TF02 Single-point Ranging LiDAR
Product Specification

Benewake (Beijing) Co. Ltd.

敦光雷达 & SLAM解决方案
.iDAR & SLAM Solution

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1. Product Overview

The product is based upon ToF (Time of Flight), supplemented by particular optics, electricity, and design, so as to measure distance with stability, precision, high sensitivity, and high speed.

Key Features：

- High sensitivity, and able to measure as far as 22 meters
- High speed measurement with a maximum sampling frequency of 100Hz
- Excellent anti-ambient light usability (operable under 100kLux ambient light)
- Protection grade: IP65
- Anti-corrosive against pesticide
- Small in size and light

Major Applications:

- Drone altitude holding and terrain following
- Machine control and safety sensors
- Range measuring instrument

2. Optical Principle

TOF is short for Time of Flight. It refers to that a sensor emits modulated near infrared light, which reflects when objects are in the way. TOF then converts the distance away from the filmed scenery by calculating the time difference or phase difference between emission and reflection, thereby generating in-depth information.

3. Electrical Properties

Item	Symbol	Minimum Value	Typical Value	Maximum Value	Unit
Power Supply Voltage	DC	4.5	5（≥1A）	6	V
Average Power	P		1		W
Peak Current	I_p		1		A
Serial Port TTL Electrical Level	LVTTL		0～3.3		V

4. Product Properties

Item	Symbol	Condition or Description	Typical Value	Unit
Operating Range	L	Indoor	0.4 - 10 (reflectivity 10%)Φ 0.4 - 22 (reflectivity 90%)	m
		Outdoor illumination intensity of 100Klux	0.4 - 10 (reflectivity 30%)	
Emission Semi-angle of Signal Light	α	Divergence angle of light spot	2	Degree

|				
Signal Acceptance Semi-angle	β	Semi-angle of LiDAR's effective detection	1.5	Degree
Range Resolution	Re	Sensitivity to range change	1	cm
Range Repeatability	σ	1σ standard deviation of indoor repetitive ranging	<1（within 10m） <2（10m-22m）	cm
Range Accuracy	Δ	Deviation between measuring range and actual distance	<6（within 5m）② <2%（5m-22m）	cm
Light Source	λ	Central wave length	850	nm
Operating Temperature	T		-10～60	°C
Protection Grade	IP		IP65	
Eye Safety	S	Compliance with EN62471	NA	
Weight	W	Connection line included	52	g
Size	LWH	Length*Width*Height	69*46*26	mm

①The reflectivity of black standard board is 10%. And the reflectivity of white standard board is 90%.

②The testing environment is indoor white standard board.

5. Protection

5.1 Protection Grade

INGRESS PROTECTION (IP) Protection Grade System is drafted by INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC) to classify electrical appliances according to their dust and moisture resistance characteristics. IP protection grade is composed of two figures, the first representing the grade of electrical appliance dust proof and preventing the intrusion of foreign objects, and the second representing degree of electrical appliance moisture proof and water proof. The greater the number is, the higher the degree of protection is.
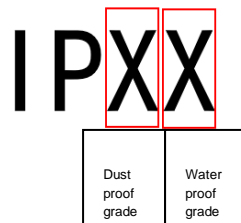
Protection grade of TF02: IP65, IP dust proof: Grade VI, IP water proof: Grade V.

Grade VI of IP dust proof represents the full prevention from intruding by foreign object and dust.

Grade V of IP dust water represents the prevention from damaging the electrical appliance by the intrusion of water from the nozzle at different directions.

TF02 protection grade can ensure its normal operation under light rain, moderate rain, pesticide spraying by drone and polluted optical windows.

If the operating environment is harsh, and you would like to know more about the impact of optical window pollution, please contact us for TF02 Single-point Ranging LiDAR Pollution Test Report.

5.2   Anti-pesticide corrosion

With special ratio and test, TF02 shell material is different from the traditional plastic material, and more resistant to pesticide corrosion, so it can work normally in the harsh outdoor environment. Especially in the field of plant protection drone, anti-pesticide corrosion can greatly improve the product's reliability and life.

TF02 shell consists of two materials, as shown in the figure below.   Material A and material B, respectively, constitute its shell and optical window. The two materials will go through the following pesticide corrosion test: the two materials were respectively and completely submerged in nine pesticides diluted 100 times for at least 48 hours.
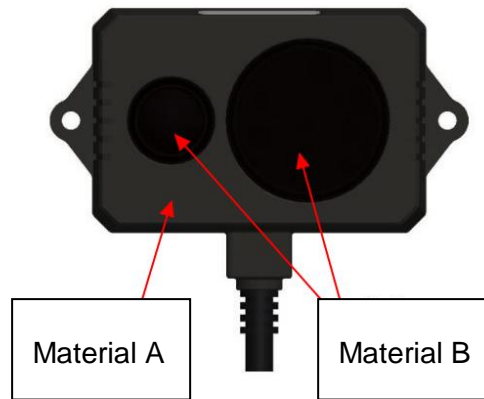
TF02 shell materials

TF02 shell material corrosion test results are shown in the following table, where material A (shell) is completely free from pesticide corrosion and material B (optical window) is partially corroded. As the pesticide concentration and contact area of test materials with pesticide under our test conditions are higher or greater than those in normal environment, it has a high anti-pesticide corrosion characteristic.

TF02 shell material pesticide corrosion test table

No.	Tested pesticide type	Material A (Shell)	Phenome non	Material B (Optical window)	Phenomenon
1	Deltamethrin	√		√	
2	Cypermethrin	√		×	Surface corrosion
3	Copper sulfate basic	√		√	
4	Glyphosate	√		√	

5	Glufosinate	√		√	
6	Azoles	√		√	
7	Hymexazol	√		×	Surface corrosion
8	Phenoxy acetic acid	√		×	There is corrosion, and material becomes soft
9	Trifluralin	√		×	There is corrosion, and material becomes soft

Description: in the test, diluted 100 times refers to the ratio of pesticide and water of 1: 100, that is, the proportion of pesticide is 1%. The proportion of pesticides in the test is higher than common pesticide proportion (0.1%-1%). The test product is completely immersed in nine pesticides for at least 48 hours. √ indicates that the material is completely free from corrosion, and × indicates that the material is affected by corrosion.

6. Detection Angle

TF02's signal acceptance angle is 3˚, so LiDAR's detection angle is 3˚. The side lengths of different distance detection ranges (the detection range takes on a square shape) are shown as below in the table.
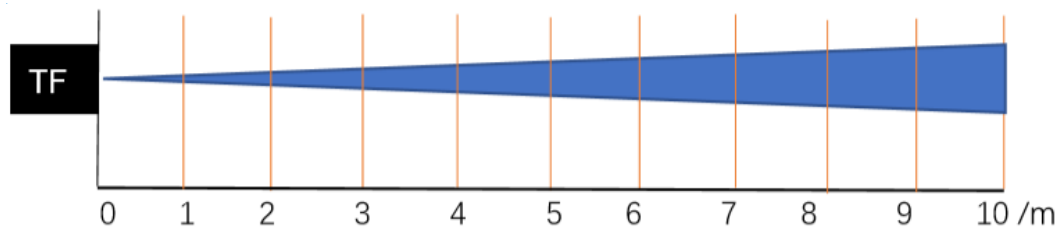
Detection Range (Acceptance Angle) Diagram

Distance (m)	1	2	3	4	5	6	7	8	9	10	15	20	22
Detection Range Side Length（cm）	5	10	16	21	26	31	37	42	47	52	79	105	115

Note: the distance in the table stands for the vertical distance between LiDAR and the detected object, with meter as unit. The side length unit of detection range is cm. Generally, the side length of detected object should be greater than that of detection range. Only in this way the LiDAR output data can be reliable. When the side length of detected object is less than that of detection range, the LiDAR output data is not stable and the error increases.

Note: the side length of detecting range is not equal to the object resolution at the corresponding distance.
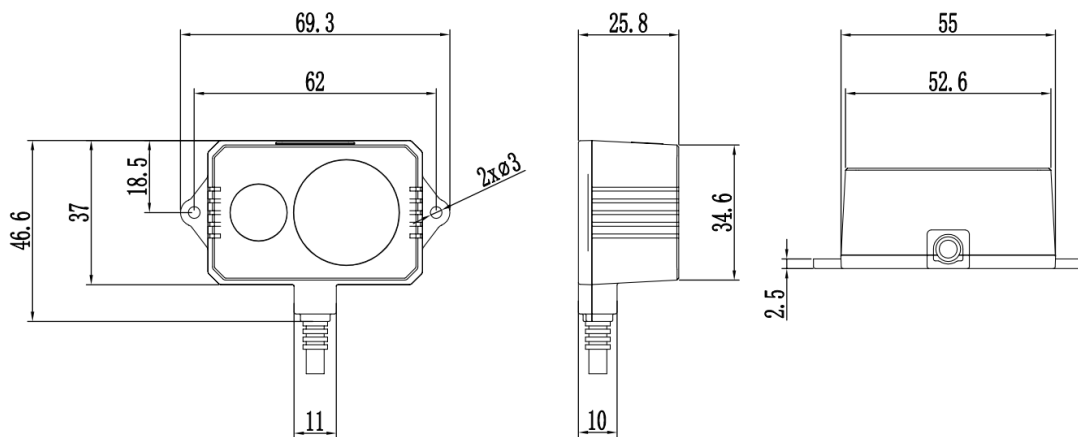
7. Dimension and Product Specification

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The following module object figures and outline dimensional drawings are all reference designs, and can be customized according to customers' requirements and actual application scenarios.

DELiDAR TF02 Outline Drawing

DELiDAR TF02 Outline Dimensional Drawing (unit: mm)

Installation Requirements:

1、 M2.5 round Philip's head screw is suggested when installing LiDAR and peripheral structures.

2、 Optical windows of LiDAR front panel cannot be blocked and shall be kept clean.

Line Sequence Description:

	Line Sequence of Serial Ports	Line Sequence of CAN Port
Red Line	+5V	+5V
Black Line	GND	GND
White	TTL-RXD	CAN-L

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Line		
Green Line	TTL-TXD	CAN-H

8. Noise Model

The repeat accuracy of LiDAR testing distance is relevant to Strength (signal strength). The higher the Strength is, the more stable the dist is, and the less the standard deviation of dist is.

Curve for Variation of Dist Standard Deviation along with Strength
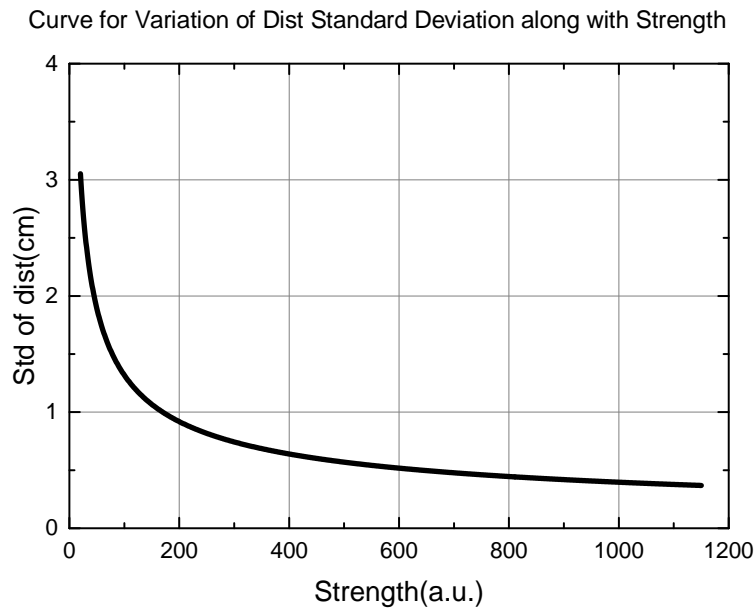
Curve for Variation of Dist Standard Deviation along with Strength

9. Data Format

9.1 Communication Protocols

The following is an introduction to the method of DE-LiDAR TF02 connecting and communicating with peripheral equipment using serial ports or CAN, including coded format of sent data and communication protocols of modules with peripheral equipment. The serial port output level is LVTTL (0-3.3V).

Communication	UART	CAN
Baud Rate	115,200	1M
Data Bit	8	--
Stop Bit	1	--
Parity Bit	None	--
None	--	0x00090002
Frame Format	--	Extended Frame

9.2 Standard Data Format of Serial Ports

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The data output by TF02 is shown as below. All the data are hexadecimal. Each frame of data totals 9 bytes. The data contains distance information, i.e. Dist; signal strength information, i.e. STRENGTH; and reliability information, i.e. SIG. The frame end is data parity bit.

Data Bit	Definition	Description
Byte0	Frame header	0x59
Byte1	Frame header	0x59
Byte2	DIST_L	DIST low 8 Bits
Byte3	DIST_H	DIST High 8 Bits
Byte4	STRENGTH_L	STRENGTH low 8 Bits
Byte5	STRENGTH_H	STRENGTH high 8 Bits
Byte6	SIG	Reliability is divided into 8 levels, respectively indicated by 0x01-0x08. When the reliability level is 7 or 8, it means data is reliable. When the reliability level is another value, the data of this frame is not recommended.
Byte7	TIME	Exposure time is divided into two levels and expressed by 0x03 and 0x06 respectively. The greater the value is, the longer the exposure time is.
Byte8	Check	Low 8 bits of Checksum parity bit, Checksum = Byte0 + Byte2 + ... + Byte7, Checksum are the low 8 bits of the checksum of former 8 bytes

9.3 Data Format of Serial Port Pix

It is output in the form of strings with m as its unit. For example, if the measuring distance is 1.21m, then the output string is 1.21. Each distance value ends with line feed.

Note: if the output distance of TF02 is 22 (m), it indicates outrange or insufficient signal intensity and so the distance is not reliable. It is suggested to eliminate this data.

9.4 CAN Standard Data Format

The data output by TF02 is shown as below. All the data are hexadecimal. Each frame of data totals 8 bytes. The data contains distance information, i.e. Dist; signal strength information, i.e. STRENGTH; and reliability information, i.e. SIG.

Note: CAN communication protocols can be customized according to customer requirements.

Data Bit	Definition	Description
Byte0	DIST_H	DIST High 8 Bits
Byte1	DIST_L	DIST low 8 Bits

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Byte2	STRENGTH_H	STRENGTH high 8 Bits
Byte3	STRENGTH_L	STRENGTH low 8 Bits
Byte4	TIME	Exposure time is divided into two levels and expressed by 0x03 and 0x06 respectively. The greater the value is, the longer the exposure time is
Byte5	SIG	Reliability is divided into 8 levels, respectively indicated by 0x01-0x08. When the reliability level is 7 or 8, it means data is reliable. When the reliability level is another value, the data of this frame is not recommended.
Byte6	Reserved Bit	Reserved Bit
Byte7	Reserved Bit	Reserved Bit

10. Interface Description of Serial Port Upper Computer

Currently, the upper computer only supports Windows® operating systems, applicable to TF series products by Benewake (Beijing) Co. Ltd. In addition, it is limited to the product with serial communication protocols output. For detailed operations, please see the following description.
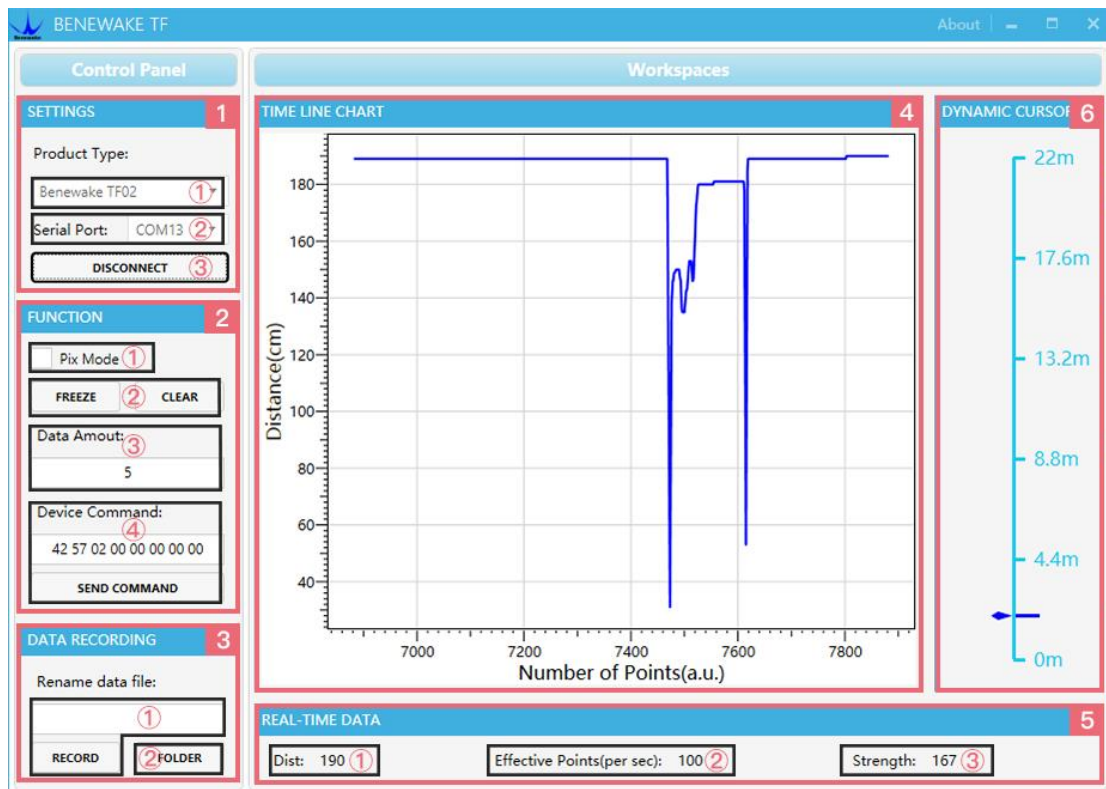
1)   Product Type/ UART Control Zone

①   Product Type (product type selection): connect the appropriate lidar type through the TTL-USB adapter plate on the computer. As shown in the figure, TF02 produced by our company is used, for which Benewake TF02 should be chosen.

    ②   Serial Port (serial communication port): select the computer to identify the port number corresponding to the lidar.

    ③   CONNECT/DISCONNECT: click the [CONNECT] button to establish connection with the lidar; click [DISCONNECT] button to cancel the connection.

2)   Functional Area

    ①   Pix Mode (pix mode selection): if Pixhawk Select the button to open the PIX mode; cancel the check button, resume the default output format

    ②   FREEZE/CLEAR (freeze/clear button): clicking the [FREEZE] button may freeze the upper computer to facilitate the analysis on the image in [4]; clicking [CLEAR] button will clear the plotted curve in [4] and start plotting anew.

    ③   Data Amount (average of the total data amount): the default value is 5, that is, for every 5 points received by the upper computer, the average value of the 5 points will be taken for the output of a point. It can be modified as needed (in order to prevent blocking of the upper computer, the value had better be greater than or equal to 5). Enter the value and send the command by pressing Enter key on the keyboard.

    ④   Device Command (serial port command sending area): this window can be used to send hexadecimal serial port commands to TF to modify or set the functions. For details, please consult Benewake FAE Group.

3)   Data Recording Area

    ①   Record (data recording column): name the data to be saved in the text window. After the input is completed, press the Enter key and record the TF data using the [RECORD] button. The data will be saved in the named text file. Click the [FINISHED] button and the data recording will be ended.

    ②   FOLDER (folder unfolding): press [FOLDER] button to unfold the folder where the data is saved.

4)   Data Image Display Area: the upper computer draws a continuous distance measuring image based on the data received, with the vertical axis indicating the current distance measured and the horizontal axis indicating the number of valid points.

5)   Real-Time Data Display Area

    ①   Dist (measured distance value): in the default unit of cm.

    ②   EffectivePoint (per sec): indicating the effective data that TF refreshes per second.

    ③   Strength (signal strength): In pix mode, the default Strength is 0 because there is no strength input.

6)   Range scale: with real-time display of the detected distance value according to the current product type.

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Application Notice:

• The product is a custom-made precision optical instrument and must be maintained by engineers of our company.

• Operating temperature: -10°C-60°C.

• Storage temperature: -20°C -80°C.

• This product adopts a special optical system. Please do not use the product under the sun for a long time, and storage away from light.