TF-UP01

HIGH-PRECISION LONG-DISTANCE SINGLE-POINT LIDAR

USER MANUAL

www.benewake.com
Benewake (Beijing) Co., Ltd.

Described Product

High-precision long-range single-point LiDAR: TF-UP01

Manufacturer

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Legal information

Original document

This document is an original document of Benewake.

Warning

The TF-UP01 range finder is equipped with a laser diode emitting in the visible spectrum. It is a class 2 laser product according to IEC 60825-1:2014.

WARNING: OPTICAL RADIATION DO NOT STARE INTO BEAM

TABLE OF CONTENTS

1 ABOUT THIS DOCUMENT

The User Manual is an operating Instructions for TF-UP01, which describes how to set up and configure the interfaces.

The User Manual contains detailed information about the interfaces including syntax and available functionality. It focuses on TF-UP01 specific topics and does not describe the basic technology behind each interface.

The details of the result output formatting and the contents and syntax of the command channels are shared by several interfaces. They are described in an appendix valid for all relevant interfaces.

1.1 Intended Readers

The intended readers of the User Manual are users working with integration between the TF-UP01 and other equipment, for example PLC programmers and Custom HMI developers.

The readers are assumed to have knowledge about TF-UP01 product and features as described in the datasheet for TF-UP01. The readers are also assumed to have knowledge about the basic functionality of the technology of the interfaces used for the integration.

1.2 Symbols and document conventions

The following symbols and conventions are used in this document:

WARNING

Indicates a situation presenting possible danger, which may lead to death or serious injuries if not prevented.

CAUTION

Indicates a situation presenting possible danger, which may lead to moderate or minor injuries if not prevented.

NOTICE

Indicates a situation presenting possible danger, which may lead to property damage if not prevented.

NOTE

Indicates useful tips and recommendations.

2 GENERAL INFORMATION

2.1 Intended use

The TF-UP01 laser rangefinder modules have been developed for range measuring of static and moving objects in the field of industrial applications.

The TF-UP01 measures distances up to 150m with high precision and support fast ranging rates of up to 50 Hz. Based on phase comparison technology the range finder is capable of accuracies of +/-3mm and below. It is powered and controlled via for interfaces, UART, CAN, RS-485 and RS-232.

2.2 Safety Advice

Read the safety advice carefully before starting to operate the TF-UP01 laser range finder. That way you will achieve a long product lifetime and will make optimum use of the device while avoiding damage to the device and human injuries.

WARNING

The TF-UP01 laser range finder is equipped with a laser diode emitting in the visible spectrum. DO NOT STARE INTO BEAM!

CAUTION

Ensure there is no voltage applied when establishing a connection to the device and while integrating the device into the upper system. There is a potential risk of damage to the device or of an electric shock to the operator.

Follow the integration advices when integrating the device in the upper system. Also, observe the safety distances when using the device. There is a potential risk of damage to the device or of an electric shock to the operator.

Do not touch the electronic parts of the device when the device is in operation or connected to the power supply. There is a potential risk of damage to the device or of an electric shock to the operator.

Do not disassemble the device or parts thereof. There is a risk of human injury by laser radiation and/or electric shock.

The disassembly of the device or parts thereof will void the warranty.

NOTICE

Do not operate the device when there is any damage visible.

Contact customer service for further assistance.

Keep the device away from water and other liquids. Avoid any soiling by dust or other contaminants. Always handle the device with the due care. When cleaning the device, follow the cleaning instructions.

Avoid touching the optics and do not use the device if the optics are soiled or clouded.

Do not perform any modification to the device as this may cause potential harm to the operator and the device. Any modification on the device will void the warranty.

NOTE

To clean TF-UP01, ensure it is disconnected from the battery or power supply. If the housing or the lenses are slightly soiled, they can be easily cleaned with a soft, slightly moistened optical cleaning cloth.

To avoid contamination of the device, always store it in the transportation package it was delivered in. Keep the device away from water, dust and other contaminants.

2.3 Maintenance, Service and Repair

The TF-UP01 is designed maintenance/service free so no maintenance of the device is required. In case the TF-UP01 is damaged, contact the customer service with bw@benewake.com for assistance. For the TF-UP01 to be repaired the device has to be returned to the manufacturer.

3 PRODUCT DESCRIPTION

3.1 Appearance Overview

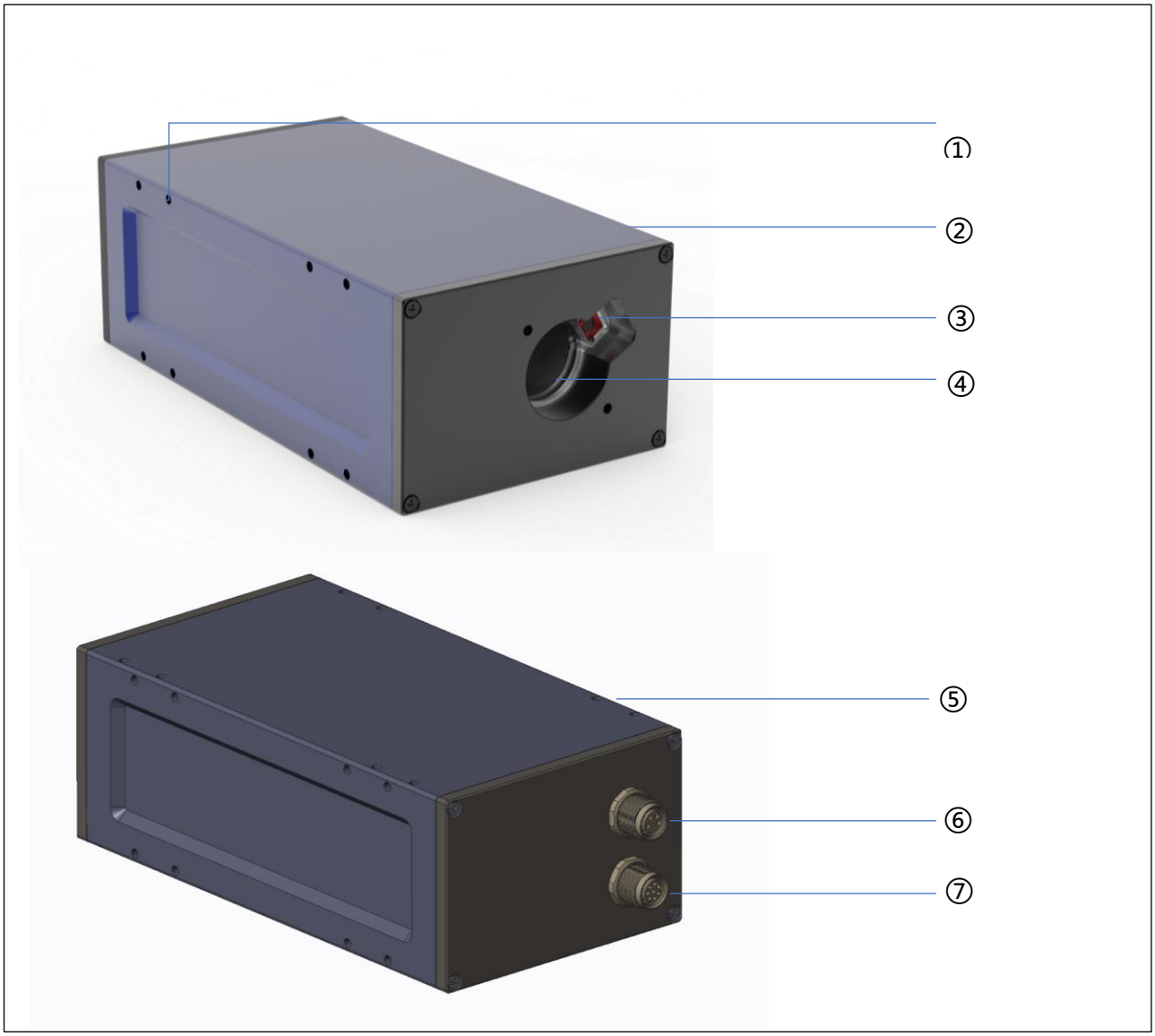

Figure 1 Module view of TF-UP01

① 3mm diameter side hole (5mm deep) for mounting (16x)

② Aluminum alloy housing

③ TX aperture

④ RX aperture

⑤ 3mm diameter bottom hole (5mm deep) for mounting (8x)

⑥ Power connector, female, 4pin

⑦ Data connector, female, 8pin

3.2 Dimensional drawing

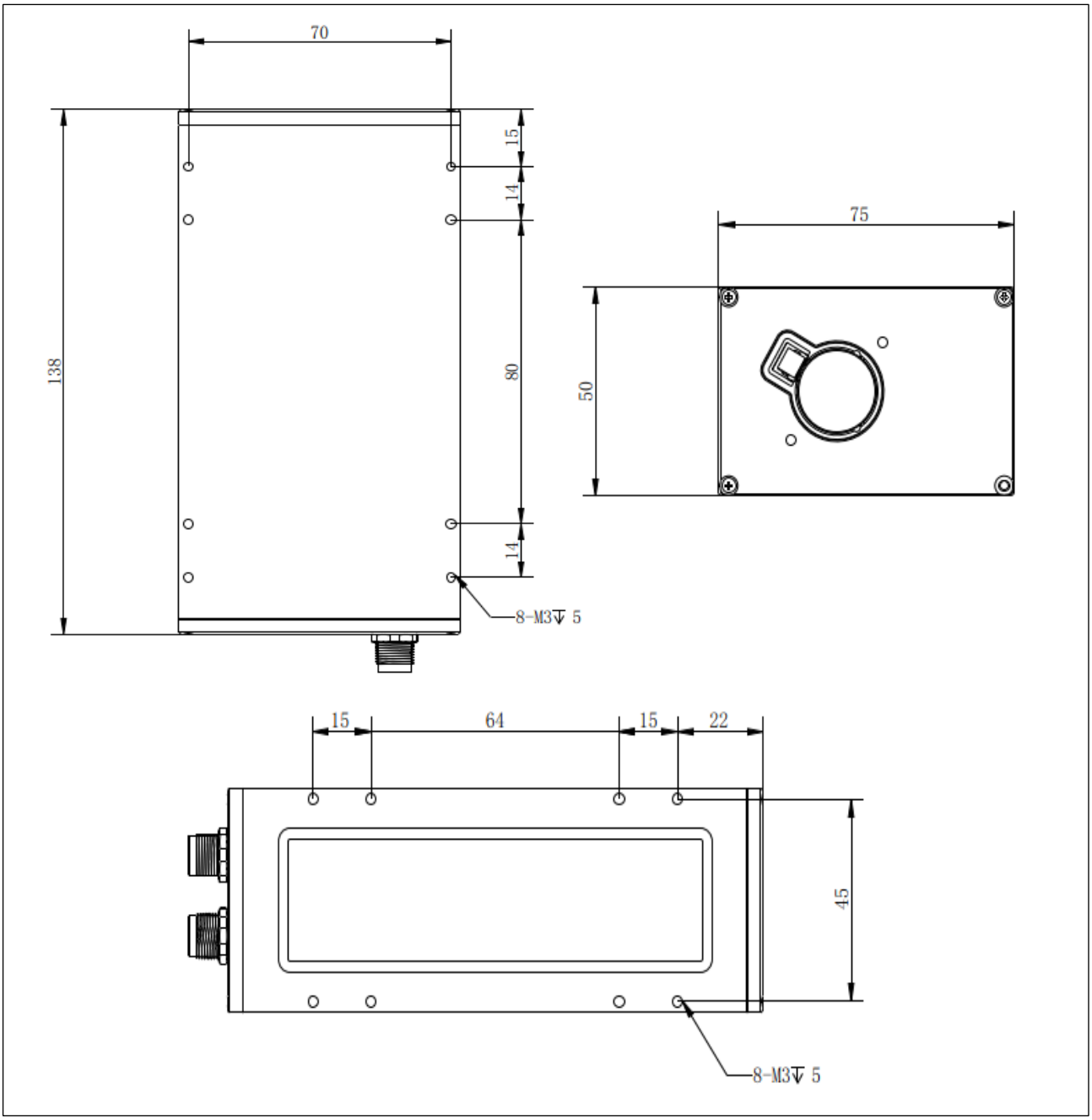

Figure 2 Dimensional drawing of TF-UP01

3.3 Technical specification

Table 1 Technical specification of TF-UP01

Parameters		Minimum	Typical	Maximum
Performance	Detection range (@80% reflectivity)	0.1m		50m
	Detection range (@10% reflectivity)	0.1m		30m
	Detection range (with reflector)	0.1m		150m
	Accuracy		±3mm@(-10~+50℃) ±2mm@(+15~+30℃，White background)	
	Distance resolution		1mm	
	Frame rate		10Hz & 50Hz	
Optical parameters	Light source		LD	
	Central wavelength		605nm	
	Photobiological safety		Class2 (EN60825:2014)	
	FoV		0.034° (0.6mrad)	
Environment	Enclosure rating		IP65	
	Operation temperature	-10℃		50℃
	Storage temperature	-20℃		70℃
Connections	Supply voltage	8V DC		30V DC
	Average current		≤150mA @ 5V, ≤80mA @ 12V, ≤50mA @ 24V	
	Power consumption		≤1.5W	
	Communication interface		UART / CAN / RS-485 / RS-232	
Others	Dimension		138mm*75mm*50mm(L*W*H)	
	Housing		Aluminum alloy	
	Weight		690g ± 5g	
	Cable length		1.5m or 5m	

NOTICE

Only two output frame rates of 10Hz and 50Hz are supported currently. TF-UP01 has three different measuring modes, each mode supports different frame rate. Please see *7.2Measuring modes* for detailed information.

3.4 Influences of object surfaces on the measurement

The signal received from a perfectly diffuse reflecting white surface corresponds to the definition of a remission of 100%. As a result of this definition, the remissions for surfaces that reflect the light bundled (mirrored surfaces, reflectors), are more than 100%.

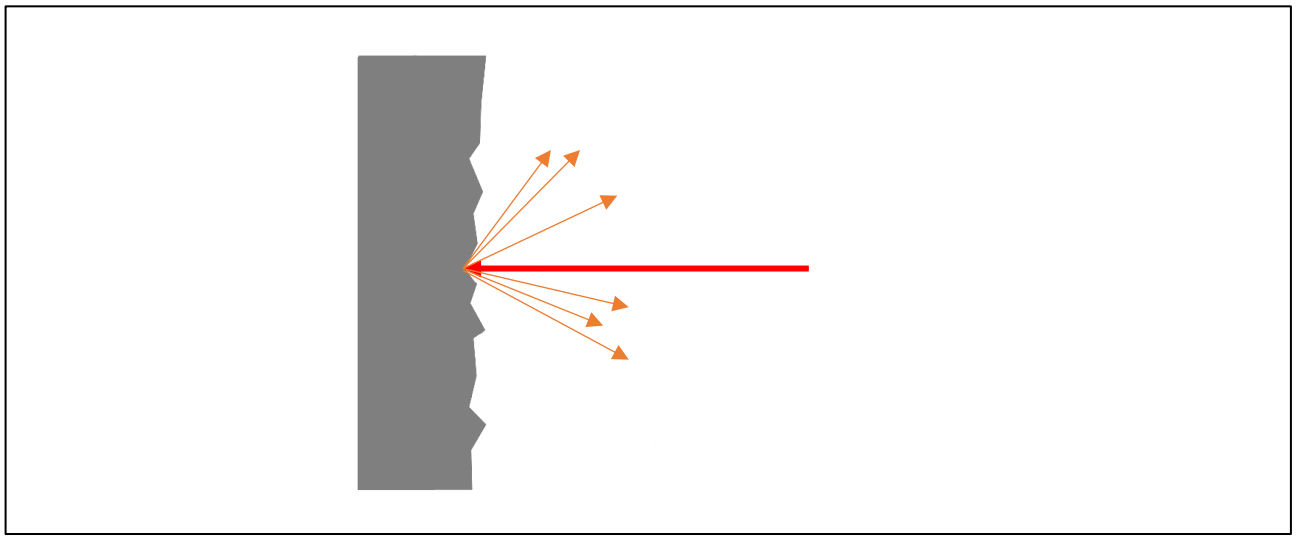

Figure 3 Reflection of the laser beam at the surface of an object

The reflection of the laser beam will vary as a function of the surface structure and color. Light surfaces reflect the laser beam better than dark surfaces and can be detected by the TF-UP01 over larger distances. Brilliant white plaster reflects approx. 100% of the incident light, black foam rubber approx. 2.4%. On very rough surfaces, part of the energy is lost due to shading. The detecting range of the TF-UP01 will be reduced as a result.

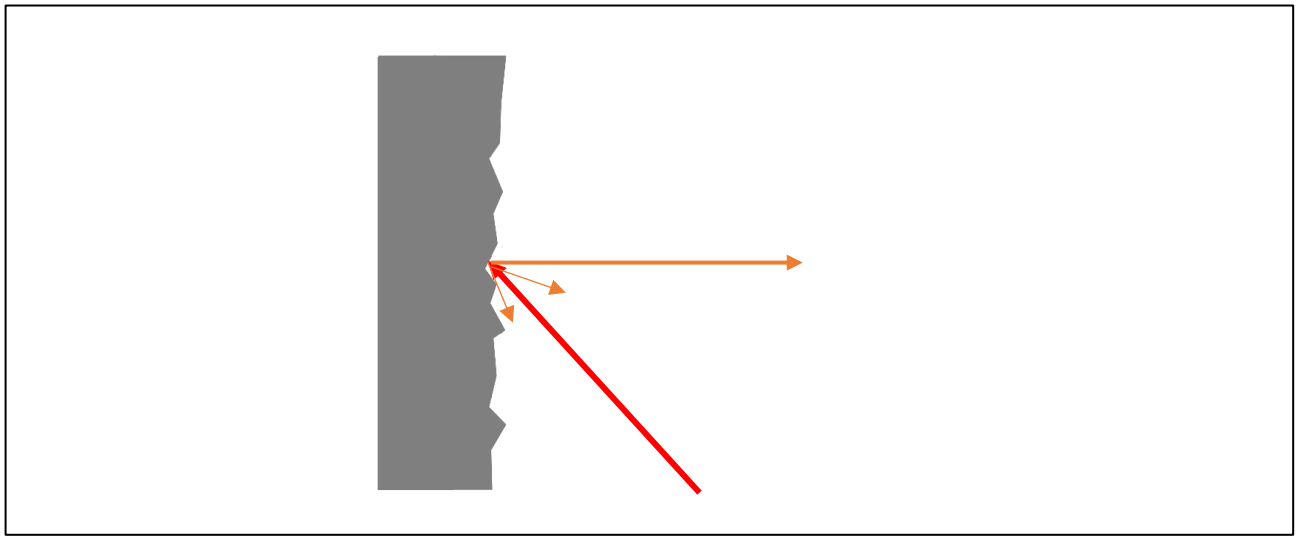

Figure 4 Reflection angle

The reflection angle is the same as the angle of incidence. If the laser beam is incident perpendicularly on a surface, the energy is optimally reflected (*Figure 4* on page 14). If the beam is incident at an angle, a corresponding energy and detecting range loss is incurred.

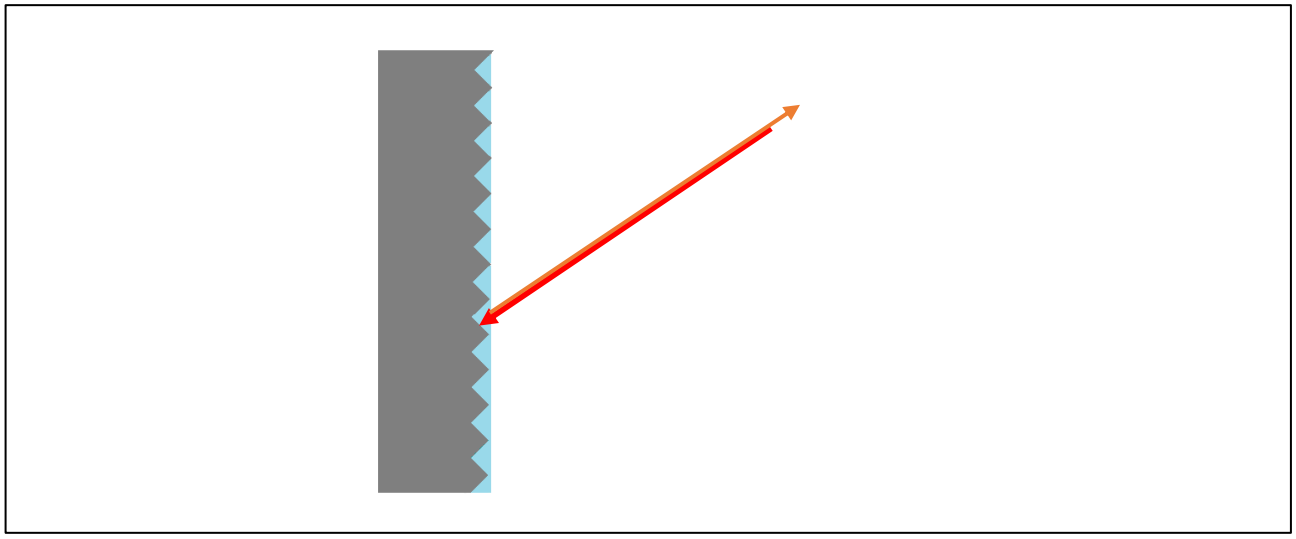

Figure 5 Degree of reflection

If the reflected energy returned is over 100% (basis: Kodak standard) the incident beam is not reflected diffusely in all directions, but is reflected in a specific direction. As a result, a large portion of the energy emitted can be received by the laser distance measurement device. Plastic reflectors (“cats’ eyes”), reflective tape and triple prisms have these properties.

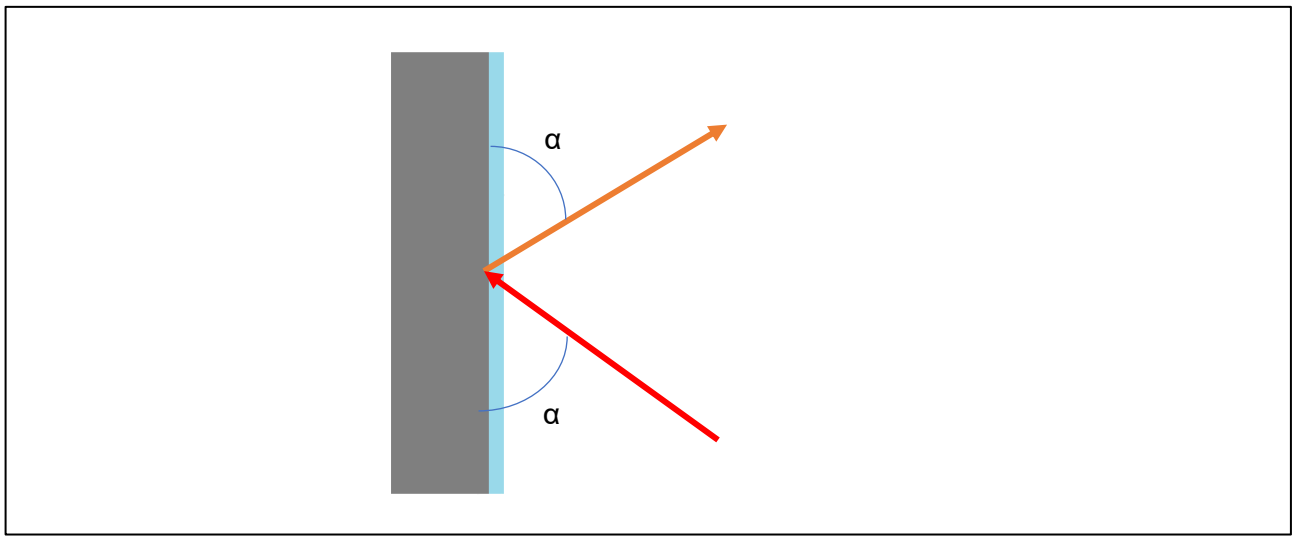

Figure 6 Mirror surfaces

At mirror surfaces the laser beam is almost entirely deflected (*Figure 6* on page 15). Instead of the surface of the mirror, it is possible that the object on which the deflected laser beam is incident may be detected.

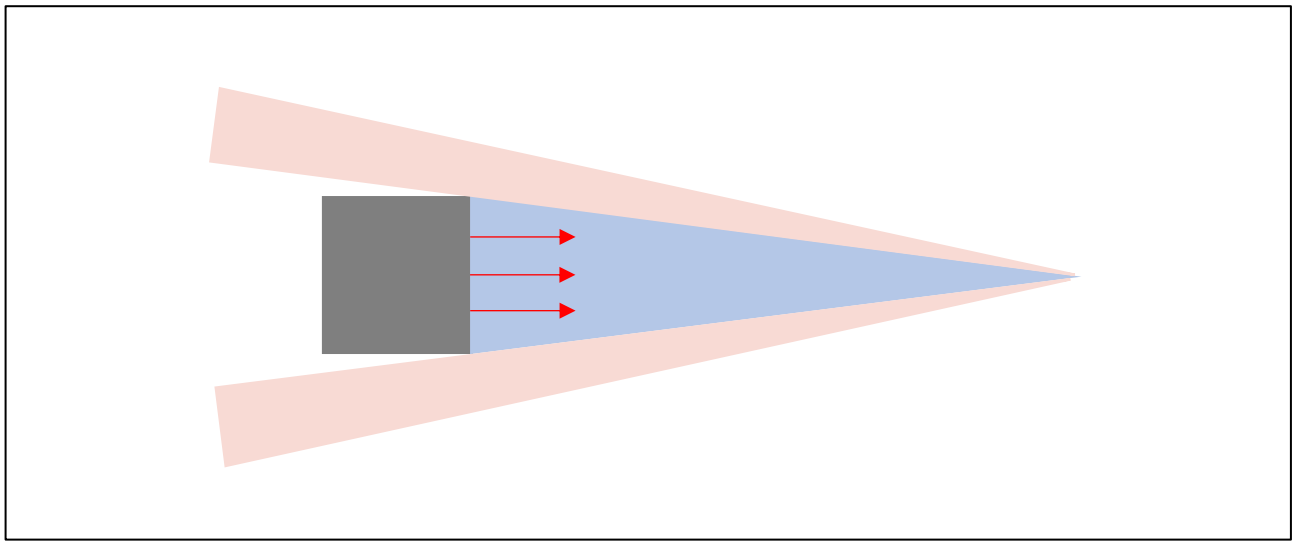

Figure 7 Object smaller than diameter of the laser beam

Objects that are smaller than the diameter of the laser beam cannot reflect all the energy of the laser light (*Figure 7* on page 15). The energy in the portion of the laser light that is not reflected is lost. This means that the detecting range is less than would be possible theoretically based on the surface of the object.

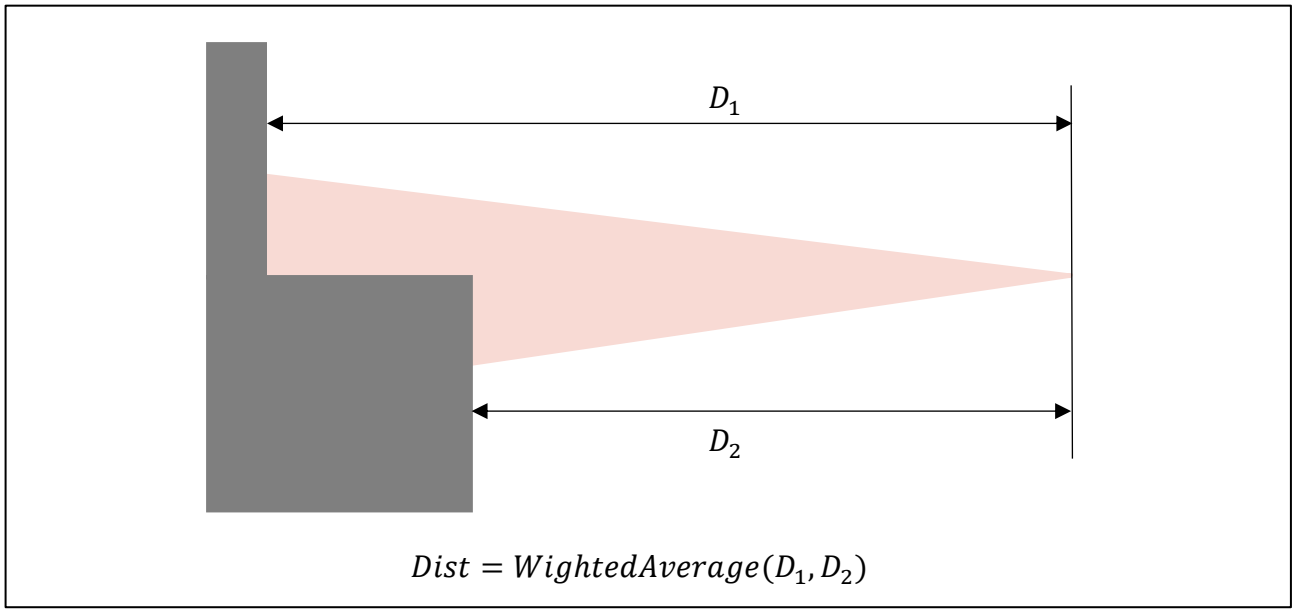

Figure 8 Staircase object

Staircase objects have two or more planes (*Figure 8* on page 16). The energy in the portion of the laser light that is reflected by different plane is different. TF-UP01 will calculate a weighted averaging energy. The measured value will possible theoretically be the weighted average of distances from TF-UP01 to different platform.

4 ELECTRICAL INSTALLATION

4.1 Pin and wire color assignment

“Power/Gnd” connection (SP-M8X-XXP-FF-SF7001-00A, 4pin).

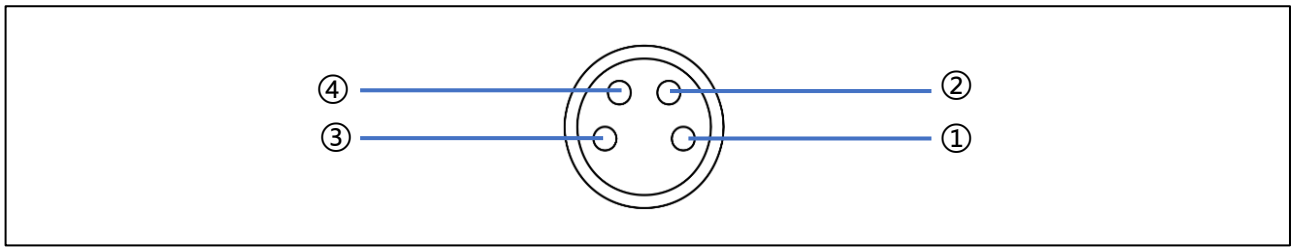

Figure 9 Female connector, SP-M8X-XXP-FF-SF7001-00A, 4pin

Table 2 Pin assignment on 4-pin female connector

Pin	Signal	Color of wire	Function
1	DC 8~30V	Black	Supply voltage
2		Blue	
3	GND	Brown	Ground
4		White	

“Data/Gnd” connection (SP-M8X-XXP-FF-SF7001-00A, 8pin).

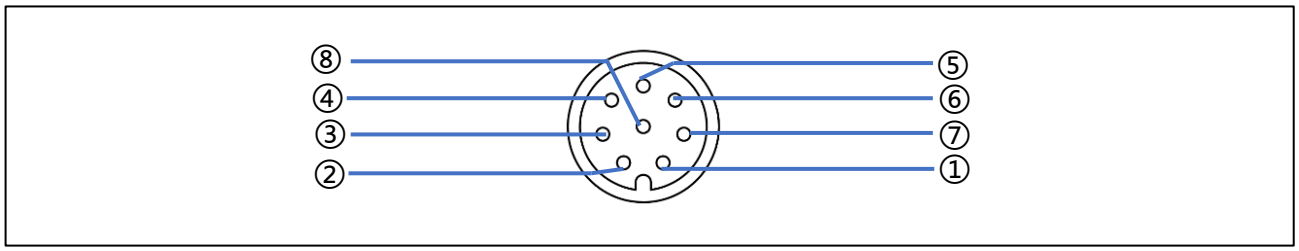

Figure 10 Female connector, (SP-M8X-XXP-FF-SF7001-00A, 8pin)

NOTICE

The interfaces, CAN and RS-485, are still under development.

Table 3 Pin assignment on 8-pin female connector

Pin	Signal	Color of wire	Function
1	GND	Brown	Ground
2	CAN_H	White	CAN-BUS High

3	CAN_L	Blue	CAN-BUS Low
4	RS-485-B	Pink	RS-485-B
5	RS-485-A	Gray	RS-485-A
6	UART_RXD RS-232_RXD	Black	UART and RS-232 receiver
7	UART_TXD RS-232_TXD	Green	UART and RS-232 transmitter
8	GND	Red	Ground

4.2 Wiring UART interface

By definition, UART is a hardware communication protocol that uses asynchronous serial communication with configurable speed. Asynchronous means there is no clock signal to synchronize the output bits from the transmitting device going to the receiving end.

A screened cable is required for the wiring of the UART interface.

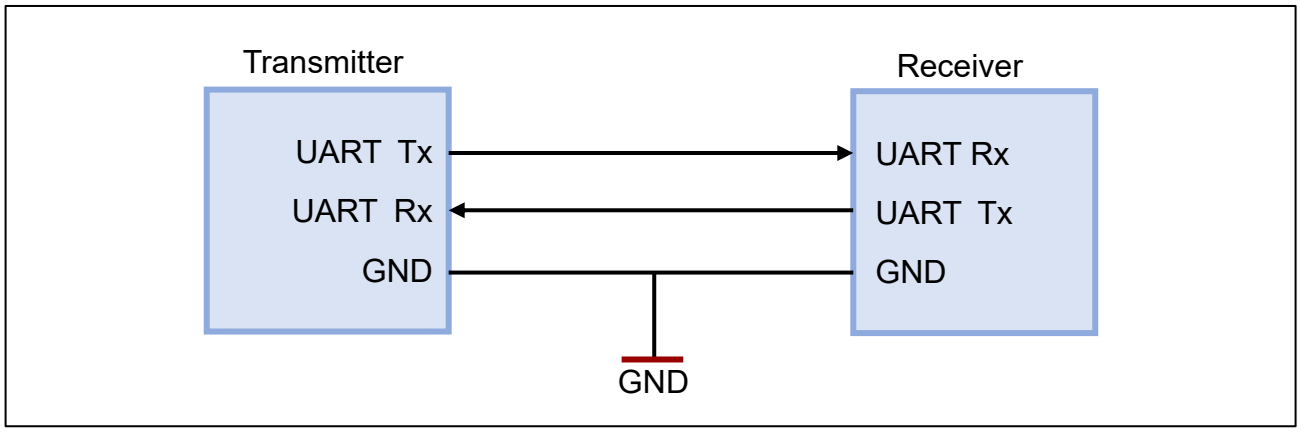

Figure 11 Wiring of the UART interface

NOTICE

To connect two devices for UART serial communication, the transmitter's TX should connect to the receiver's RX and the receiver's TX should connect to the transmitter's RX.

4.3 Wiring CAN interface

To wire the CAN interface a screened "twisted-pair" cable is required.

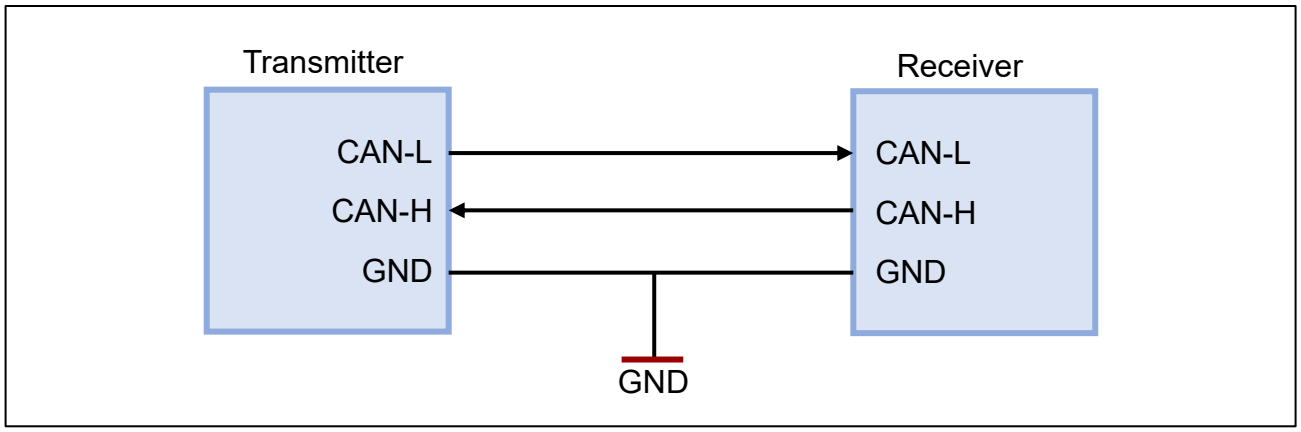

Figure 12 Wiring of the CAN interface

4.4 CAN Bus

Unlike a traditional network such as USB or Ethernet, CAN does not send large blocks of data point-to-point from one node to another under the supervision of a central bus master.

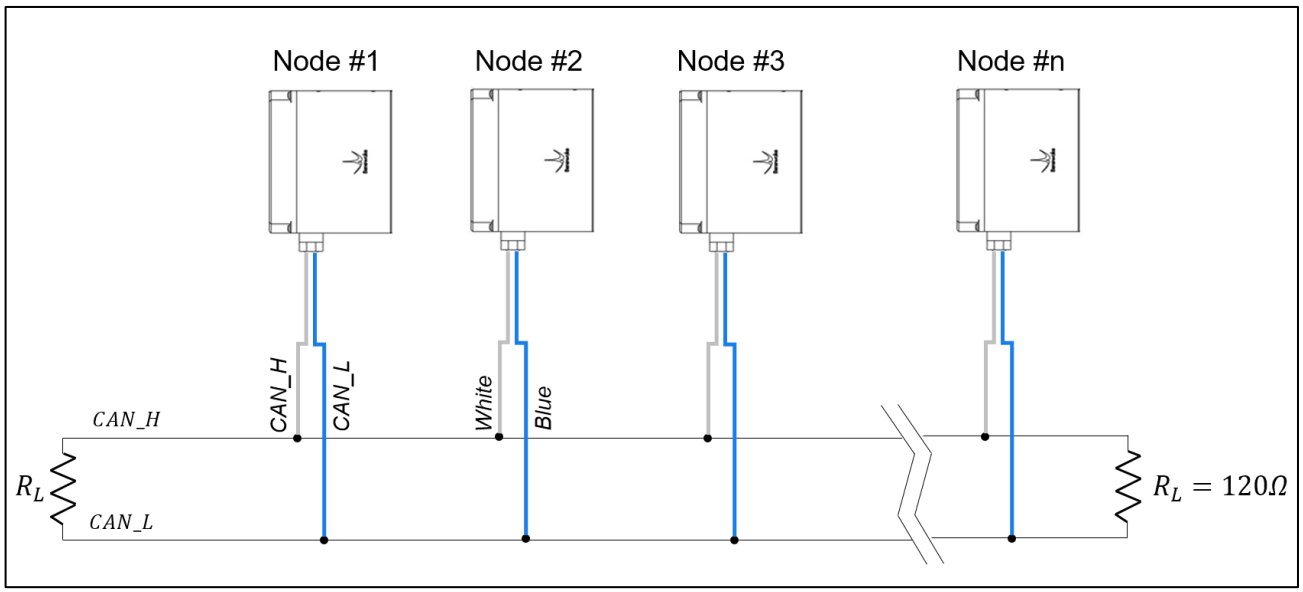

Figure 13 CAN networking of TF-UP01

The High-Speed ISO 11898 Standard specifications are given for a maximum signaling rate of 1 Mbps with a bus length of 40 m with a maximum of 30 nodes. It also recommends a maximum unterminated stub length of 0.3 m. The cable is specified to be a shielded or unshielded twisted-pair with a 120-Ω characteristic impedance (Zo). The ISO 11898 Standard defines a single line of twisted-pair cable as the network topology as shown in Figure 6, terminated at both ends with 120-Ωresistors, which match the characteristic impedance of the line to prevent signal reflections. According to ISO 11898, placing RL on a node must be avoided because the bus lines lose termination if the node is disconnected from the bus.

5 INTERFACES AND PROTOCOLS

The standard version of TF-UP01 supports four communication interfaces: UART, CAN, RS-232 and RS-485.

NOTICE

The interfaces, CAN and RS-485, are still under development. The related information will be updated with the release of CAN and RS-485.

5.1 Communication protocol

TF-UP01 supports UART (Universal Asynchronous Transmitter Receiver), the most common protocol used for full-duplex serial communication.

Table 4 Communication protocol detail of UART and RS232

Character	Value
Baud rate	115200
Data bit	8
Stop bit	1
Parity	None

5.2 Date frame

Each data frame which contains the distance and signal strength consists of 9 bytes of hexadecimal number.

Table 5 Data frame of TF-UP01

Bytes	0	1	2	3	4	5	6	7	8
Description	Frame header	Frame header	Distance			Reserved bytes			Checksum
Typical value	0x59	0x59	Low byte	Middle byte	High byte	0x00	0x00	0x00	Sum

6 CUSTOM CONFIGURATION

6.1 Protocol description

To meet the need of different customers, parameters can be set by yourselves. Parameters, such as data format, frame rate could be changed by sending command. Parameter will be stored in flash after configured successfully and customers don't need to configure again when restart.

Please change the parameter according to certain need and do not try irrelevant commands. Please configure the product according to the demands of the manual and never send unstated command.

Table 6 Description of TF-UP01 instruction protocol

Byte	Definition	Description
Byte 0	Header	Fixed to 0x5A
Byte 1	Len	The length of the entire instruction frame (unit: Byte)
Byte 2	ID	Identifies the function of each instruction
Byte 3~Byte N-2	Payload	Different meanings and lengths in different ID instruction frames
Byte N-1	Check sum	the lower 8 bits of the Len-1-byte data

6.2 Command protocols

Table 7 List of TF-UP01 command protocols

Description	Command	Response	Remark	Default setting
Obtain firmware version	5A 04 01 5F	5A 07 01 VA VB VC SU	The version is VC.B.A	/
System reset	5A 04 02 60	5A 05 02 00 61	/	/
Singe measurement trigger	5A 06 03 61	Data frame	/	/
Change frame rate to 10Hz	5A 05 04 01 64	Data frame at 10Hz	/	/
Change frame rate to 50Hz	5A 05 05 01 65	Data frame at 50Hz	/	/

Output control	On: 5A 05 07 01 67 Off: 5A 05 07 00 66	Same as command	/	Enabled
Laser switch	On: 5A 05 0A 01 6A Off: 5A 05 0A 00 69	Same as command	/	/
Modify baud rate	5A 08 06 H1 H2 H3 H4 SU	Same as command	See chapter 6.3Command editing	115200
Save settings	5A 04 0B 69	5A 05 0B 00 69	same as above	/

WARNING

Do not send the command that is not in the list above.

NOTE

Baud rate of UART can be set to 9600, 14400, 19200, 38400, 56000, 57600, 115200, 128000, 230400, 256000, 460800, 500000, 512000, 600000, 750000, and 921600. If other value were set, TF-UP01 will set it to 115200.

6.3 Command editing

The Command Channel is used to read and update a selected set of device parameters. This section describes the Command Channel from a generic point of view. The Command Channel is available via all of the device interfaces: UART, CAN. There are differences depending on the possibilities each interface provides. The differences are described in the chapters about each interface.

To send command with certain parameter to TF-UP01, follow these steps to generate command:

- Confirm the ID and the length of the command
- Convert decimal parameter to hexadecimal
- Fill the hexadecimal parameter into the command in little endian mode
- Calculate the sum of all the bytes of the command except the last byte, take the low 8-bit of the sum and fill it into the last byte of the command

For example, changing the baud rate to 460800. Firstly, find the command ID and length from *Table 7 List of TF-UP01 command protocols*. Secondly, convert 460800 to hexadecimal which is ***0x00 07 08 00***. Thirdly, fill hexadecimal parameter into the command, ***5A 08 06 00 08 07 00 SUM***.Finally, calculate the sum of the first 7-bytes of the command, and fill the low

8-bit of the sum into the last byte of the command, which is ***5A 08 06 00 08 07 00 77***.

7 QUICK START GUIDE

7.1 Connection

- Download the latest version **BW_TFDS** from http://en.benewake.com/support onto your PC or laptop.

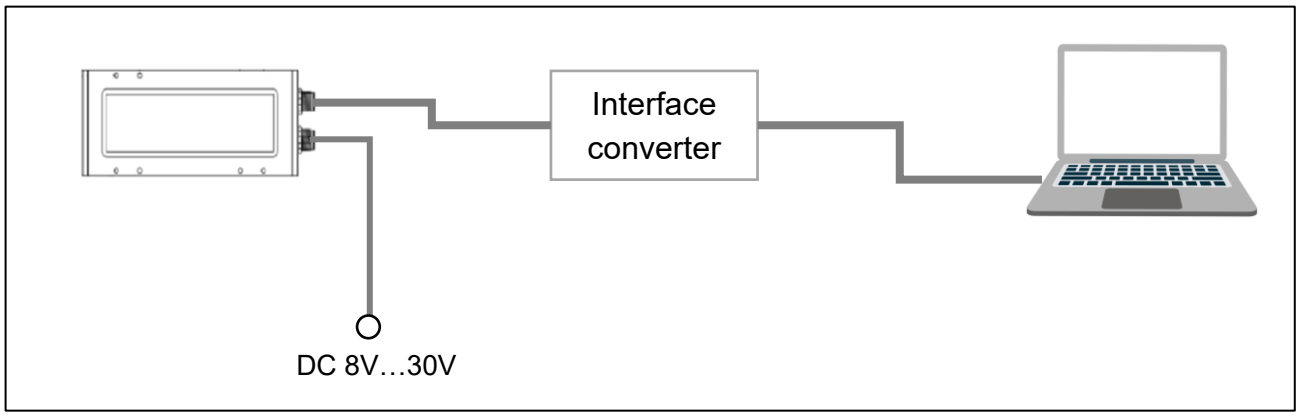

Figure 14 TF-UP01 connection to PC

- Connect TF-UP01 to the PC or laptop with a **paired USB converter** as shown in *Figure 14 TF-UP01 connection to PC*. The UART version TF-UP01 needs a UART-USB converter, and the CAN version TF-UP01 needs a CAN-USB converter.

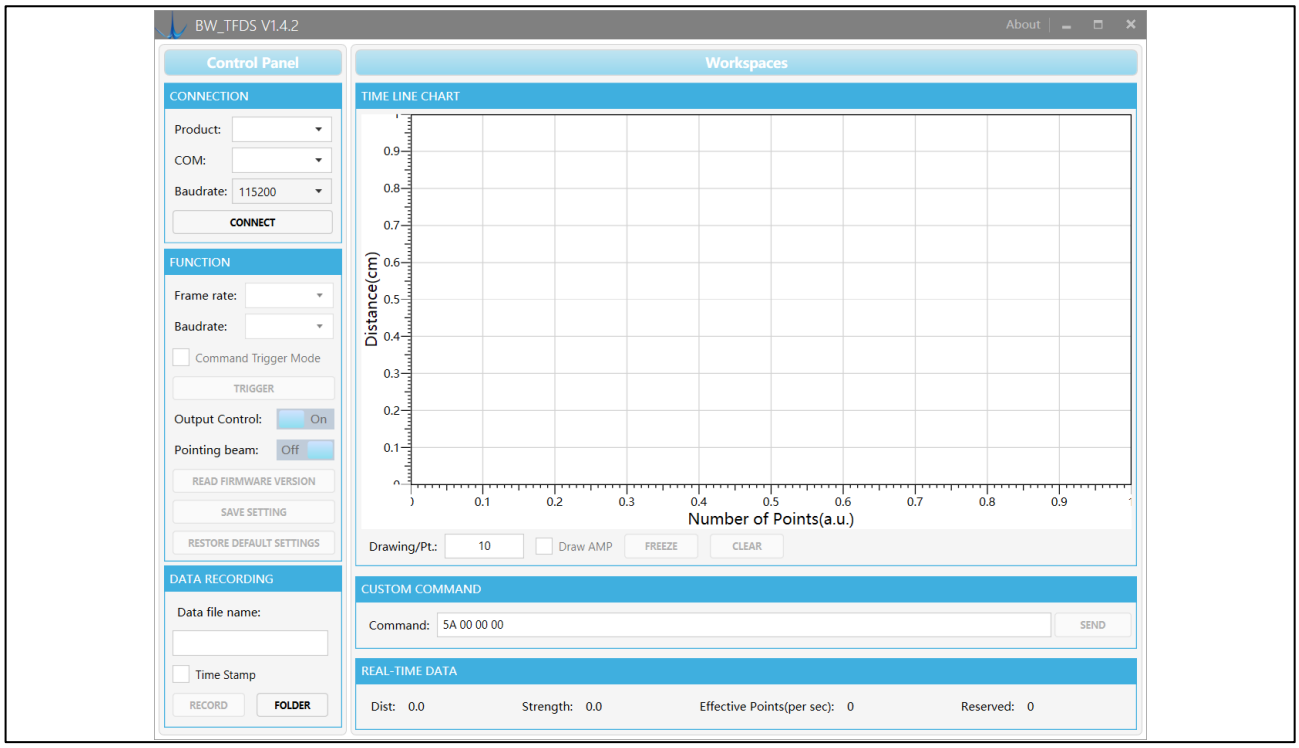

Figure 15 GUI of TF-UP01

- Run **BW_TFDS.exe**, choose the right baud rate and communication port, and click **CONNECT** to start the test. See *Figure 15 GUI of TF-UP01*. The GUI supports several commonly used functions, like changing baud rate, switching on/off pointing beam.

NOTICE

The product package contains only TF-UP01. If you need USB converter, please contact sales or technical support.

7.2 Measuring modes

TF-UP01 has three different measuring modes, invisible continuous measuring mode, visible continuous measuring mode and visible trigger measuring mode.

- Invisible continuous measuring mode. Only measuring beam which is invisible is enabled. This mode only supports 10Hz output. Follow the following steps to enable this mode:
  - Follow the instructions in *7.1 Connection*. Connect TF-UP01 to PC or other control systems.
  - Send the command **Change frame rate to 10Hz** listed in *Table 7 List of TF-UP01 command protocols* to enable the mode.
- Visible continuous measuring mode. The pointing beam which is a visible red beam needs to be enabled. This mode can support 10Hz and 50Hz output. Follow the following steps to enable this mode:
  - Follow the instructions in *7.1 Connection*. Connect TF-UP01 to PC or other control systems.
  - Switch on the pointing beam the command **Laser switch** listed in *Table 7 List of TF-UP01 command protocols*.
  - Send the command **Change frame rate to 10Hz** or **Change frame rate to 50Hz** listed in *Table 7 List of TF-UP01 command protocols* to enable the mode.
- Visible trigger measuring mode. The pointing beam which is a visible red beam needs to be enabled. TF-UP01 measures only when it receives the triggering command.
  - Follow the instructions in *7.1 Connection*. Connect TF-UP01 to PC or other control systems.
  - Switch on the pointing beam the command **Laser switch** listed in *Table 7 List of TF-UP01 command protocols*.
  - Send the command **Singe measurement trigger** to trigger measurement.

NOTICE

Currently, the TF-UP01 only supports the listed three measuring modes. More

measuring modes are under development. For more information, updates and useful links, please visit our website http://www.benewake.com/.

8 TROUBLESHOOTING

NOTICE

Claims under the warranty rendered void!

The housing screws of the TF-UP01 are sealed. Claims under the warranty against Benewake will be rendered void if the seals are damaged or the device opened. The housing is only allowed to be opened by authorized service personnel.

This chapter describes how to identify and rectify errors and malfunctions during the operation of TF-UP01.

Table 8 Troubleshooting and rectification

Fault	Possible cause	Solution
Measurement exceeds the allowed error.	Optical signal was blocked.	Remove the obstacle or adjust the detecting direction.
	The target is a low reflectivity object.	Paste a reflector on target object.
Measurements in the near range with no measurement target.	Contaminated or scratched window.	Carefully clean optics using soft, fluff-free cloth. If the optics are scratched, contact Benewake service.
TF-UP01 is not transmitting a measured result.	Wiring fault in the data connection.	Check wiring.
	Wrong USB converter.	Check USB converter.
Data transmitted is garbage.	Baud rate mismatch.	Check baud rate of the receiving device. Check TF-UP01's baud rate setting.
A certain target cannot be detected	The target is too small.	Replace it with a larger target.
	The target is of low reflectivity.	Paste a reflector on target object.

9 ANNEX

9.1 Reflectivity of Different Materials

The reflectivity of different materials is listed below, ranging from low to high. According to the test target and the corresponding reflectivity, we can measure whether the range of TF-UP01 and other parameters meet the requirements.

No.	Materials	Reflectivity
1	black foam rubber	2.4%
2	black cloth	3%
3	black rubber	4%
4	Coal (varies from coal to coal)	4~8%
5	Black car paint	5%
6	Black paper	10%
7	opaque black plastic	14%
8	Clean rough board	20%
9	translucent plastic bottles	62%
10	packing case cardboard	68%
11	Clean pine	70%
12	opaque white plastic	87%
13	white card	90%
14	Kodak standard whiteboard	100%
15	Unpolished white metal surface	130%
16	Shiny light metal surface	150%
17	stainless steel	200%
18	Reflective board, reflective adhesive tape	>300%