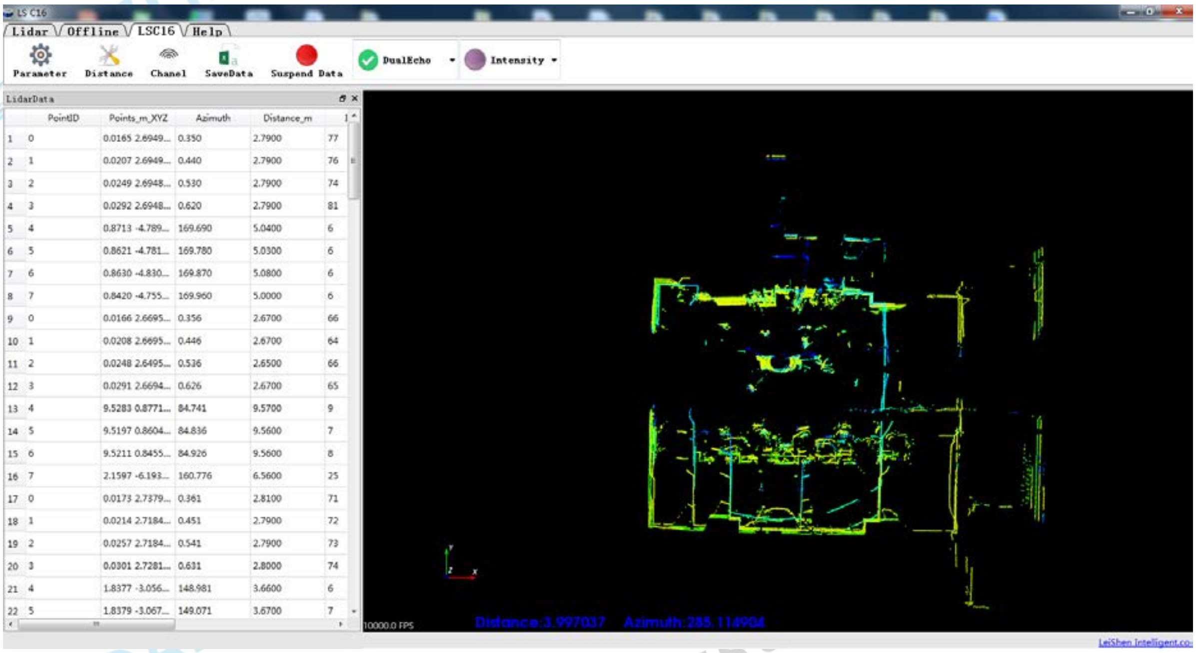
1) Introduction of Real-time LiDARData Receive Button

Setting data port number (default 2368) ,telemetry port(default 2369)



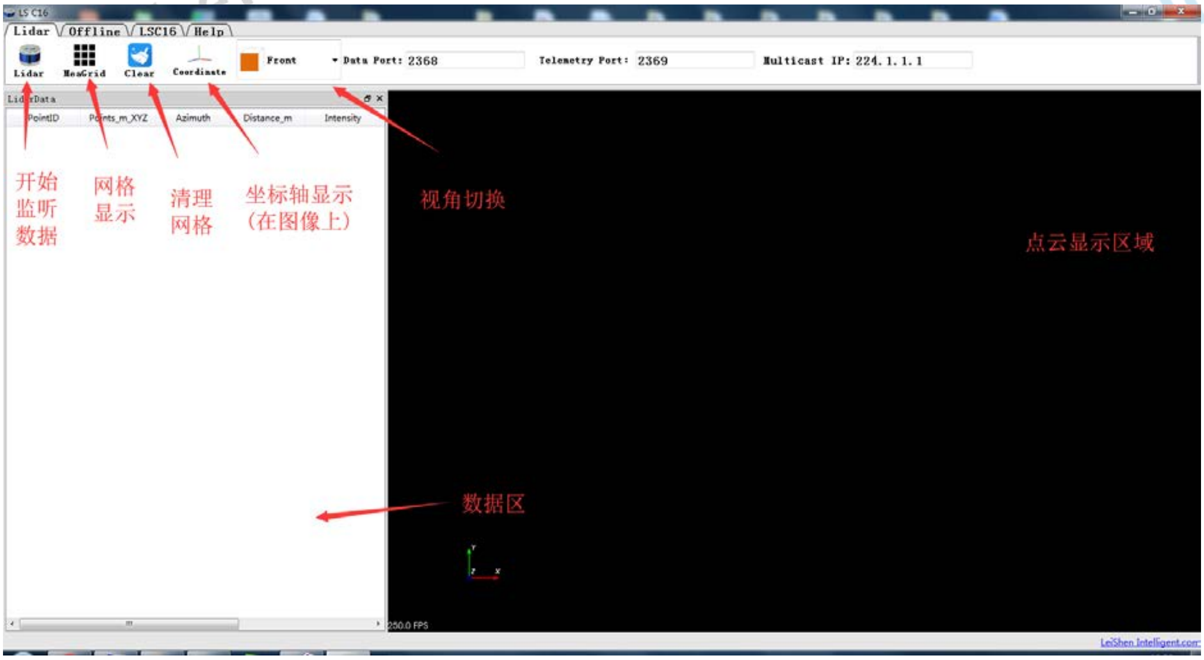
When LiDAR's power supply is connected to the network cable, click on  to get real-time receiving LiDAR data. Click on “Confirm” button on interface to check whether the software automatically detects the received data or not.It also can check real time data and display condition.If click “Cancel”,no LiDAR date shows. Select LSC32(single channel)or LSC32-2(dual channel) data to display directly.





2) Software Interface Related Introduction

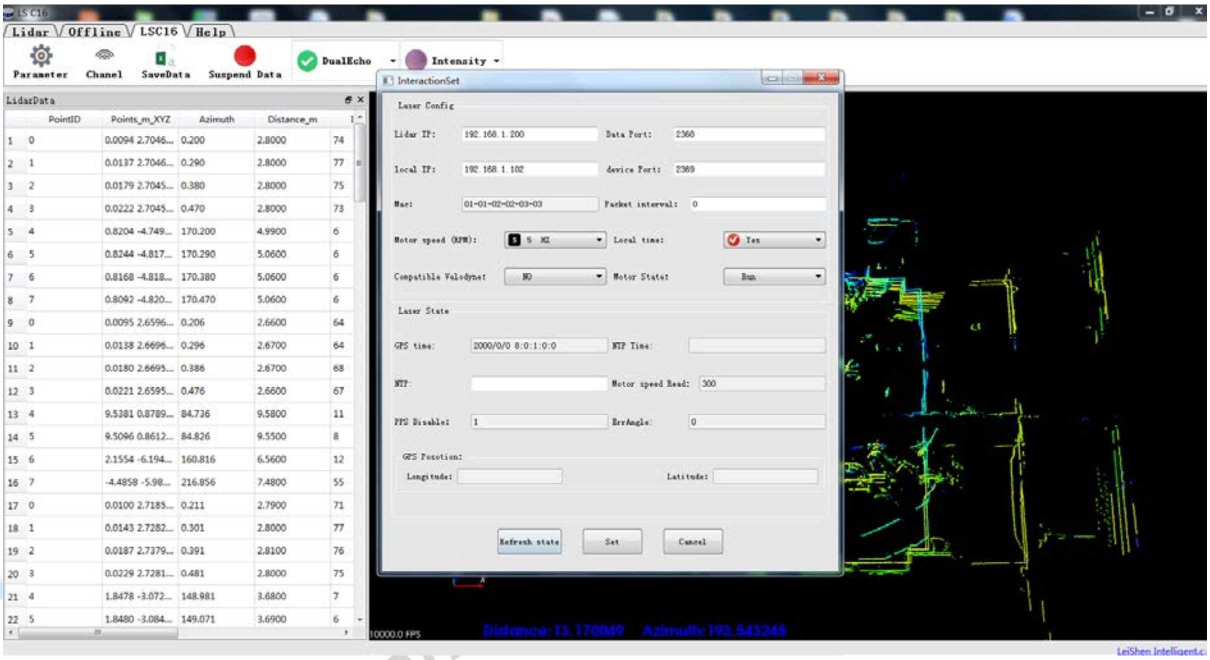
The software interface includes menu area, toolbar area, 3D window area, data table area, play frame information area, company website link and so on. The sections are shown in the following figure.



The data sheet contains (PointID, Points_m_XYZ, adjustedtime, Azimuth, Distance, Intensity, Laser_id, timestamp). In particular, Point ID is the point number, Points_m_XYZ is coordinate of the space x, y and z. Azimuth is the azimuth, Distance the distance, Intensity the reflection intensity, Laser_id the LiDAR channel, adjustedtime the adjusted time, and timestamp the time stamp.

3)User Configuration Write

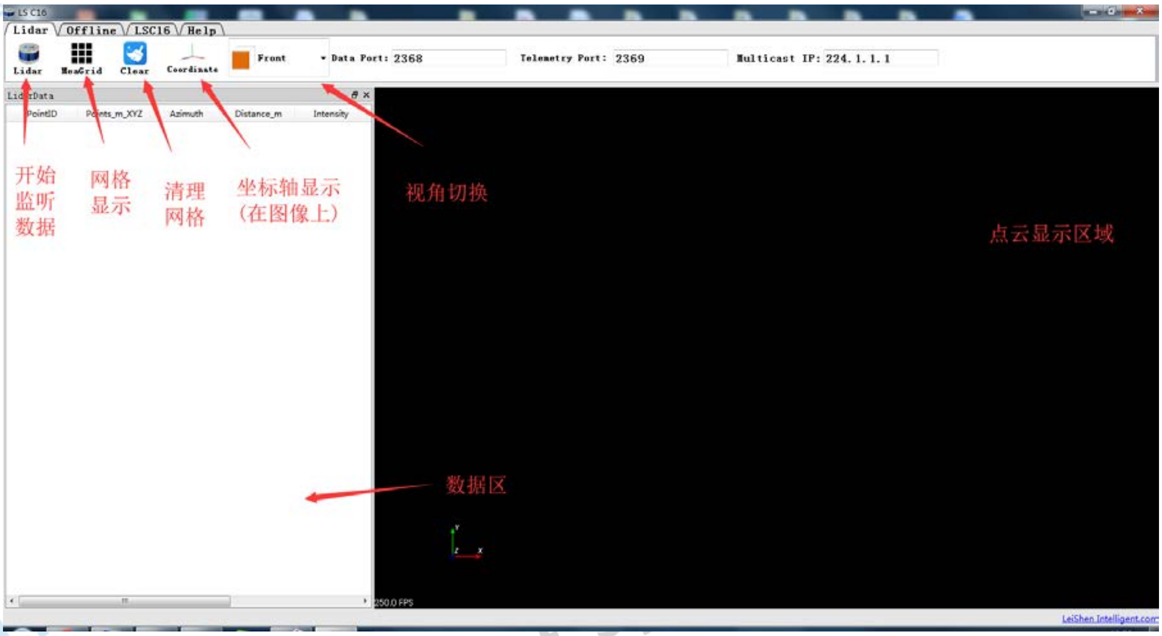
Click the icon  to pop up the LiDAR parameter setting form as shown below, where it is possible to set the relevant LiDAR.



LiDAR parameter setting is in the upper section of the form, where it is possible to set such parameters as LiDAR local IP, LiDAR destination IP, LiDAR local port, LiDAR destination port, LiDAR speed setting, get local time or not, and Mac address information. Users can also set “compatible with Velodyne or not” (the device information stream packet is not sent with the main data stream), and “stop LiDAR or not” (the third item under the combobox option offers choice whether to send the current LiDAR speed information; if it is selected, distance will no longer be shown in the distance column and is replaced by speed value). The LiDAR real-time status information is in the lower section. The DIFOP status packet sent periodically according to the LiDAR shows its current status information, including GPS location information, satellite time information, motor speed, current LiDAR IP, and the current LiDAR port number.

Clicking the Status Information Refresh allows to get the previous configuration information of the LiDAR (content of device information stream). After filling in the setting information, click the Settings button to send the UCWP packet to the LiDAR. When the LiDAR receives the UCWP packet, it is necessary to disconnect the power for the settings to take effect.

4) LiDAR Menu

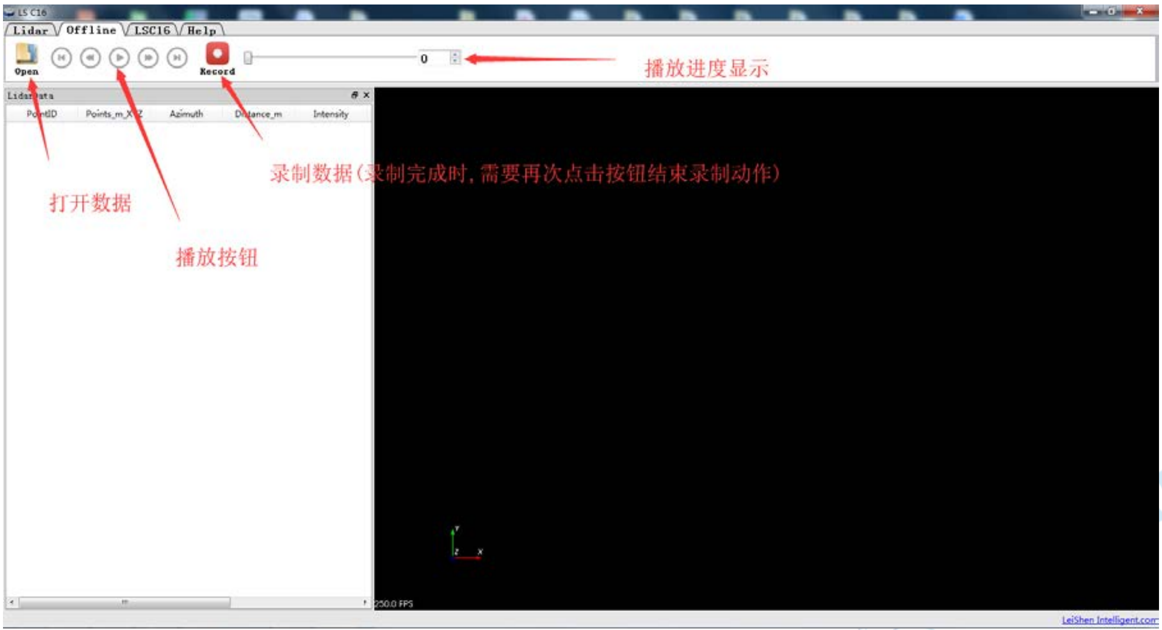


Offone menu

Click Button, select LiDAR type.

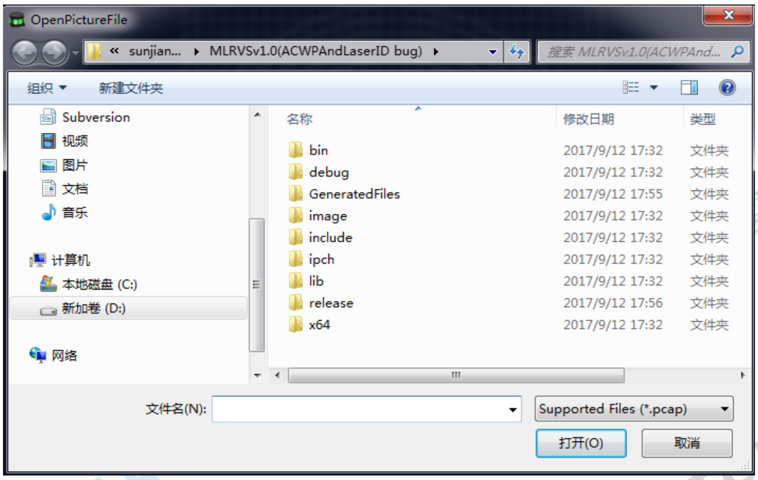
Click button, open offline data.

Click button, start saving offline data, valid when LiDAR receives data in real time.



Play pcap offline point cloud

Click button to pop up the dialog box:



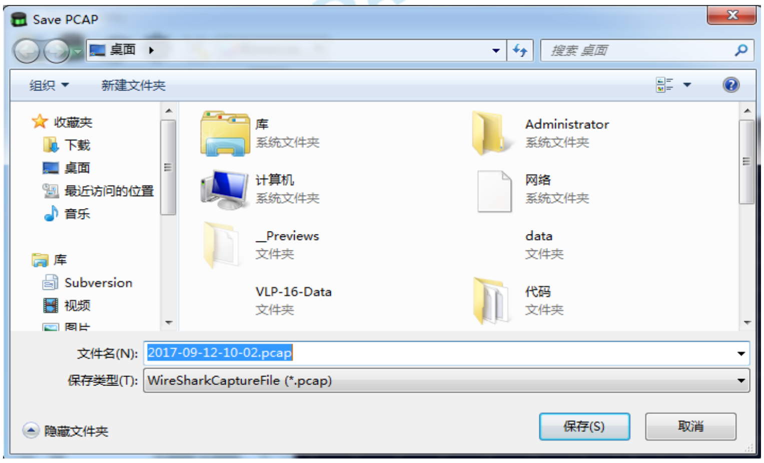
Select the pcap file you want to play and click the Open button.

Click button, chose LSC32 data to connect display, Start play offline point cloud pcap files and visualize point cloud data.

Introduction of play related buttons:

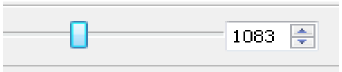
For the play/pause button, a pause is enabled by clicking when it is playing and playback resumes by clicking when it is paused.

Clicking the button stores data and records pcap point cloud file. This function can only be used when the LiDAR data is received in real time and in playback mode. After clicking, the pcap file storage dialog will pop up and storage starts after the path is selected, as shown below:



Clicking  again stops storing.

Note: When an offline pcap file is playing, the button is gray and the function is disabled.



The progress bar in the toolbar shows the progress of the playing file, with the data in the input box being the number of frames at which the file is playing.

5) Introduction of Point Cloud Display

In the point cloud data, there are 20 circles and 40 × 40 grids in the display box. There is a distance of 10m between the radius of two neighboring circles and 10m between two grids (horizontal or vertical). The radius of the outermost circle is 200m. Grids and auxiliary circles make it easy for users to see the location of point cloud.

3D Display the orientation of the interface axes with XY on the axis of the point cloud reference system xyz Axis in the same direction.

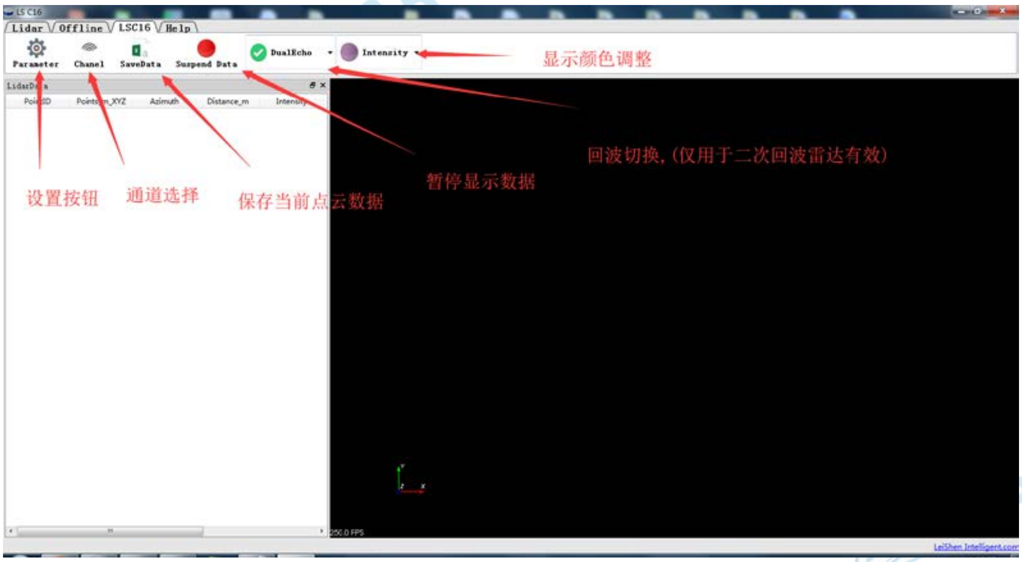
Point cloud display interface supports the following operations:

a) By moving the mouse wheel the display interface zooms in/out; holding down the right mouse button to drag up/down can also do.

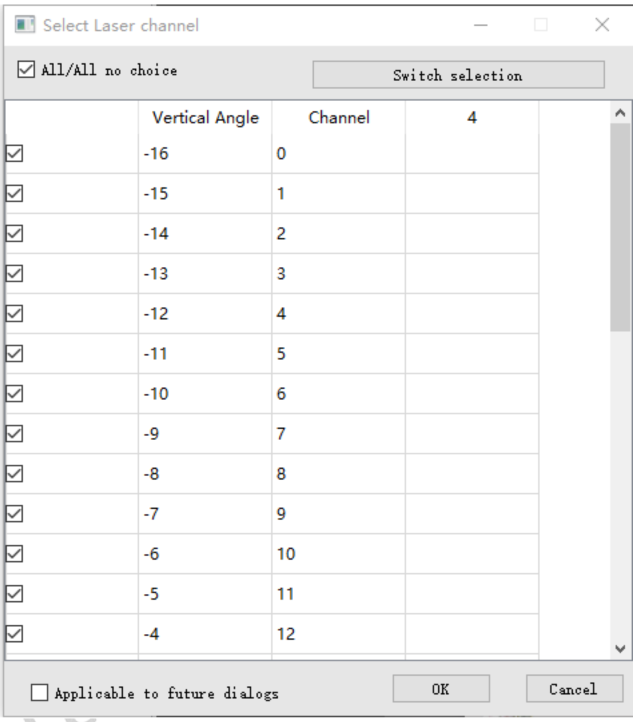
b) Dragging while holding down the right mouse button helps to adjust the perspective of the display interface.

c) Dragging while holding down the mouse wheel helps to pan the display interface; pressing the shift key on the keyboard while clicking the left mouse button can also do.

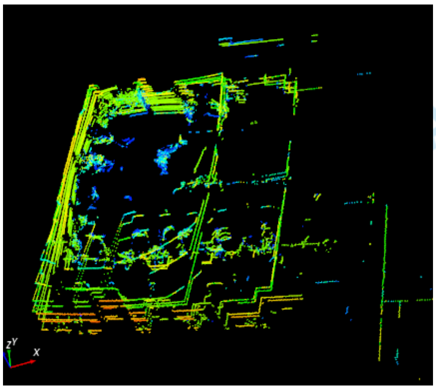
LSC32 Menu



Click button to control the LiDAR channels signals. click on the left check box to close (open) a channel data, click on the upper left corner of the selection all / all can open (close) all channel data. Click on the lower left corner of the applicable dialog box, you can record the current state of LiDAR harness selection for the next application. The vertical angle in the form table indicates the perpendicular angle of the corresponding channel data, and the channel denotes the data arrangement sequence number of the channel corresponding to the channel, laser id indicates the LiDAR channel number.



As shown in the following figure, the left image shows some of the channel data hidden in the 32 lines, and the right image is the complete data:



7.4Attention

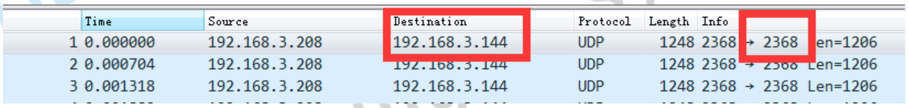
7.4.1 LiDAR Setup and Use Issues

(1) LeiShen 32-line LiDAR display software cannot be used in two processes (opened twice when it is already running) in the same PC to receive data because the use of PC port

is generally exclusive. When one process is bound to a specified port number , other same processes or software using the same port number cannot work normally. For example, if software Veloview uses the same port number, it is impossible to use either of the software in the same PC to receive LiDAR data synchronously, in which case one of the software crashes. Moreover, as the underlying software development using Qt is unable to identify a Chinese path, no Chinese path is recommended in naming a file or a path folder.

When LeiShen 32-line LiDAR display software detects the port is temporarily used, it will prompt for communication network port configuration failure and automatically close the software. Users need to close the process of software that occupies the port, and re-open LeiShen 16-line LiDAR display software for normal operation.

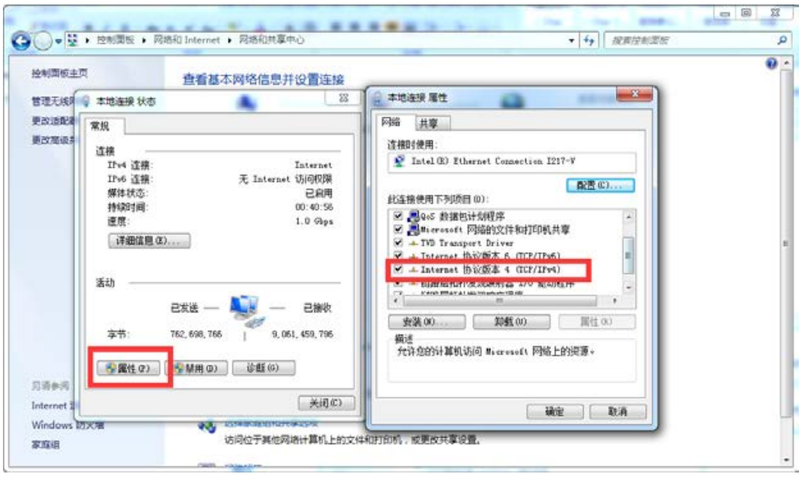
(2) As LeiShen 32-line LiDAR is able to modify the port number through the user configuration so that the LiDAR sends data to the upper computer through the preset destination IP and port, it is necessary to set the IP as the destination IP of the LiDAR when the local notebook or desktop and other device are receiving data. The port bound to program in the local upper computer shall have the set destination port number, as shown below. The packet parameters captured and analyzed by Wireshark are as follows:



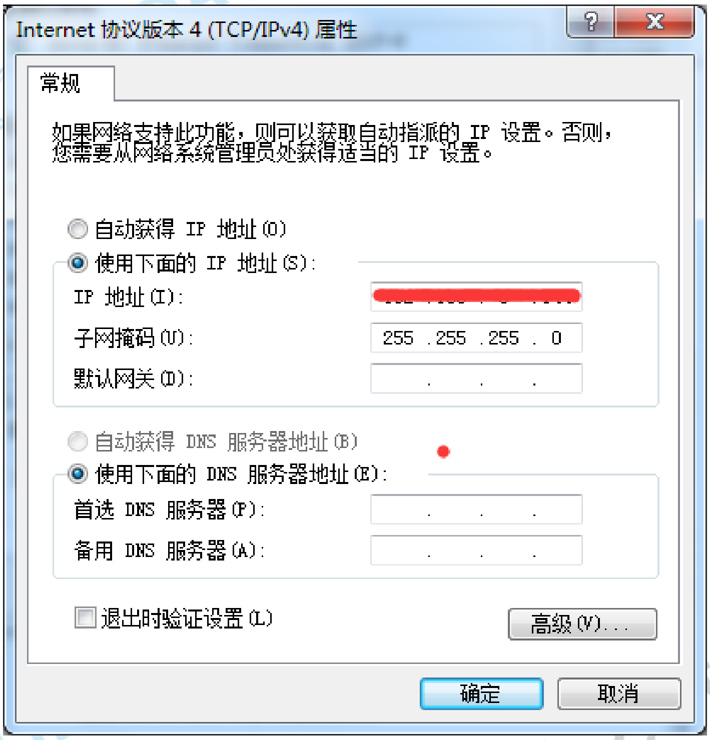
The red boxes indicate the destination IP and port of the LiDAR, respectively.

In Control Panel -> Network and Internet -> Network Share Center, click the Local Area Connection button.

Click Properties in the pop-up status box and click TCP/IP4 Protocol Version in the pop-up Properties box, as shown below.

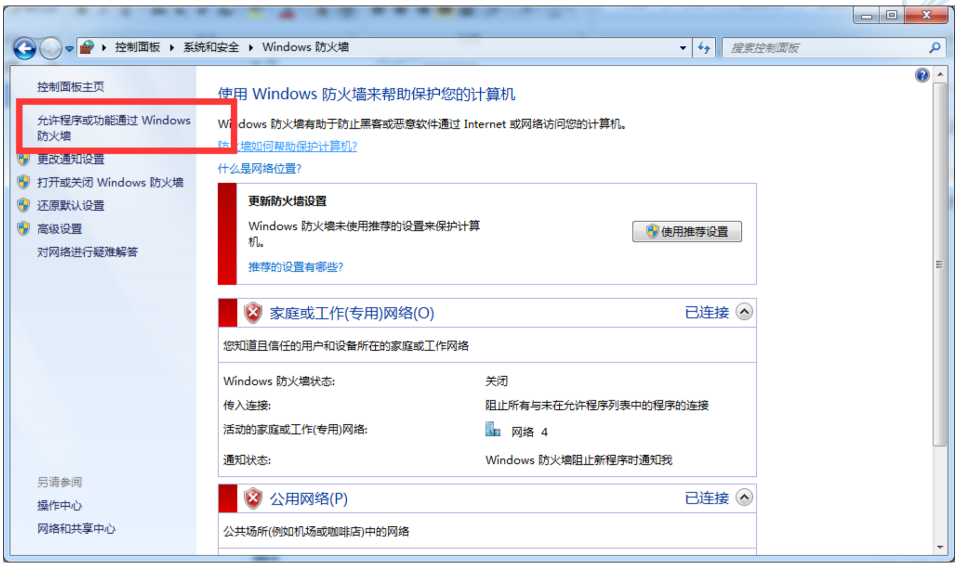


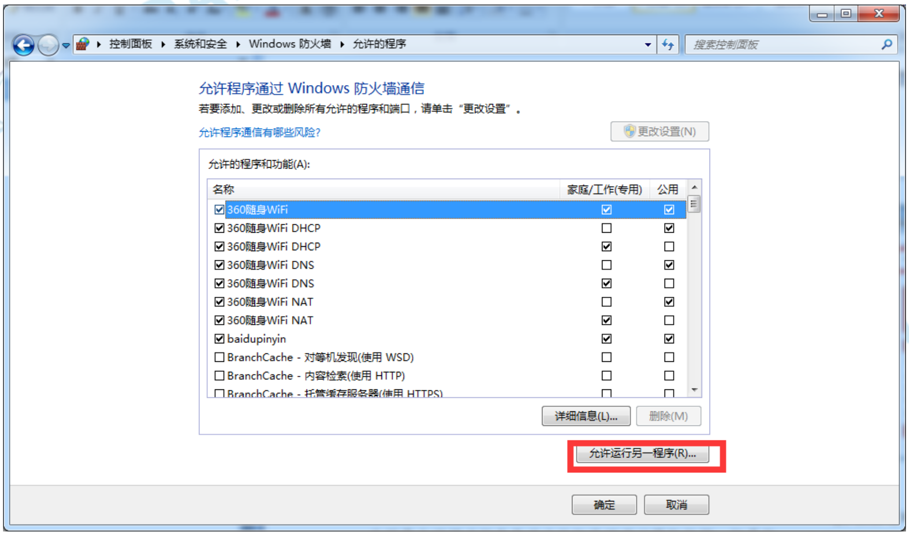
In TCP/IP4 Properties Settings set the IP address to the destination IP of the LiDAR (the default factory IP and port of the LiDAR are shown in the LiDAR communication protocol) and the subnet mask to 255.255.255.0.

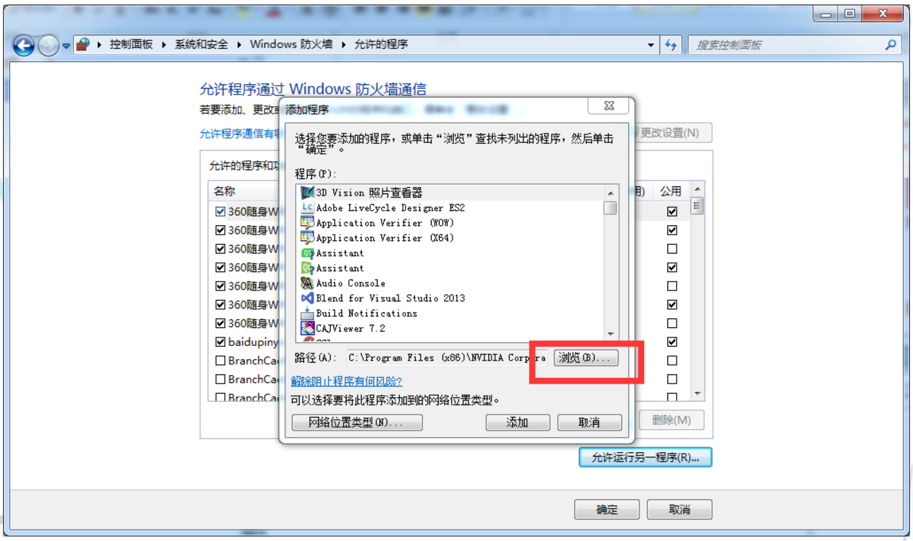


(3) Since LeiShen multi-line LiDAR display system program needs to acquire massive packets via the Internet in a short period of time, it may be prohibited by the network firewall as a malicious program. It is possible that packets are seen to have been sent to the computer using software wireshark to capture packets but are not displayed on the upper computer.

In Control Panel -> System and Security -> Windows Firewall Settings, click Allow a Program or Feature to Pass Through Windows Firewall, as shown below.







Browse to find the software installation path (by default, C:\Program Files (x86)\LeiShenIntelligentSystem\LSVIEW\LSView.exe), and click OK after it is selected to apply the program’s network settings. See the following figure for details:

According to the nature of the user's network, check the boxes marked in the red box and click OK to view the data.

7.4.2 Windows Display

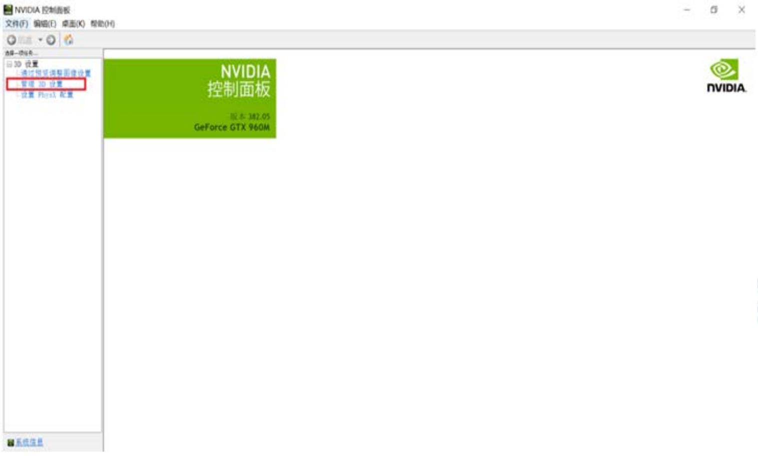
When LeiShen Intelligent multi-line LiDAR display software is installed in a desktop or laptop with dual GPUs, the default global settings for the computer operating system as use global settings (automatic selection: integrated GPU) have an effect on the display efficiency of the software. To ensure the use and display efficiency of the software, it is necessary to menually set the computer GPU settings.

Dual GPUs can be viewed in the computer configuration. As shown below, the computer's display adapter can be seen in My Computer -> Right Button -> Properties -> Device Manager:

So it is necessary to menually adjust the settings by switching the applicable GPU of the software menually to HP discrete GPU. The setting steps are as follows:

(1)In case of a notebook with integrated GPU Intel(R)HD Graphics 530 and discrete GPU NVDIA GeForce GTX 960, right-click on the desktop space to pop up the right-click menu and select NVDIA Control Panel.

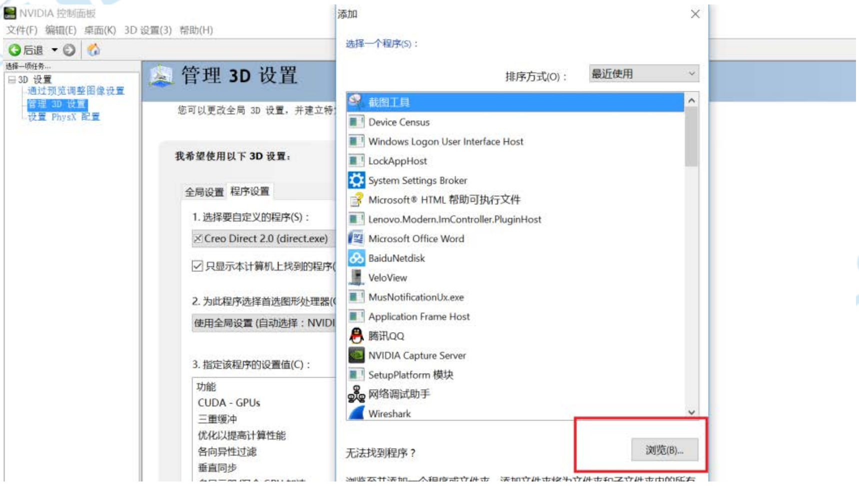
(2)Select Manage 3D Settings button in the pop-up program interface of NVDIA Control Panel, as shown below.



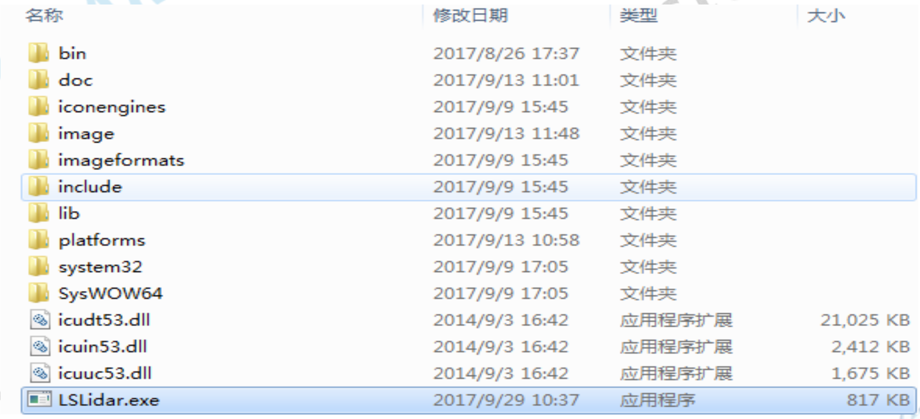
(3)Select Program Settings button in Manage 3D Settings interface, as shown below.

(4)Click Add button in Manage 3D Settings interface, as shown below.

(5)Click Browse button in the pop-up Add interface, as shown below.



(6)Find the application file of the software (.exe file) in the pop-up Browse interface according to its installation path:



(7)Click OK to automatically return to NVDIA Control Panel. Select HP NVDIA Processor from the dropdown box under option 2. Select Preferred GPU for This Program and click on the application in the lower right corner. After the computer application is set, close NVDIA Control Panel to complete settings, as shown below.