Copyright

Document name	ChotestLaser SJ6000 User manual
Document No.	QW-YF-SJ6000-032
Software version	V3.0
Model	SJ6000
Scope	Introduction of ChotestLaser software application and the alignment of optical sets, for user reference.

Introduction

This manual introduces the ChotestLaser software interface and operation and provides the information about safety precautions.

Please read this manual carefully before use in order to make the best use of the instrument.

You can preserve this manual for future reference.

Conventions Used in the Manual

The symbols below are used for important information.

Danger	Indicates the failure to follow the instruction will result in personal injury or death.
Warning	Indicates the failure to follow the instruction may result in personal injury or death.
Caution	Indicates the failure to follow the instruction may result in personal minor or moderate injuries.
Notice	Indicates the failure to follow the instruction will result in damage to the product or property damage.
Important	Indicates the rules and restrictions you must comply with during operation.
Point	Indicates the information you need to pay attention to for a better use.
Reference	Indicates the keys for a better use and understanding of related information.
	Indicates the page number in this manual or other document.

Notice

✦ The information contained herein is subject to change without notice.

✦ If you find any problem in this manual, such as unclear description, omission of content and errors etc., please contact our after sales.

✦ If there is missing page or binding error in this manual, we will provide you with a new one.

ChotestLaser software license agreement

We will provide ChotestLaser SJ6000 software on condition that you agree and accept the terms below.

Please read these terms below carefully before using the software.

By using the software, you agree the statement herein and accept this agreement.

License terms

User notice: please read this software license agreement (”Agreement”) carefully. By using the whole or part of the ChotestLaser SJ6000 software (”Software”), you agree to be bound by the terms and conditions of this Agreement. If you do not agree the terms and conditions of this Agreement, do not use the Software.

1. Definitions

1.1 “Use” or ”using” means the access, installation, download, copying of the functions of the Software or the action of getting benefits from the Software.

1.2 The Software means the software and the related documents provided by Chotest Technology Inc.

2. Grant

Upon the compliance of all terms and conditions of this Agreement, Chotest Technology Inc. (”Chotest”) grants the user a nonexclusive, nonassignable and nontransferable right and license to install and use the Software on a computer. The user may make one copy of the Software only for backup or archival purpose.

3. Restrictions

3.1 The user shall not copy the whole or part of the Software for any other purposes except for backup.

3.2 The user shall not sell, distribute or upload the whole or part of the Software.

3.3 The user shall not adapt, alter, amend, modify, reverse engineer, decompile, disassemble or decode the whole or any part of the Software.

3.4 The user shall not rent out, rent or share the whole or part of the Software.

3.5 The user shall not directly or indirectly export the whole or part of the Software without authorization by related government.

4. Chotest owns all rights of the Software.

5. Chotest grants the user the license of the Software according to the “status quo” and does not provide any form of guarantee. Chotest and its distributors are not responsible for the damages, compensations, charges or any other profits loss caused by using the Software by the

user under any conditions.

6. Termination

6.1 The user rights under this Agreement will terminate automatically if the user keeps any copy of the Software after destroying the Software or return the Software to Chotest.

6.2 The user rights under this Agreement will terminate automatically without notice from Chotest if the user fails to comply with any term(s) or restriction(s) of this Agreement. . Upon the termination of the Agreement, the user shall cease all use of the Software and destroy all copies, full or partial, of the Software.

6.3 The user shall pay Chostest for the cost and profit loss caused by the user failure to comply with any term(s) or restriction(s) of this Agreement.

7. Applicable law

7.1 This Agreement is governed by the laws of the People's Republic of China. If any provision of this Agreement is found to be invalid or unenforceable, the remainder of this Agreement shall continue in full force and effect.

Manual framework

This manual includes the introduction of hardware and software, the description of measurement operation and analysis, information about system setting and technical support and services and the appendix A about error compensation of machine tools.

Hardware introduction

The general introduction to ChotestLaser and the introduction of each hardware component.

| Chapter 1 | Hardware | Introduce the instrument and each hardware component. |

Software introduction

The description of software installation process and information about operation environment and basic functions.

| Chapter 2 | Static software | Introduce the software installation and the basic functions of static software. |
| Chapter 3 | Dynamic software | Introduce the basic functions of dynamic software. |

Measurement operation and results analysis

The description of the software operation and the application and alignment of every optics kit

Chapter 4	Linear measurement and analysis	The alignment of optics kit for linear measurement, software operation and data analysis.
Chapter 5	Angular measurement and analysis	The alignment of optics kit for angular measurement, software operation and data analysis.
Chapter 6	Straightness measurement and analysis	The alignment of optics kit for straightness measurement, software operation and data analysis.
Chapter 7	Parallelism measurement and analysis	The alignment of optics kit for parallelism measurement, software operation and data analysis.
Chapter 8	Perpendicularity measurement and analysis	The alignment of optics kit for perpendicularity measurement, software operation and data analysis.

Chapter 9	Flatness measurement and analysis	The alignment of optics kit for flatness measurement, software operation and data analysis.
Chapter 10	Rotary axis measurement and analysis	The alignment of optics kit for rotary axis measurement, software operation and data analysis.
Chapter 11	Dynamic measurement and analysis	Dynamic measurement and analysis.

Product specifications

The parameters of each measurement module.

| Chapter 12 | Product parameters | Detailed product parameters |

Maintenance and technical support and services.

The storage and maintenance of the instrument and troubleshooting.and the information about software upgrade and the after-sales technical support.

Chapter 13	Maintenance	Introduce product storage and maintenance.
Chapter 14	Troubleshooting	Provide the information on common problems and the solutions.
Chapter 15	Software upgrade and technical support	Provide the information about the software upgrade and technical support.

Appendix A Error compensation of machine tools

The explanation of compensation of thread pitch, a case on Mitsubish 70 system.

| Appendix A | Error compensation of machine tools | Explain the error compensation of machine tools |

Contents

Chapter 1   Hardware
1.1 Instrument introduction

General

Laser interferometer uses the wavelength as a carrier to define the meter. The wavelength can be traced to national standard; so far, laser interferometer instrument is recognized as high precision and high sensitivity measuring instruments, widely used in high-end manufacturing.

ChotestLaser SJ6000 rolls the technology of optics, machinery, electricity and computer etc. into one. It uses 1)import high-performance He-Ne laser whose life span is up to 50,000 hours, 2)dual-longitudinal-mode laser thermal frequency stabilization technology which can output high precision and high accuracy, high anti-interference and stabilised laser for a long time, 3) the technology of high-speed interference signal acquisition, conditioning and subdivision which can achieve up to 4m/s measurement speed and nano-level resolution, 4)high precision and high accuracy environmental compensation unit which can be achieve the automatic compensation to wavelength and material, and 5)high-performance computer control system and software which supports Chinese, English and Russian with user friendly interface, guided operation process and simple record management mode.

FIGURE 1-1 CHOTESTLASER SJ6000

With distinguishing features of high accuracy and precision, quick measurement, high resolution in maximum measuring speed and large measurement range, you can measure linear length, angle, flatness, straightness, perpendicularity, parallelism and other geometric measures by applying different optical components. By using ChotestLaser SJ6000 dynamic measurement software, you can also perform the dynamic measurement and performance analysis of linear displacement, angle and straightness and analyse the displacement, velocity, eration, amplitude and frequency, e.g. Vibration analysis, dynamic performance analysis of ball screw guideway and response characteristic analysis of the drive system.

1.2 Product module

SJ6000 laser system contains various measurement modules, you can select different components according to the specific measurement requirements. The main optical kits are listed in the following figure; they are, from the left to the right, linear optical kit, angular optical kit, straightness optical kit, perpendicularity optical kit, flatness optical kit and the high precision automatic rotary table.

| Linear | Angle | Straightness | Perpendicularity | Flatness | Rotary Axis |
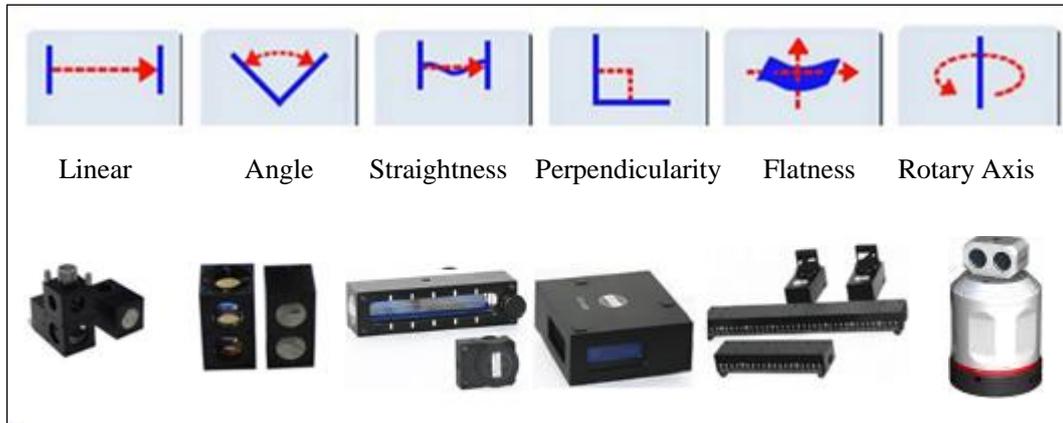
FIGURE 1- 2ALL OPTICAL KITS

The linear optical kit is the standard configuration, including linear interferometer, linear reflector and clamping base. It can be used to measure and analyse the positioning accuracy and repeatability and backlash of linear displacement machines and used for the backlash correction and pitch compensation.

1.3 Introduction of components

FIGURE 1- 3FULL SYSTEM CASE (FIXED LAYER)

FIGURE 1- 4FULL SYSTEM CASE (HAND-HELD LAYER)

备用孔座

激光器

Host machine
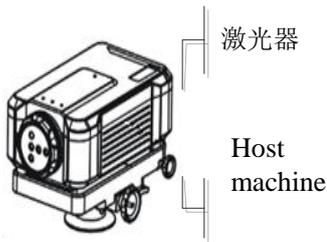
Laser: the basis of laser measuring system. It applies import helium neon laser, helium-neon laser with highly stabilized frequency stabilization, the thermal frequency stabilization technology of dual-longitudinal mode and high-precision laser interference signal processing system, achieving the high-precision control of laser frequency stabilization. It emits highly stable laser beam and the wavelength can be traced to national standards.

Tripod stage: connect tripod and hold laser; adjust the laser for quick alignment of laser beam. Translation adjustment range: 40mm; pitching adjustment range: $\pm 1.5°$; yaw adjustment range: $\pm 1.5°$.

Compensation device

Holder

Sensors
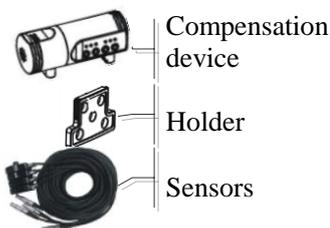
Environmental compensation unit: the key to the SJ6000 accuracy of measurement. Through the accurate measurement of environmental factors (temperature, air pressure and relative humidity) and the automatic update of data in every 7 seconds, it compensates for the laser wavelength, eliminating the measurement error caused by environmental changes.

The environmental compensation unit is connected with three material temperature sensors, which can accurately measure the temperature of the machine or material to be measured. The measured values can be normalized to the values in 20℃ by inputting the corresponding thermal expansion coefficient of the material in the measurement interface.

Interference prism
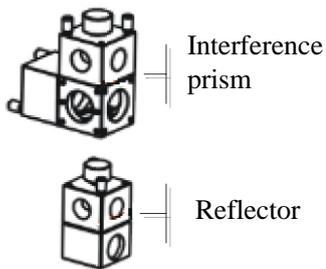
Reflector

Linear optical kit: consist of linear reflector for the measurement of positioning accuracy and repeatability.

Linear interferometer: combined by a beam-splitter and linear reflector.

Linear reflector: also known as corner cube, it can return an incident light beam in the opposite direction.

Note: the linear interferometer is set as the stationary component with the linear reflector as the moving component during linear measurement.

Interference prism
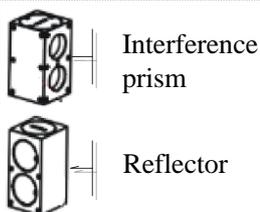
Reflector

Angular optical kit: consist of angular interferometer, angular reflector for small angle measurement.

Angular interferometer: with two optical faces, one has one aperture for incident beam; the other has one aperture for outgoing beam.

Angular reflector: consist of two corner reflectors.

Note: the angular interferometer is set as the stationary

component with the angular reflector as the moving component during angular measurement.
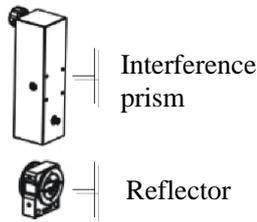
Interference prism Reflector	**Straightness optical kit:** consist of straightness interferometer, straightness reflector for straightness measurement. Straightness interferometer: split the incident bean into two beams which diverge at a small angle. The straightness interferometer and reflector are matched in pairs, you cannot interchange elements with other straightness kits. Each straightness interferometer and reflector is marked with a unique serial number. Note: the straightness interferometer is set as the stationary component with the straightness reflector as the moving component during straightness measurement.
Optical square Auxiliary block	**Optical square**: an important device used for perpendicularity measurement. It deflects the input beam through a precise 90°. The auxiliary block is used to mount the 90° veering prism on the optical square for the perpendicularity measurement of Z axis. It is used in conjunction with straightness optical kit to perform perpendicularity measurement.
Bases Turning prism	**Flatness optical kit**: consists of flatness bases and turning prisms; perform flatness measurement in conjunction with angular optical kit. Two flatness bases are available, one is 180mm long and 360mm long for the other one. The turning prism is used to align the laser beam in flatness measurement. The flatness optical kit is used in conjunction with angular optical kit to perform flatness measurement.
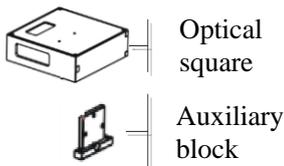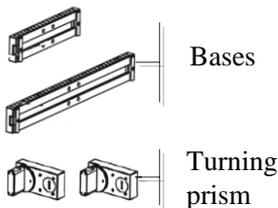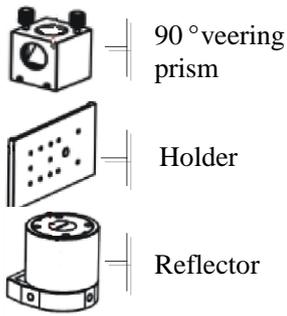
90 ° veering prism Holder Reflector	**Straightness accessories**: consists of 90 ° veering prism, straightness base, large retro-reflector used for the straightness measurement of Z axis. **Straightness base:** fix 90 ° tuning prism and straightness reflector. **90 ° veering prism:** deflect the laser beam at 90 ° and can slightly adjust the yaw and pitch of the laser beam. **Large retro-reflector:** fix the straightness interferometer to deflect the beam. It is the main component for Z axis straightness measurement.	
Interference prism Reflector	**Lightweight linear accessories**: consists of beam reducer and small retro-reflector, used in conjunction with linear optical kit. Small retro-reflector is 7g to 8g in weight, it can be magnetically attached onto machine under test and minimise the influence of the weight of the interferometer and its components during the measurement.	
Veering prism	Veering prism: deflect the horizontal laser beam through 25 ° at least, mainly applied in the measurement of a slant-bed lathe or coordinate measuring machine in combination with linear optical kit.	
三坐标 测头支具 Holders	Three-coordinate probe holder: the connectors have different threads, which can be screwed into the corresponding probe heads to fix the linear reflector. The hollow structure can reduce the influence of weight of the accessories on measurement to the greatest extent.	
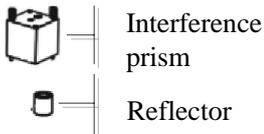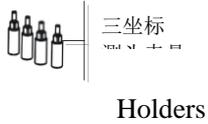
Static measurement software

2.1 Software installation

Software installation procedure
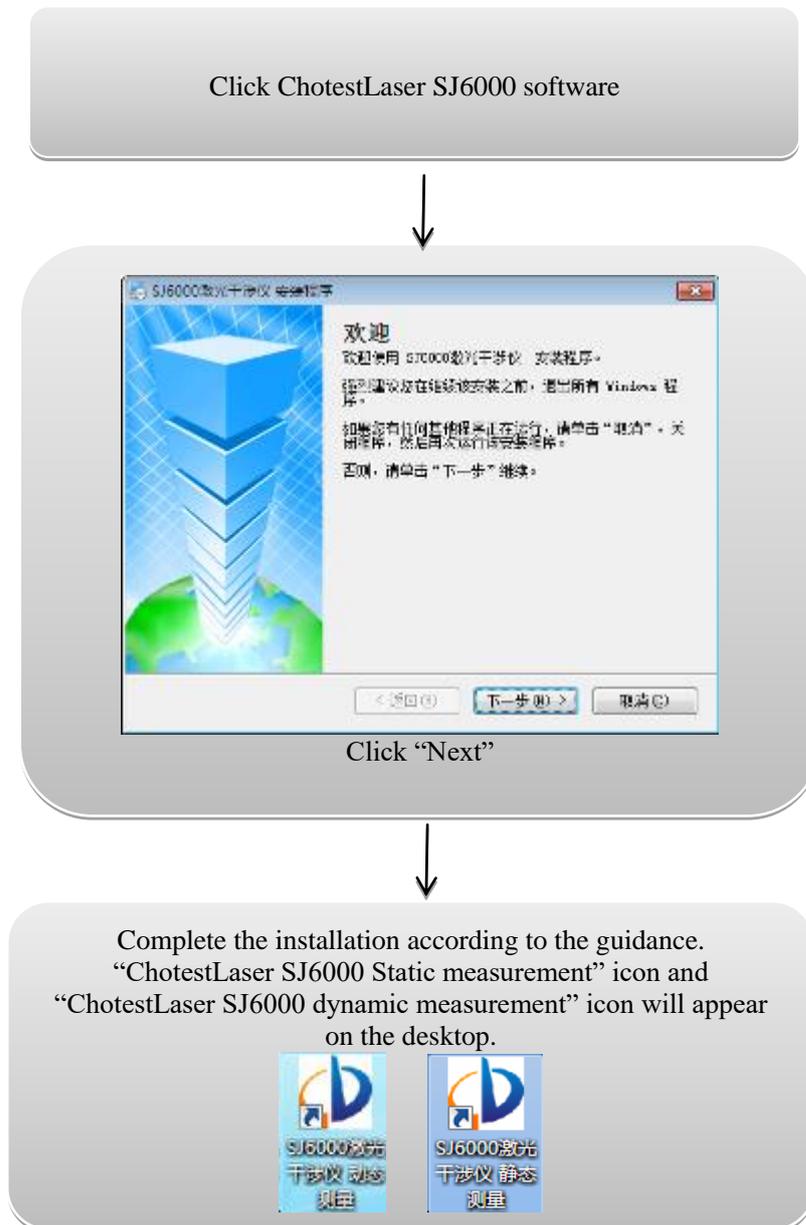
FIGURE2- 1SOFTWARE INSTALLATION PROCEDURE

After installation, two module icons, "ChotestLaser SJ6000 Static measurement" and "ChotestLaser SJ6000 dynamic measurement" will appear on the desktop, please select the correct one for measurement.

Device driver installation procedure

In most cases, the driver installation is required by automatic detection and the driver can be installed automatically. You can also install the driver by yourself, refer to the following steps.

In "Control panel", open "Device Manager", and then select SJ6000 devices

↓

↓

Click "Browse my computer for driver software", click "Let me pick from a list of device drivers on my computer", and then select the file according to the directory "SJ6000\USBDriver\win7\x86"

x86 signifies the 32-bit operating system.

x64 signifies the 64-bit operating system.

↓

↓

Select "Always install" if the security notification appears when installing the driver.

↓

This installation method applies to the installation of SJ6000-Main FX2 driver.

FIGURE2- 2DRIVER INSTALLATION PROCEDURE

2.2 Static software functions

Switch on the computer and double-click the "ChotestLaser SJ6000 static measurement" icon, a logon window will appear.

FIGURE2- 3 LOGON WINDOW

Select username, type password and then click "OK" to log on. If you just installed the software for the first time, no password is required for the user "Admin", you can directly click "OK" to log on.

📖 "System setting-User setting" (page 39)

After logging on, the main window will appear.
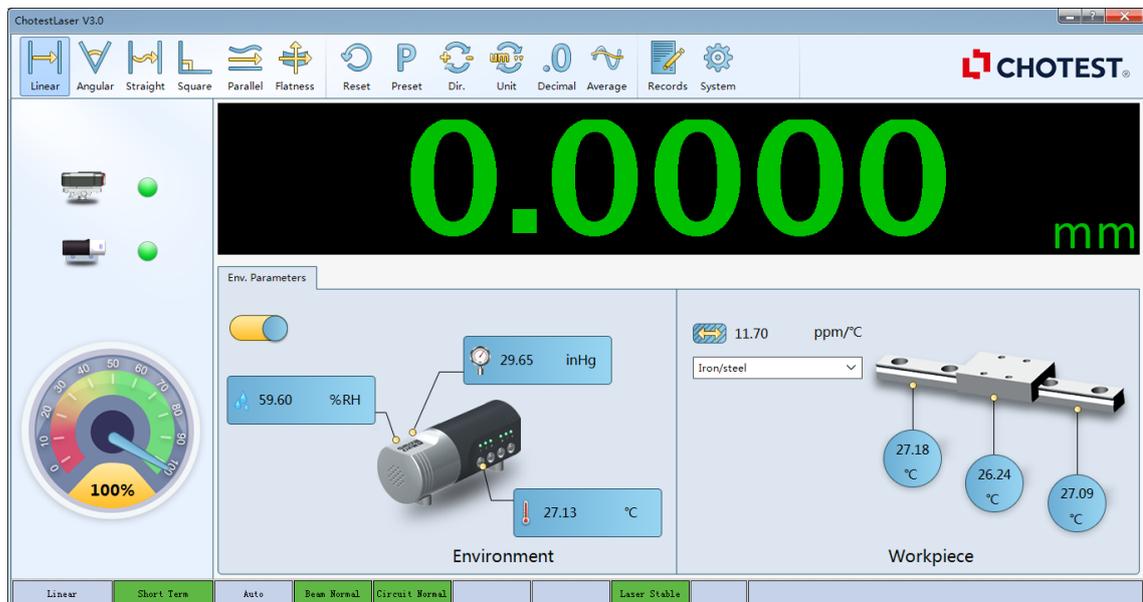
FIGURE2- 4MAIN WINDOW

The connection status indication is normal as the laser and the compensation unit are connected well.
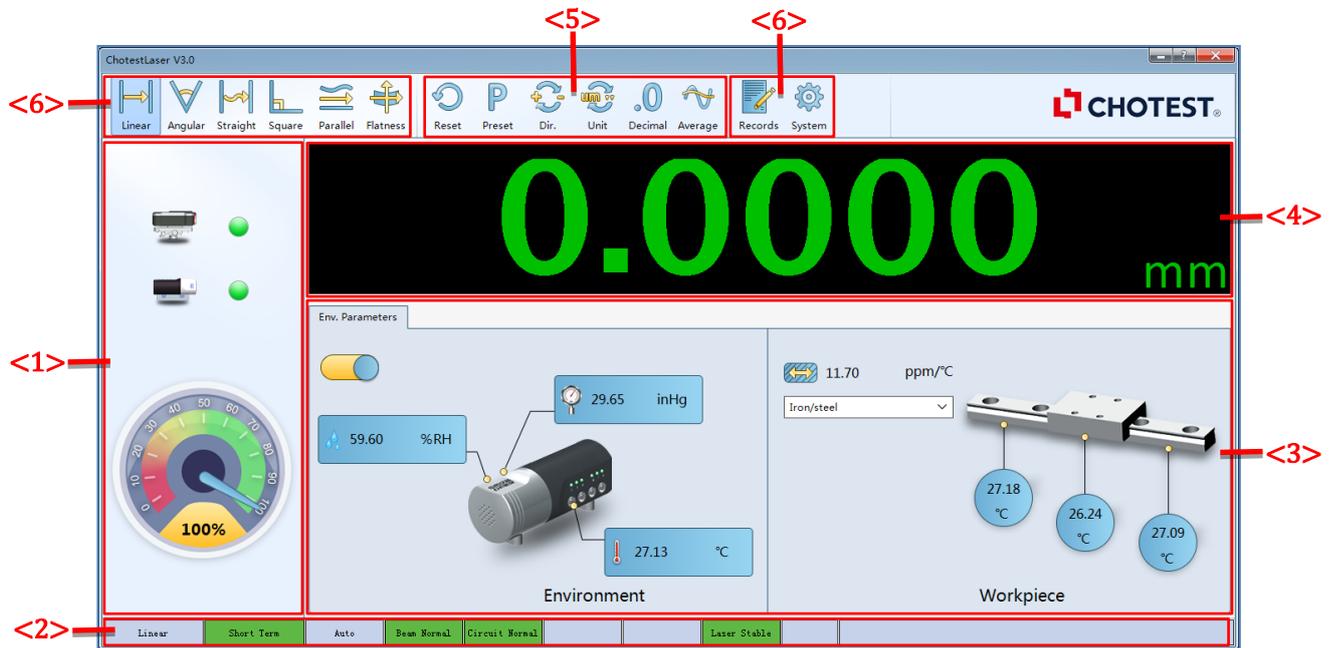
FIGURE2- 5MAIN WINDOW STRUCTURE

<1>Signal strength field

Indicate the device connection status and the current signal strength.

<2> Status bar

Display the current measurement mode and the measurement status.

<3> Environment window

Display the environment information and the workpiece information.

<4> Data display bar

Display the current measured value.

<5> Tools window

Set the measurement data displayed during measurement.

<6>Menu bar

Set the measurement type and the related information and system.

2.2.1 Signal strength field

The signal strength meter indicates the strength of laser beam signal. The higher the meter reading, the stronger the received laser beams.

Connection status: indicate the connection status of PC with the laser head and the environmental compensation unit.

2.2.2   Status bar

Linear	Short Term	Auto	Beam Normal	Circuit Normal			Laser Stable

FIGURE 2- 6STATUS BAR

Measurement mode: display the current measurement mode. For static measurement, linear measurement, angular measurement, straightness measurement, perpendicularity measurement, parallelism measurement, flatness measurement and rotary axis measurement, 7 modes in total, are available. You can click the button to switch measurement mode.

Averaging type: provide a way of overcoming fluctuations in environmental parameters (such as vibration, poor machine stability, or other external effects). If you find that the measurement display fluctuates because of these conditions, especially when the display is configured to use its full digit resolution, you may want to switch averaging on before starting to capture data. Three averaging types are available: No averaging, short term averaging, long term averaging. You can select the averaging type according to your requirement.

Compensation mode: display environment compensation mode, either the manual compensation or the automatic compensation.

Beam strength: display either "Beam Normal" or "Beam Obstructed". The measurement should be made when it displays "Beam Normal".

Circuit status: display the circuit status.

Laser status: display "Preheating" or "Stabilizing" or "Stable".

It displays "Preheating" when the laser is switched on, and then "Stabilizing" after preheating and finally it displays "Stable" when the laser beam is stable.

2.2.3   Environment window

The environment window consists of compensation mode, air parameters and workpiece parameters.

Compensation mode: composed of automatic compensation mode and manual compensation mode.

"ON" status means the automatic compensation mode is turned on. The software will automatically capture the related information monitored by the environment compensation unit.

"OFF" status means the automatic compensation mode is turned off, it is in manual compensation mode.

Air parameters: include air temperature, relative humidity and air pressure.

Workpiece parameters: include the material temperature (three temperature points) and the material type. Different material types have different thermal expansion coefficient.

2.2.4   Data display bar

Display the measured value. In normal measurement, the background colour is green and red when the beam is obstructed or not aligned and a lock icon will appear in the upper right corner. Double-click the display bar can enter full-screen display mode.

FIGURE2- 7FULL-SCREEN DISPLAY

2.2.5   Tools window

	Reset the data, keyboard shortcut: Ctrl+C When there is no pre-set value, this command is equivalent to zeroing, otherwise it will reset the value to "a" if "a" is the pre-set value.
	Set the current position displayed as the value "a", keyboard shortcut: Ctrl+P
	Switch the laser reading direction(switch between the plus and minus sign), keyboard shortcut: Ctrl+MIMUS SIGN(-)
	Switch the unit among mm, inch, minch and μm or among degree, μm/mm and arc minute in angular measurement, Keyboard shortcut: Ctrl+U.
	Open resolution dialog box which allows you to set the displayed decimal places, keyboard shortcut: Ctrl+R.
	Switch between averaging OFF, long term averaging ON and short term averaging ON, keyboard shortcut: Ctrl+A.

Note: other keyboard shortcuts.

Previous step: PAGE UP; next step: ENTER; Start: ENTER; unlock: Ctrl+W

2.2.6 Menu bar

Menu bar consists of linear measurement, angular measurement, straightness measurement, perpendicularity measurement, parallelism measurement, flatness measurement, rotary axis measurement, record management, system setting and rotary indexer.

Linear measurement

Click the "Linear" button to switch to linear measurement mode. Click it again to open the "linear measurement guide" window.
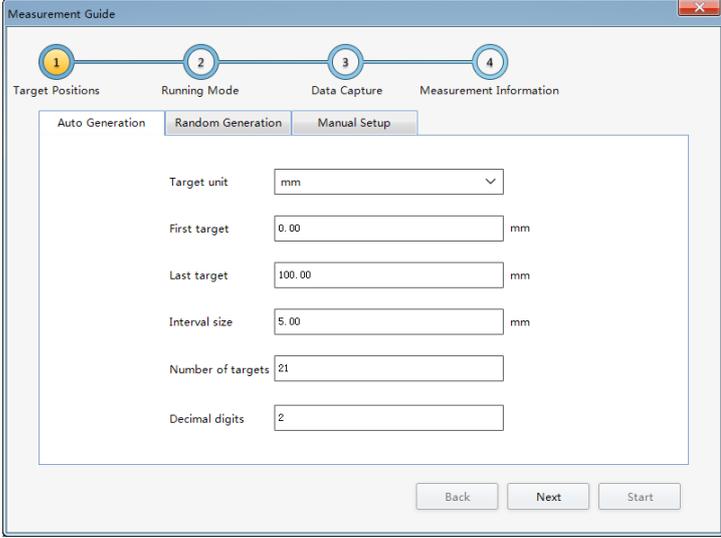
FIGURE2- 8LINEAR MEASUREMENT GUIDE

Target unit: select the desired unit form mm, inch, μm and minch.

Target generation type: three generation types are available. Example of the measurement range 0-400mm.

Automatic generation: automatically generate the target number by entering the first position, the last position and the interval size.
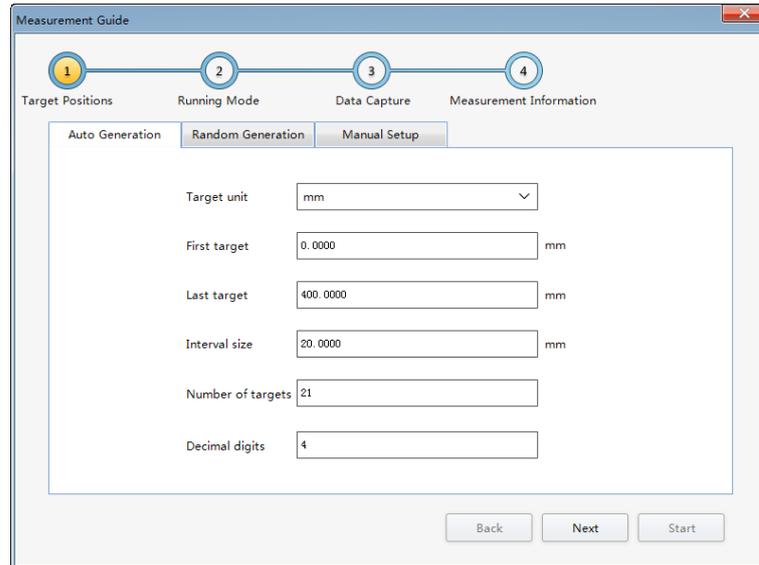
FIGURE2- 9LINEAR MEASUREMENT GUIDE-AUTOMATIC GENERATION

Random generation: similar with the automatic generation type, except the option of "Maximum random element"
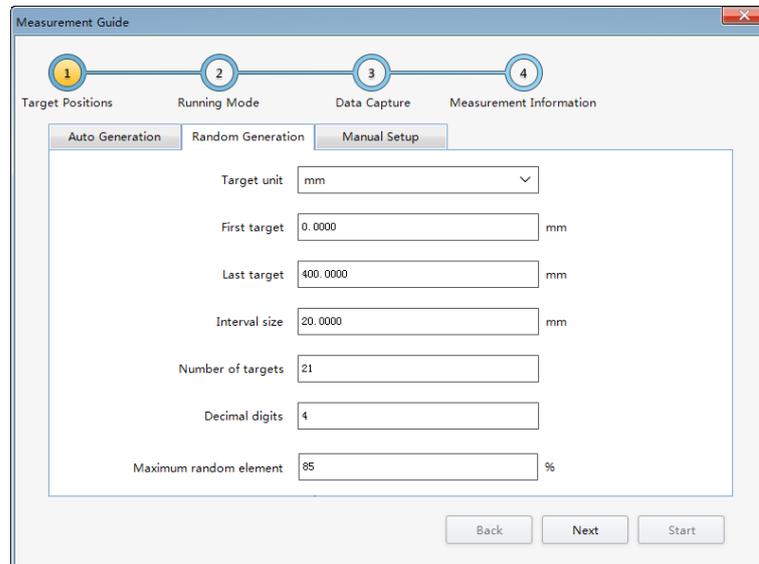
FIGURE2- 10LINEAR MEASUREMENT GUIDE-RANDOM GENERATION

Manual setup: allow you import target positions and modify them manually.
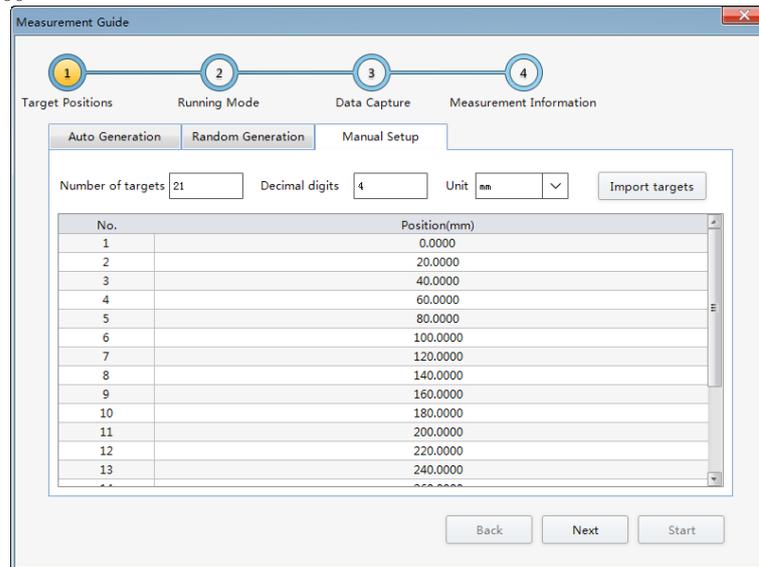
FIGURE2- 11LINEAR MEASUREMENT GUIDE-MANUAL SETUP

Click "Import targets" to import the automatically generated targets, double-click the row to modify the target position and then click in the blank space to save the modification.

\ Point In the "Measurement Guide" window, pressing ENTER cannot save the data but the shortcut for "Next" step.

After setting target positions, click "Next" to start the setting of "Run Mode".
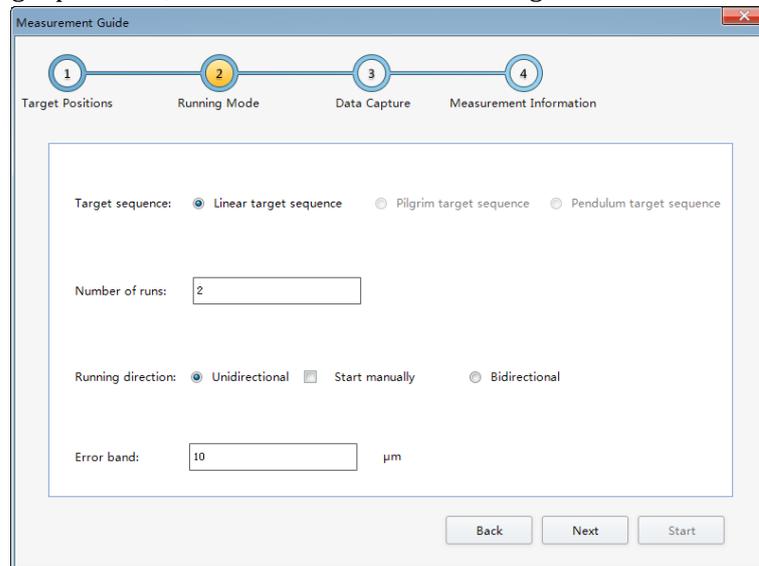
FIGURE2- 12LINEAR MEASUREMENT GUIDE-RUN MODE

Target sequence: select the one target sequence from linear target sequence, pilgrim target sequence, pendulum target sequence.

Unidirectional   Bidirectional

Linear target sequence		
Pilgrim target sequence		
Pendulum target sequence		
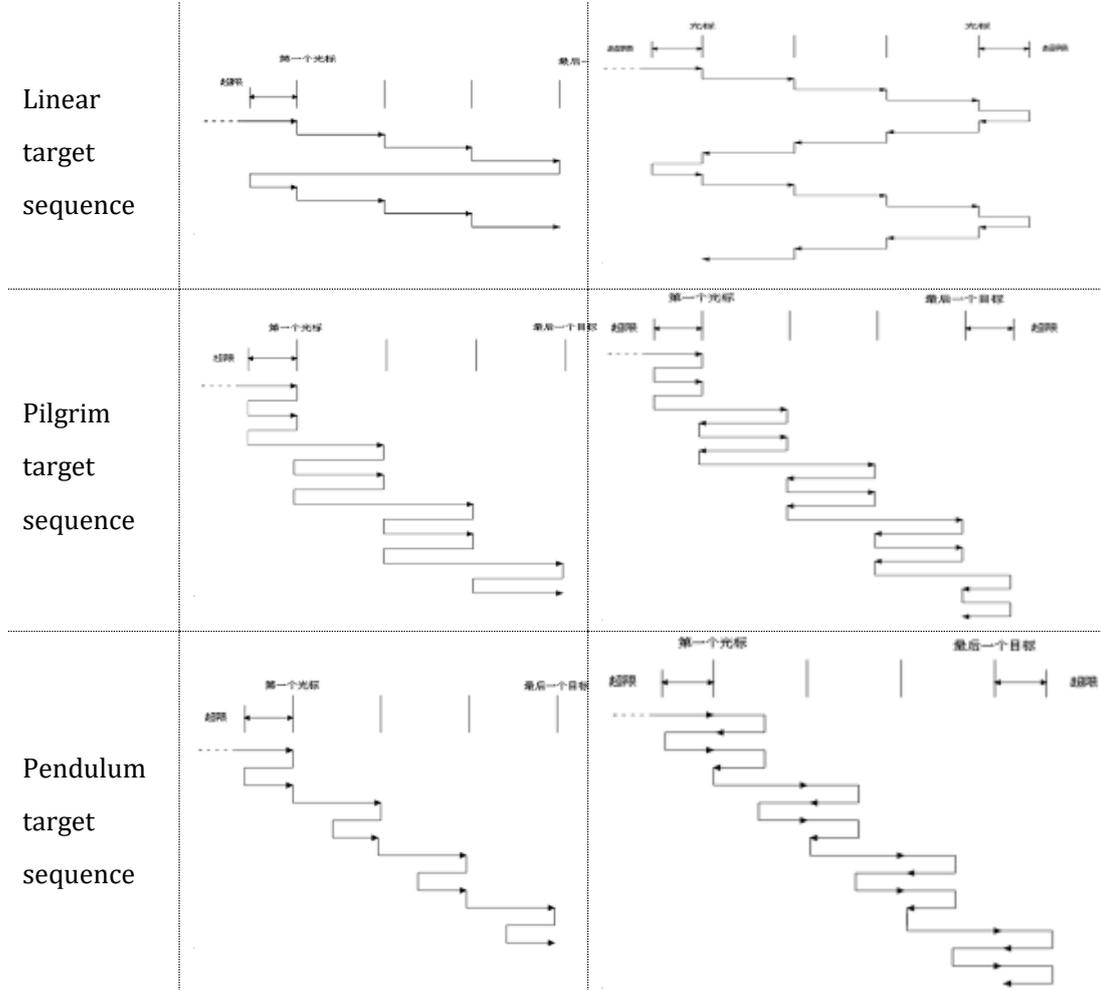
In general, the linear target sequence, bidirectional run are selected for measurement, the moving part will be moved towards each target from both directions. By this way, every target position will be measured two times each run in two directions (in the order of the forward direction and the backward direction). Repeat the same action several times to assess the reverse backlash, positioning accuracy and repeatability of positioning.

Number of runs: set the number of measurement times according to your requirements.
This parameter defines how many runs should be made through the targets.
The machine should visit each target several times to allow assessment of both the measurement and machine axis repeatability. If statistical analysis is to be performed on the results, it is usual to visit each target at least three-five times.

Running direction: set the running direction either unidirectional or bidirectional.
Bidirectional indicates the moving part will be moved towards each target from both directions. And this means that two readings of the moving part position at each target will be captured per run. A bidirectional run will show up the reversal error at each target position

because of the difference in the measured positions of a target on the forward and return runs. Unidirectional indicates the moving part will be moved towards each target from one direction. This type of run should not be used if you want to measure the amount of backlash for "reversal error". In unidirectional run, if you select "manual capture mode", you must click "Capture" to go on to the next capture process from the second target position.

Data capture: two types of automatic data capture are available, position-based capture and time-based capture.
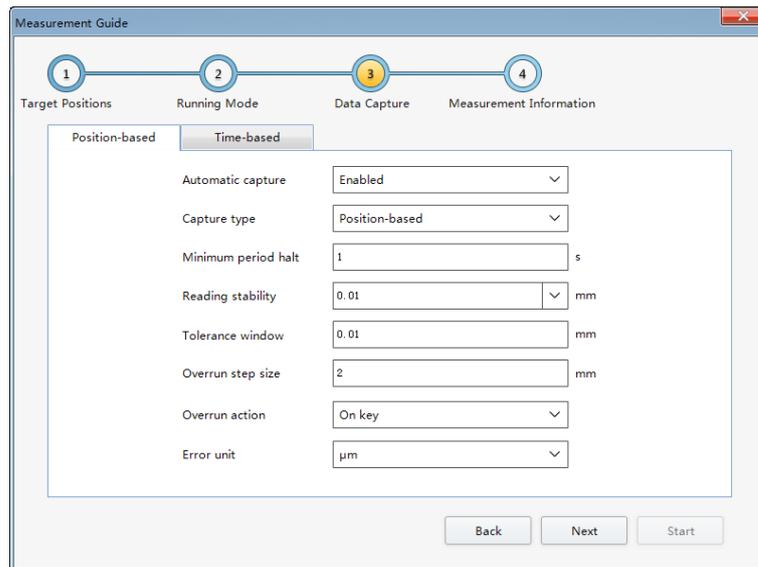
Figure2- 13Linear measurement guide-Data capture

(1) Automatic position-based capture

Position-based capture compares the laser reading with the target position and only records a reading when the machine is stationary within a defined distance (tolerance window) from the target and is stationary for a defined period (the minimum period halt within the stability of reading). Position-based capture is only used in the linear displacement measurement and the angular measurement of rotary axis. This is because the two mentioned measurement modes provide positional feedback from the machine allowing the software to determine if the machine has stopped and is at the correct position.

Please make sure the "Automatic capture" is set to "Enabled" and the "Capture type" is set to "Position" in the "Data Capture" dialog box.

FIGURE2- 14LINEAR MEASUREMENT GUIDE-POSITION-BASED CAPTURE SETTINGS

Minimum period halt: once the software detects that the laser reading has come to rest (i.e. the laser reading is stable within the limit specified) and the reading is within a certain tolerance (defined in the Tolerance window field) of the target position, it will wait for a certain period before taking a reading. This period is the "Minimum period halt".

This period may be set to any value between 0.10 and 9999999.00 seconds. During this period a progress bar will appear to indicate progress.

Reading stability: when a machine is nominally stationary, the laser reading will not necessarily be stable. This may be due to a variety of reasons that depend on the machine and its local environment. Therefore, for the software to be able to recognise that the machine has actually stopped, a "Stability of reading" value is required.

To set the required stability value, click "Reading stability" arrow to display the drop-down list and select or type the value which the laser reading changes cannot exceed between consecutive readings when the machine is stopped.
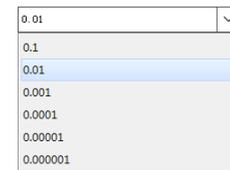
Tolerance window: if the laser reading is within this distance of either side of the target position (and stationary, as defined in "Minimum period halt" and "Stability of reading"), then a reading will be recorded.

Overrun action: "Overrun" is used to indicate the action of the software at the ends of the axis. It is important to ensure that backlash has been removed from the machine's motion when the machine turns around at the end of the axis.

The type of overrun expected is different for position-based capture and time-based capture. In position-based capture, the software will expect the machine moves beyond the last target by the distance specified in the "Overrun step size" field. The machine needs to be programmed to move beyond the step size, for long enough to allow the software to detect the move, and then return to the target position.

For a positive move, the step size is added to the target position, for instance, for a target position of 100 mm and an overrun step size of 1 mm, the machine should move to beyond 101 mm then back to 100 mm. For a negative move, the step size should be subtracted from the target position, for instance, for a target of -100 mm, the move should be to beyond -101 mm. If you do not want to use overrun, you can set "Overran step size" to zero.

Overrun step size	1	mm
Overrun action	On move ⌄	
Error unit	On key	
	On move	

The selection of "On move" means that the software expects to see the machine move past the end of the axis by the defined "Overrun step size" before moving to the first target of the return run. The selection of "On key" makes the software to wait for a keystroke before starting the next run.

▶Important For the setting of overrun step size in position-based capture, zero means no overrun will take place and the other set value must be smaller than the actual overran step size of the machine and the value in tolerance window field.

(2) Automatic time-based capture

In angular measurement mode and straightness measurement mode, the laser system does not provide the actual position information of the machine. Thus, all recorded errors are the absolute reading from the laser system.

You can pre-define a time period within which the data can be captured. This is time-based capture.

In time-based capture, the software can take readings at user-defined time intervals. In use, the machine under test is set to make a series of moves and dwell periods and the software is programmed to take a reading at a time interval equal to the combined move and dwell time, so that data would be recorded at the times when the machine was stationary. It should be noted that there is a danger of the machine and the laser getting out of step if the matching between the timings is not accurate.

Time-based capture can be used for detecting drift or creep or thermal growth.

In the "Data Capture" dialog box, ensure that the "Automatic capture" field is set to "Enabled", and then set the "Capture type" field to "Time-based".

FIGURE2- 15LINEAR MEASUREMENT GUIDE-TIME-BASED CAPTURE SETTINGS

> ▶Important   If the "Disabled" is selected in "Automatic capture", the data capture mode is in manual mode.

Overrun period: in time-based capture, "overrun" is specified as a time period, so that a different time period can be set for handling the end of the axis from that used for data capture. The software will wait for the defined period to expire before starting the next timed data capture run. If the "Timeout" is selected in "Overran action", the status bar will display "Overrunning..." when the software is waiting for an overrun to take place.

If the "On key" is selected in "Overran action", the status bar will display "Overrun on key, press SPACEBAR!" when the software is waiting for an overrun to take place, Press the SPACEBAR to complete the overrun action.

Measurement information: input the information related to the measurement.
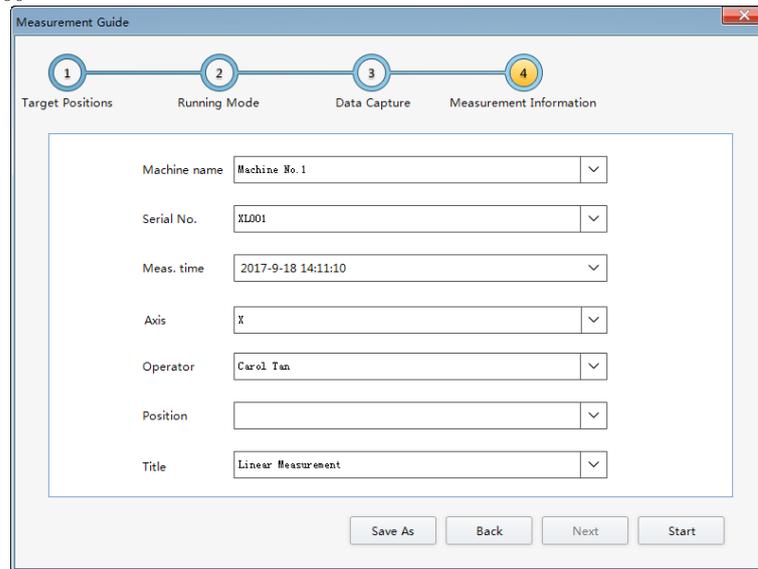
FIGURE2- 16LINEAR MEASUREMENT GUIDE-MEASUREMENT INFORMATION

Click "Start" to enter into measuring mode.

FIGURE2- 17DATA CAPTURE IN LINEAR MEASUREMENT

The software will automatically save the record and pop up the measurement results after the measurement is completed. For more information about record view and management, refer to "Record management"

📖 "Record management" (page 31)

Angular measurement

Click the "Angular" button to switch to angular measurement mode.
Click it again to open the "angular measurement guide" window.
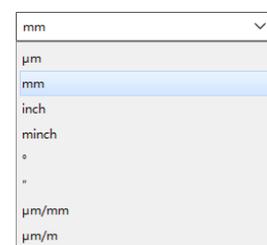
Target unit: select one unit type form mm, inch, μm and minch as length units or °, ″, °, ′, ″, and μm/mm as angle unit.

Data capture: two types of automatic data capture are available, position-based capture and time-based capture.

If the length unit is selected as the target unit, SJ6000 laser system can not capture the actual displacement of the machine under measurement, thus, only the time-based data capture and the manual data capture are available.

If the angular unit is selected as the target unit, both time-based capture and position-based capture are available.

The software will automatically save the record and pop up the measurement results after the measurement is completed. For more information about record view and management, refer to "Record management"

Straightness measurement

Click the "Straightness" button to switch to straightness measurement mode. Click it again to open the "straightness measurement guide" window.

Target unit: select one unit type form the length unit, mm, inch, μm and minch.

Data capture: as the length unit is selected as the target unit, SJ6000 laser system cannot capture the actual displacement of the machine under measurement, thus, only the time-based data capture and the manual data capture are available.

The software will automatically save the record and pop up the measurement results after the measurement is completed. For more information about record view and management, refer to "Record management"

Perpendicularity measurement

Click the "Perpendicularity" button to switch to perpendicularity measurement mode. Click it again to open the "perpendicularity measurement guide" window.

Target unit: select one unit type form the length unit, mm, inch, μm and minch.

Data capture: as the length unit is selected as the target unit, SJ6000 laser system cannot capture the actual displacement of the machine under measurement, thus, only the time-based data capture and

the manual data capture are available.

| **⟍ Point**	When you set up the two axes for perpendicularity measurement, you must take the travel of the two axes into consideration.

The software will automatically save the record and pop up the measurement results after the measurement is completed. For more information about record view and management, refer to "Record management"

📖 "Record management" (page 31)

Parallelism measurement

Click the "Parallelism" button to switch to parallelism measurement mode. Click it again to open the "parallelism measurement guide" window.

Target unit: select one unit type form the length unit, mm, inch, μm and minch.

Data capture: as the length unit is selected as the target unit, SJ6000 laser system cannot capture the actual displacement of the machine under measurement, thus, only the time-based data capture and the manual data capture are available.

⟍ Point	When you set up the two axes for parallelism measurement, you must take the travel of the two axes into consideration.

The software will automatically save the record and pop up the measurement results after the measurement is completed. For more information about record view and management, refer to "Record management"

📖 "Record management" (page 31)

Flatness measurement

Click the "Flatness" button to switch to flatness measurement mode. Click it again to open the "flatness measurement guide" window.
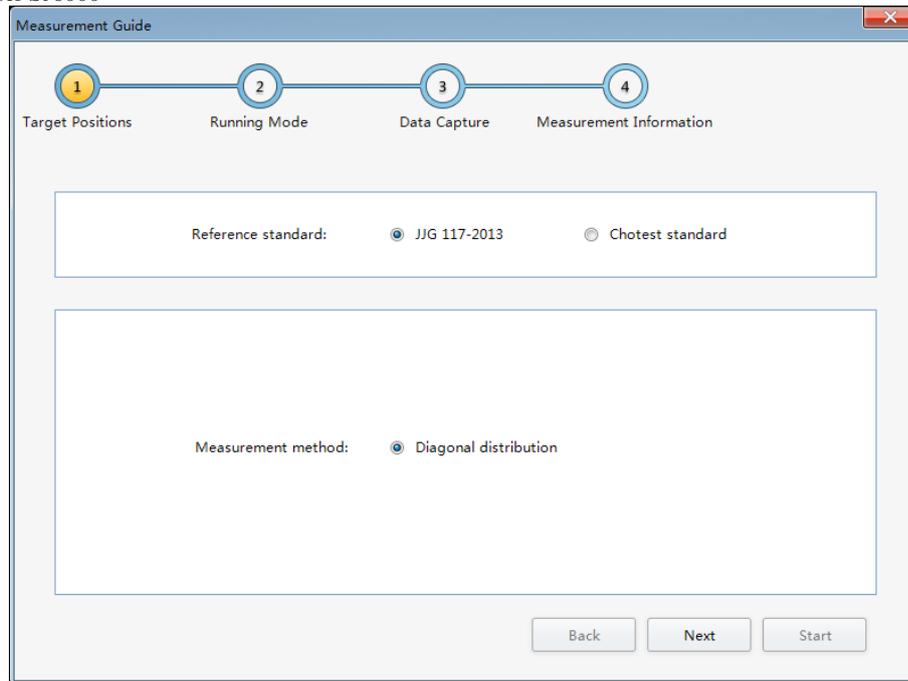
FIGURE2- 18FLATNESS MEASUREMENT GUIDE-MEASUREMENT METHOD

You can select China national standard JJG 117-2013 as the evaluation standard, and then click "Next".

Target information: the length unit is mm. You can input other information about the table to be measured and the measurement points, and then click "Next", see figure 1-23 Flatness measurement guide-target information setting.

Measurement information: input the information about the machine to be measured, and then click "Start" to start the measurement.

⟍ Point	In flatness measurement, you should adjust the size flatness base according to the actual condition; and the data capture is in manual mode.

The software will automatically save the record and pop up the measurement results after the measurement is completed. For more information about record view and management, refer to "Record management"

📖 "Record management" (page 31)
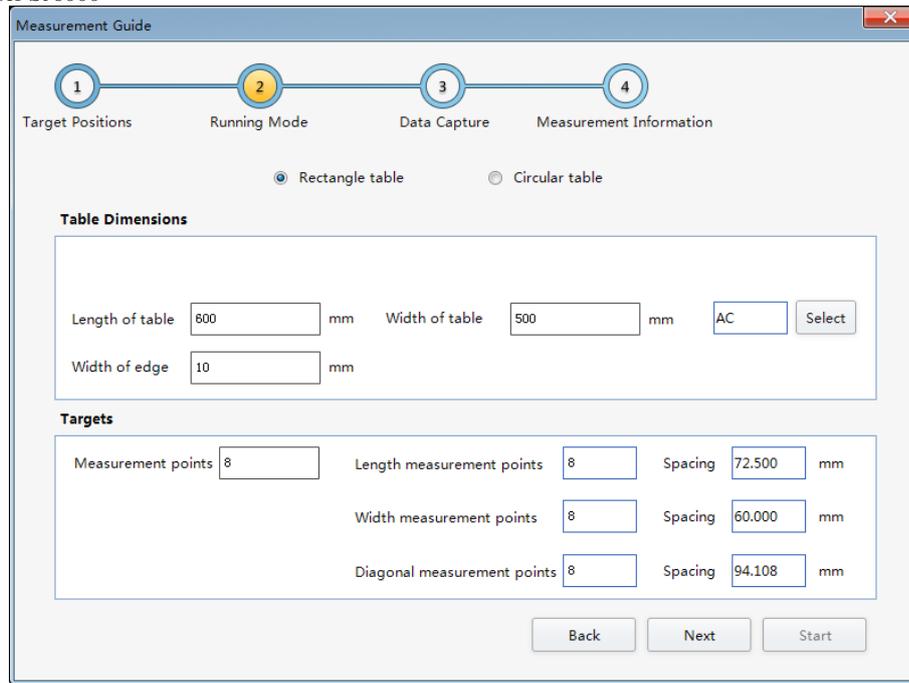
FIGURE2- 19FLATNESS MEASUREMENT GUIDE-TARGET INFORMATION SETTING

Rotary axis measurement

Click the "Rotary axis" button to switch to rotary axis measurement mode. Click it again to open the "rotary axis measurement guide" window.

Target unit: select one unit type from the angular unit°, ″, °, ′, ″, and μm/mm.

Target generation type: the same as those in linear measurement.

Target sequence: the same as that in linear measurement.

Number of runs: set the number of measurement times according to your requirements.

Data capture: both time-based capture and position-based capture are available.

 "Linear measurement" (page 54)

FIGURE 2- 20ROTARY AXIS CALIBRATION WINDOW

Reference

In flatness measurement, you should adjust the size flatness base according to the actual condition; and the data capture is in manual mode.

After calibration, click "Start" to start the measurement. And then the software will automatically save the record and pop up the measurement results when the measurement is completed. For more information about record view and management, refer to "Record management"

Record management

Click the "Record Management" button in upper main window to open the record management window, see the illustration below.
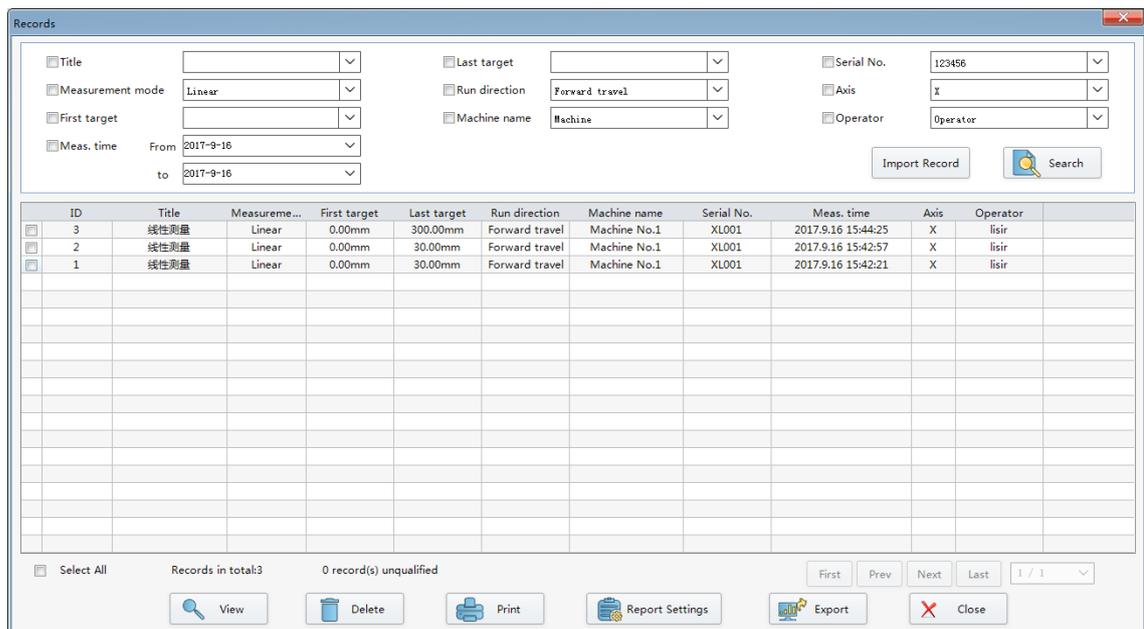
FIGURE2- 21RECORD MANAGEMENT INTERFACE

Search: search for the matched measurement records and return a list. Select the available item check boxes, such as the "Title" check box, and the "Measurement method", and select or type the contents you want to search for in the selected check box field, and then click the "Search" button.

The items "Machine name" and "Serial No." use fuzzy searching. For example, if you type a "6" in the "Serial No." box field, all records which contains "6" in the serial number will be found after you click "Search".

View: view the selected record including measured data table and the corresponding analysis plots

Note: the analysis plot and results may be different from each other when assessed by different standards. The illustrations below are based on ISO230-2-2006.
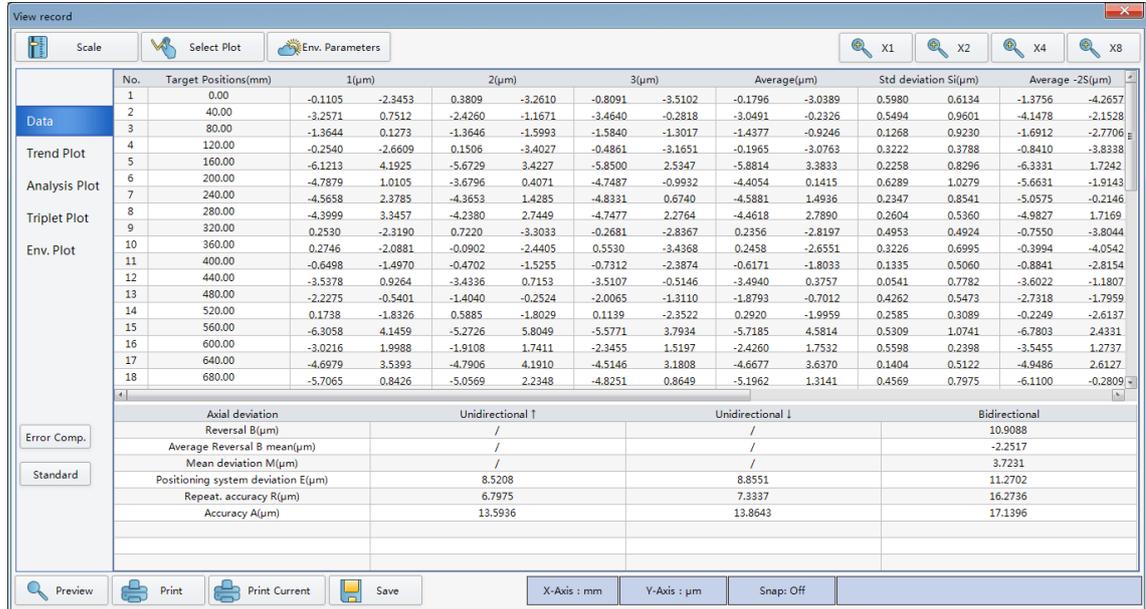
FIGURE2- 22 VIEW RECORD-DATA SHEET
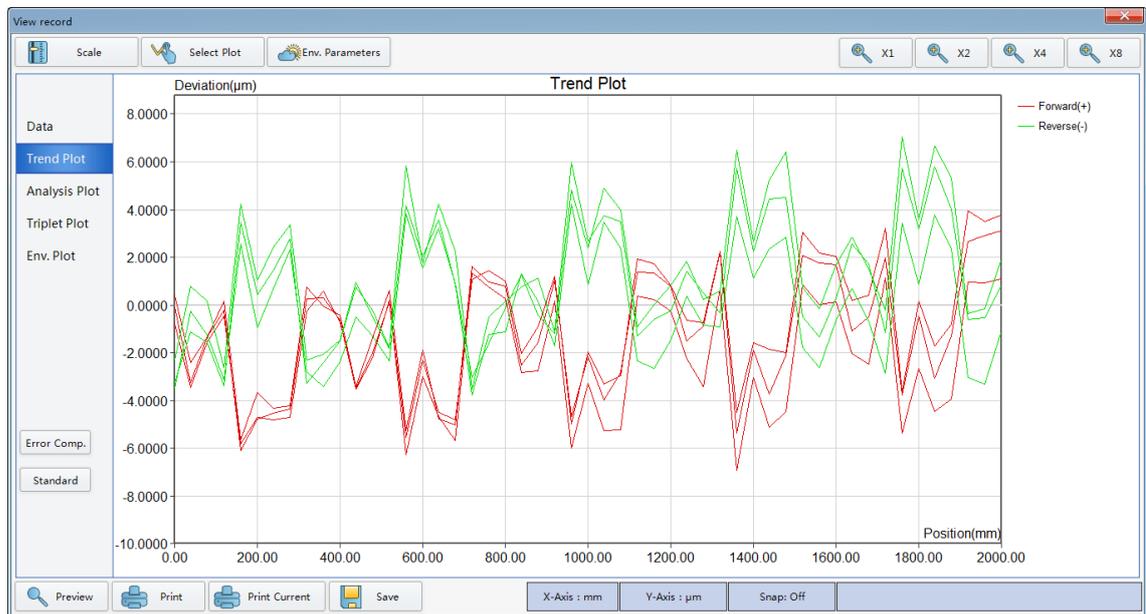
FIGURE2- 23 VIEW RECORD-TREND PLOT

ChotestLaser SJ6000
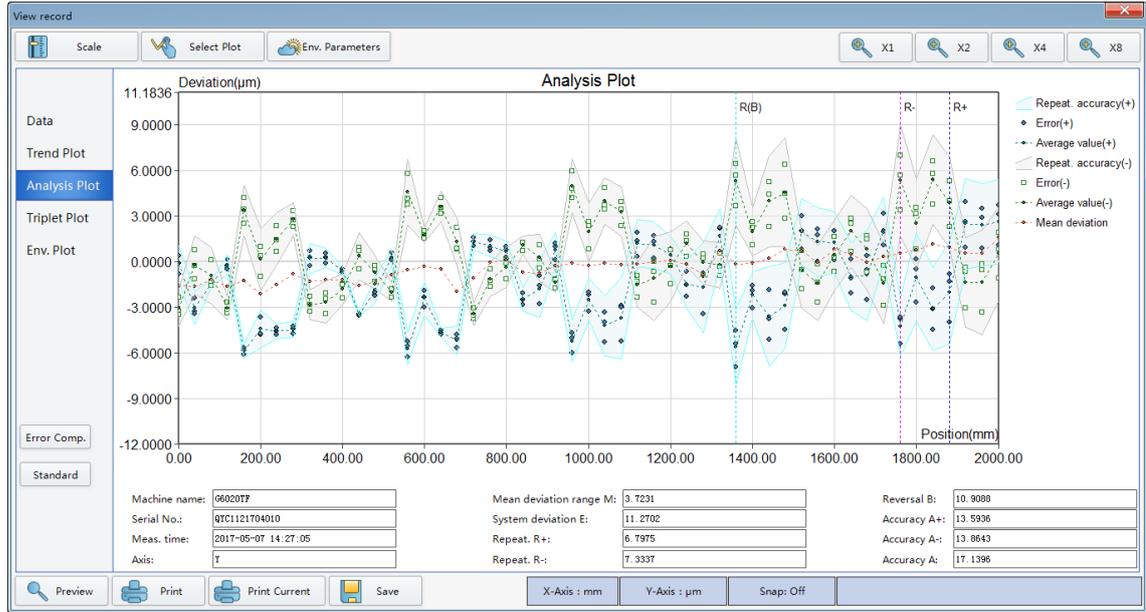
FIGURE2- 24VIEW RECORD-ANALYSIS PLOT
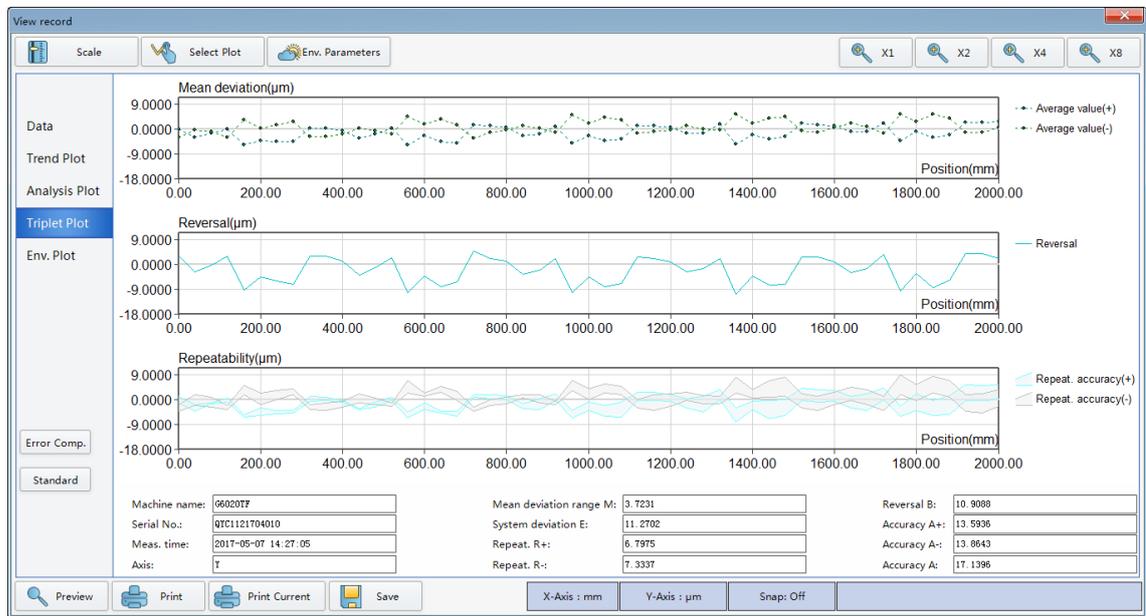
FIGURE2- 25VIEW RECORD-TRIPLET PLOT
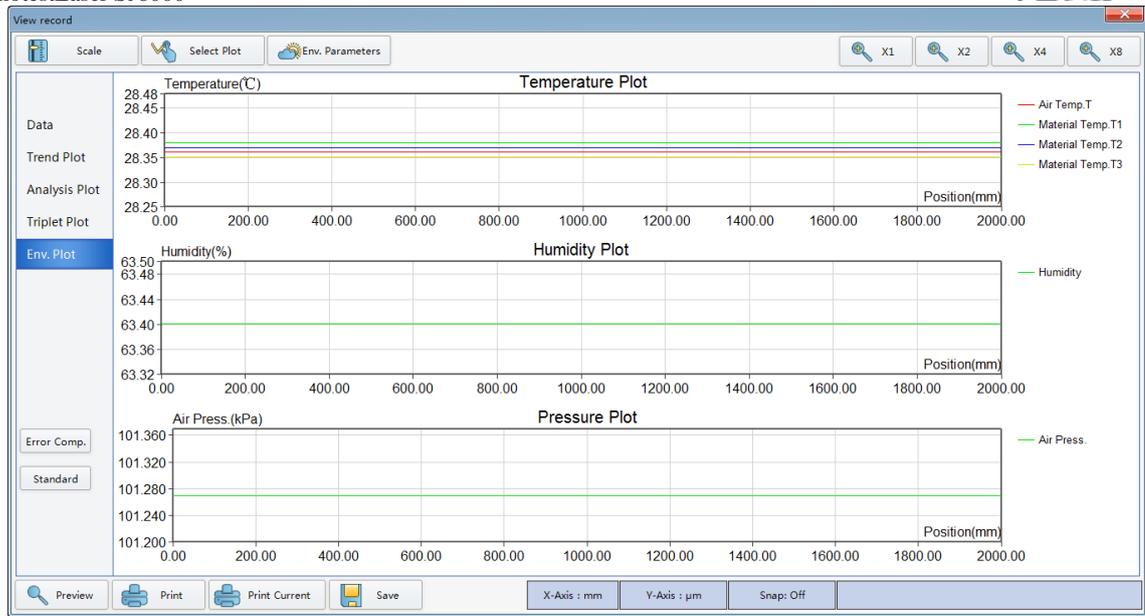
FIGURE2- 26VIEW RECORD-ENVIRONMENT PLOT

By clicking the buttons [X1] [X2] [X4] [X8], the displayed plot can be magnified at certain times indicated on the buttons.

Analysis of measured results: in "view record" status, you can click the "error compensation" button to view error compensation information in "separate" table or "combined" table by click "Produce error compensation table".

FIGURE2- 27ERROR COMPENSATION SETTING
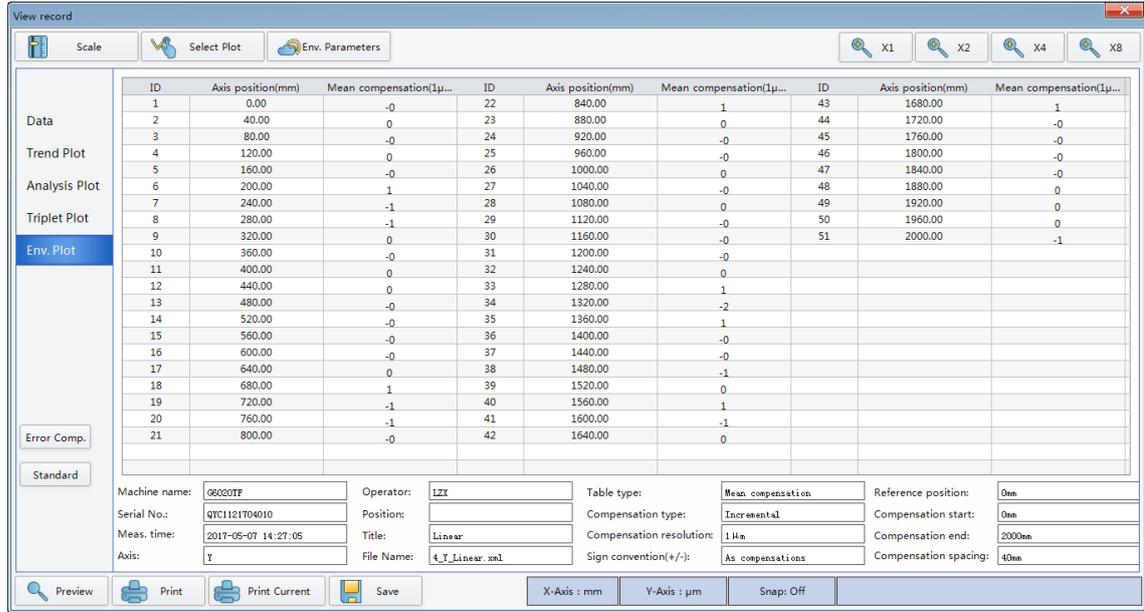
FIGURE2- 28ERROR COMPENSATION DATA

By clicking "Preview", you can view the error compensation table in the generated Excel spreadsheet.
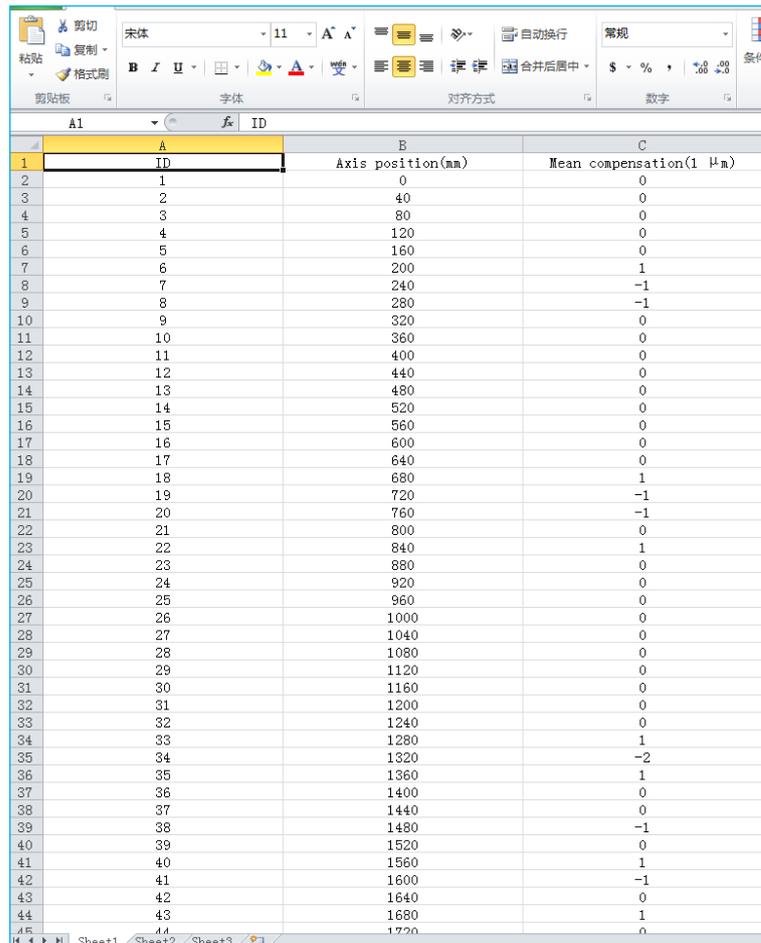
FIGURE2- 29THE GENERATED ERROR COMPENSATION TABLE IN EXCEL SPREADSHEET

Analysis standard: view the currently applied standard and change to another standard.

Environment parameters: view the environment state during the measurement.

Delete record: click "Delete" to open the "Delete record" dialog box. You can delete the current record, other records defined by record number and all records.
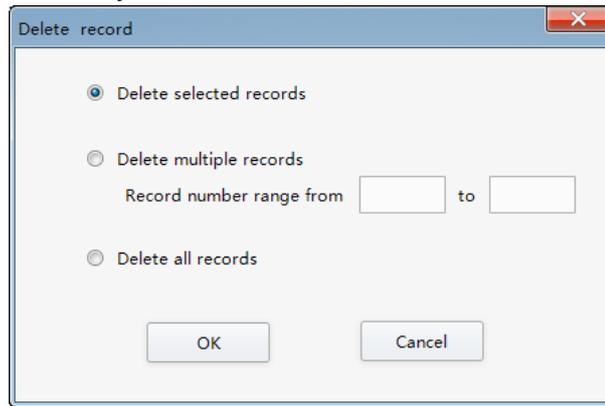
FIGURE2- 30DELETE RECORD

Report setting: set the report style and mode for preview, printing and export. Export type: select the format you want to save as, the default format is pdf.
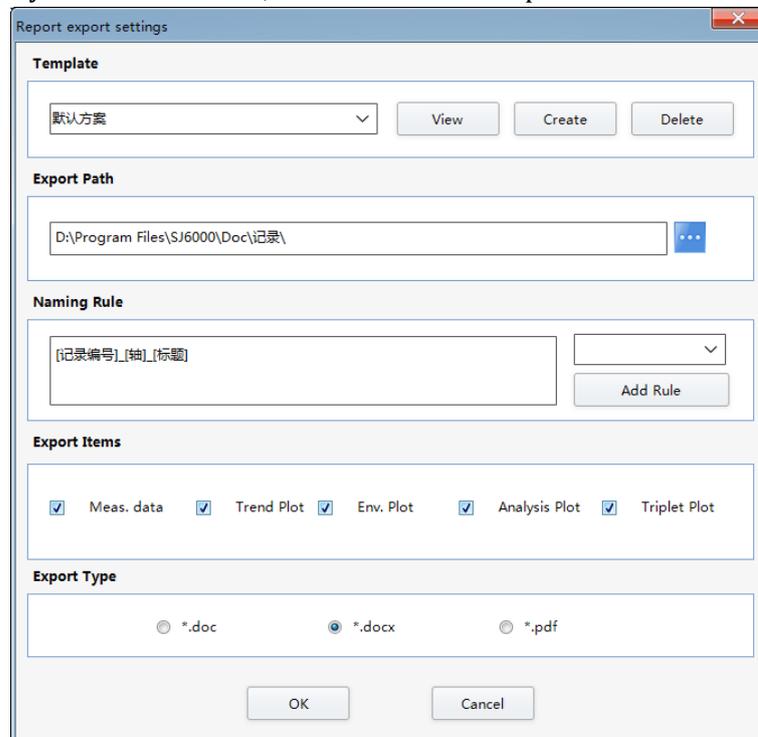
FIGURE2- 31REPORT SETTING

Print: print the selected record(s).

ChotestLaser SJ6000
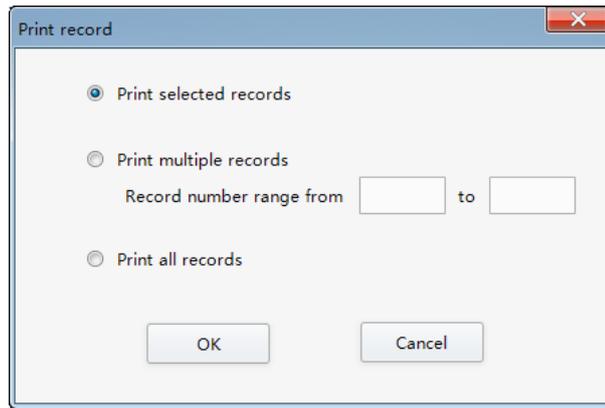
FIGURE2- 32PRINT RECORD

Export: export the selected record(s) or the record(s) within the entered record No. to Word document or the document in other formats.

FIGURE2- 33EXPORT DOCUMENT

The records will be automatically saved in the selected file folder after export.

System setting

System management consists of system options, measurement units, lens parameters, user settings, software version and static measurement calculation.

System options

Specify the configuration file, record mode, gain setting for the software running.
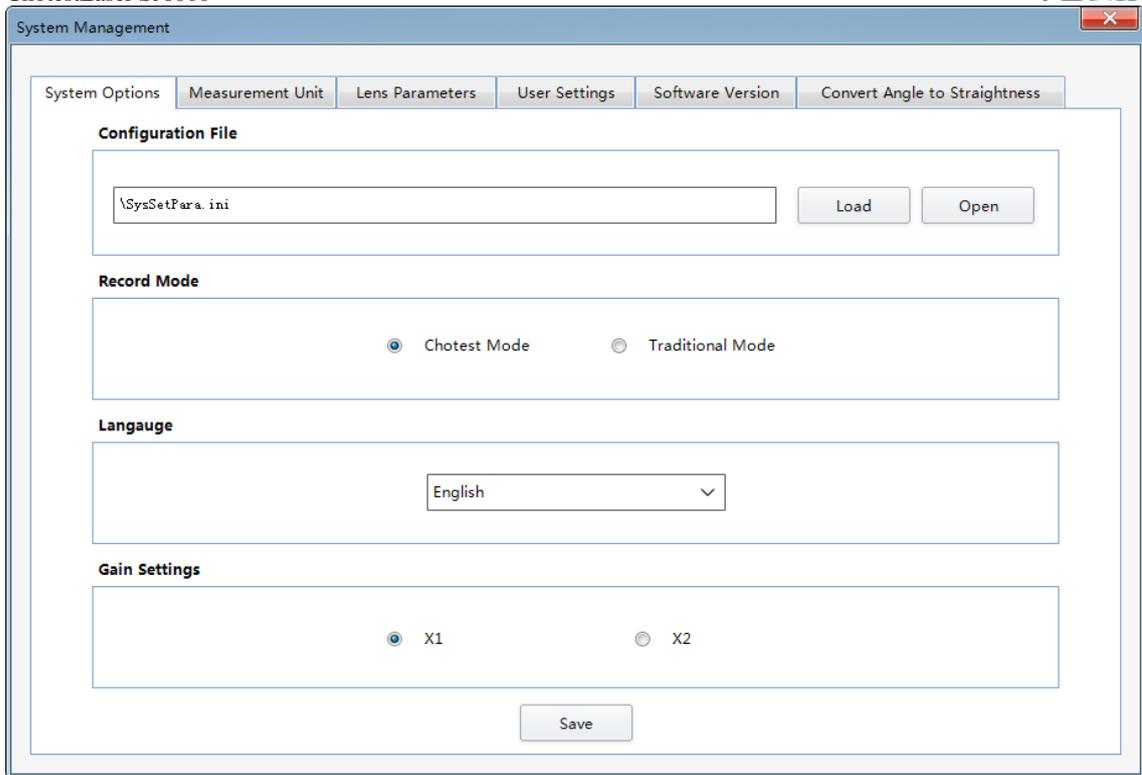
FIGURE2- 34 SYSTEM MANAGEMENT-SYSTEM OPTIONS SETTING

Configuration file: have been set in the manufacturer.

Gain setting: set the signal strength amplification, the default ratio is 1 time. Set the gain ratio to 2 times for the measurement length up to 40m before starting the measurement.

Record mode: switch between "Chotest mode" and "Traditional mode".

FIGURE2- 35 CHOTEST MODE

In Chotest mode, the data are organized in columns for the overall view of the record, and it does not have restriction on the number of runs of the machine.

View record

| Scale | Select Plot | Env. Parameters | | X1 | X2 | X4 | X8 |

Data
Trend Plot
Analysis Plot
Triplet Plot
Env. Plot

Error Comp.

Standard

```
--- ISO 230-2-2006   Statistic Table -   Linear ---                                                        -1/22Page ---
Machine:G6020TF                    Date:2017-05-07 15:06:30              Title:线性测量
Serial No:QYC1121704010            Axis:X                               FileName:5_X_Linear.xml

Units of error values and calculated statistical values: μm

Target Number i        1              2              3              4              5              6              7
Pos. (mm)             0.00           40.00          80.00          120.00         160.00         200.00         240.00
Approach Direction    ↑     ↓        ↑     ↓        ↑     ↓        ↑     ↓        ↑     ↓        ↑     ↓        ↑     ↓

           j= 1    -0.0519 -0.3127  -7.9177 -7.2172  2.1861  3.3457  5.3050  6.2026  1.1492  0.4343  3.6897  4.1604  9.5572 10.4541
Positional    2    -0.4596 -0.3470  -7.1702 -6.7570  2.8032  3.4882  5.4101  5.1989  0.7631 -0.4340  4.0791  3.3921  9.6060 10.0388
Deviation     3    -0.8531 -2.0517  -7.5601 -7.8938  3.2351  2.6240  5.4132  4.3053 -0.0076 -1.7608  3.5139  2.7326  9.7664  8.5331
Xij           4
              5

Mean Deviation      -0.4549 -0.9038  -7.5493 -7.2893  2.7415  3.1526  5.3761  5.2356  0.6349 -0.5868  3.7609  3.4283  9.6432  9.6763
Std Uncertainty Si   0.4006  0.9943   0.3739  0.5718  0.5272  0.4633  0.0616  0.9492  0.5890  1.1055  0.2893  0.7146  0.1094  1.0108
2Si                  0.8012  1.9886   0.7477  1.1437  1.0544  0.9267  0.1232  1.8984  1.1780  2.2110  0.5785  1.4292  0.2189  2.0215
Mean ↓Si            -1.2561 -2.8924  -8.2971 -8.4330  1.6871  2.2260  5.2529  3.3372 -0.5430 -2.7978  3.1824  1.9992  9.4243  7.6538
Mean ↑Si             0.3463  1.0848  -6.8016 -6.1456  3.7959  4.0793  5.4993  7.1339  1.8129  1.6241  4.3395  4.8575  9.8621 11.6969
4Si                  1.6024  3.9772   1.4955  2.2874  2.1088  1.8533  0.2464  3.7967  2.3559  4.4219  1.1571  2.8583  0.4378  4.0430
Reversal Bi              0.4489             -0.2600          -0.4112          0.1405           1.2217           0.3326          -0.0322
Bidi. Repeat. Ri         3.9772              2.2874           2.3922          3.7967           4.6106           2.8583           4.0430
Mean Deviation          -0.6793             -7.4193           2.9471          5.3058           0.0240           3.5946           9.6593

---Statistics---
Axis Deviation(μm)           Unidirectional(↑)     Unidirectional(↓)     Bidirectional
Reversal  B                  Not Applicable        Not Applicable        2.7149 (at i=80)
Mean Reversal B'             Not Applicable        Not Applicable        1.0916
Mean Deviation M             Not Applicable        Not Applicable        54.0735
System Deviation E           55.3154               52.8315               55.5464
Repeatability R              15.8467 (at i=149)    16.8552 (at i=149)    16.8552 (at i=149)
Accuracy A                   65.9424               65.8120               66.6777
```

← →

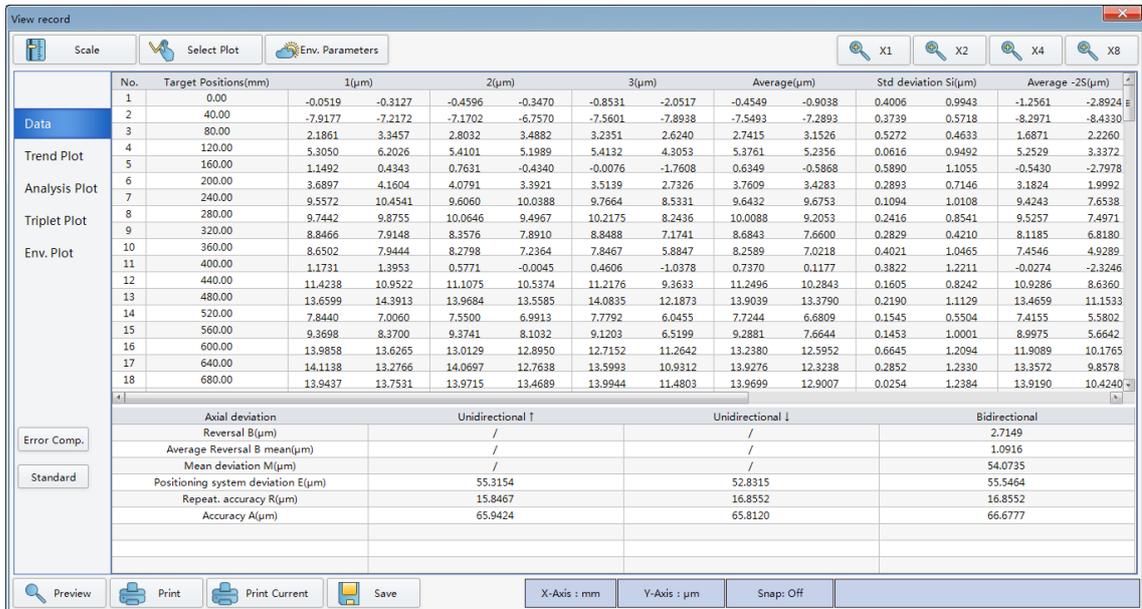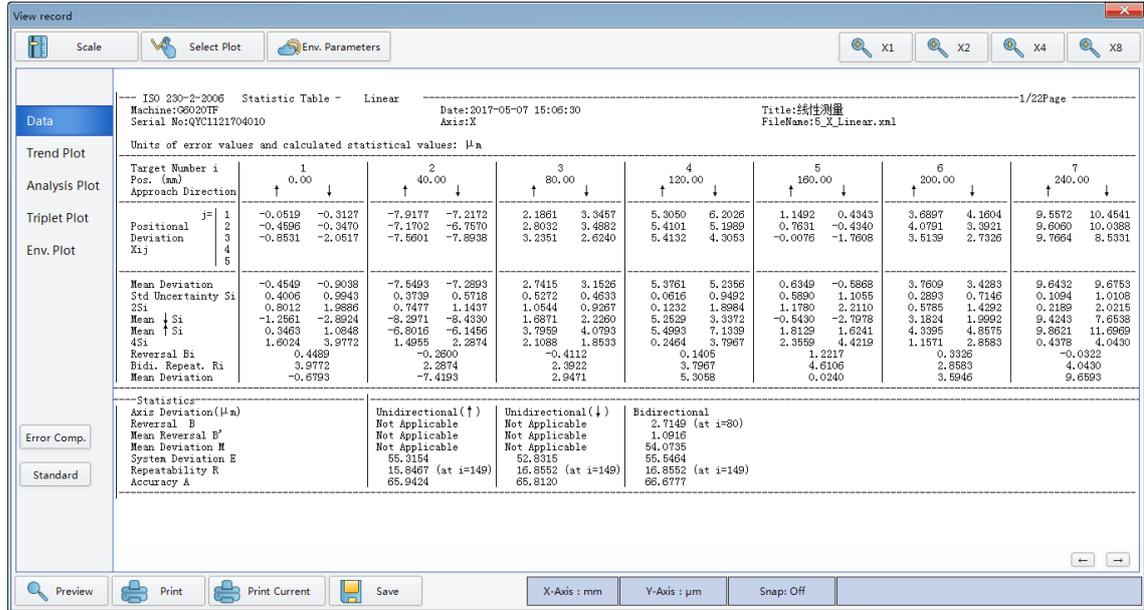| Preview | Print | Print Current | Save | | X-Axis : mm | Y-Axis : μm | Snap: Off |

FIGURE2- 36TRADITIONAL MODE

In traditional mode, all data are organized in fixed layout, you can view the data no more than five runs.

Measurement unit: set the default unit and decimal places.

Reading Unit

Unit Type		Decimal Digits					
Linear unit	mm	mm	4	μm	4	inch	4
Angular unit	°	minch	4	°	2	"	2
Straightness unit	μm	μm/m	2	μm/mm	2		

Error unit

Unit Type		Decimal Digits					
Linear unit	μm	mm	4	μm	4	inch	4
Angular unit	"	minch	4	°	2	"	2
Straightness unit	μm	μm/m	2	μm/mm	2		

Save

FIGURE2- 37MEASUREMENT UNIT SETTING

User setting: assign user rights and set logon password.

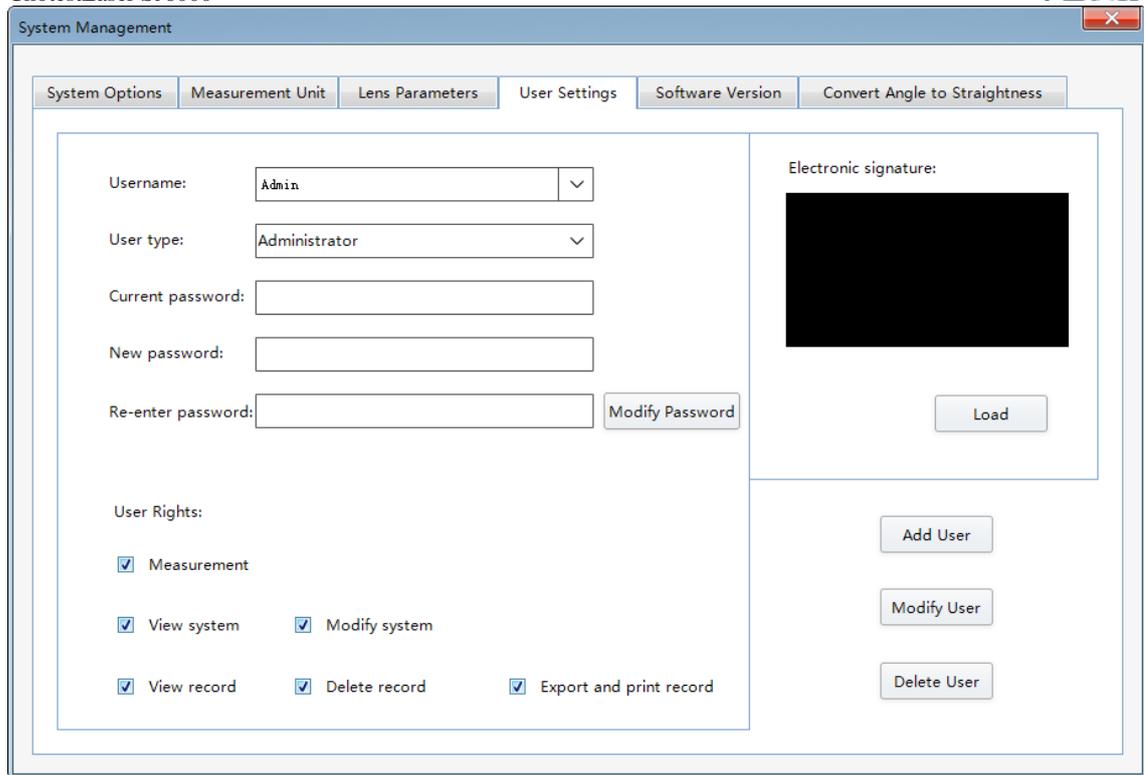ChotestLaser SJ6000

FIGURE2- 38USER SETTING

Lens parameters: set lens parameters for error correction.

FIGURE2- 39LENS PARAMETERS

Software version: view the information about ChotestLaser SJ6000 software version, instrument hardware version, valid time and other related information.

FIGURE2- 40SOFTWARE VERSION INFORMATION

Static measurement calculation: set the required measurement item according to different standards or regulations. Select the standard in "Standard" drop-down list and then click "Add" after selecting the calculation item.

FIGURE 2- 41CALCULATION ITEMS

Chapter 2   Dynamic software functions
3.1 Start dynamic measurement software

Switch on the computer and double-click the "ChotestLaser SJ6000 dynamic measurement" icon, a logon window will appear.
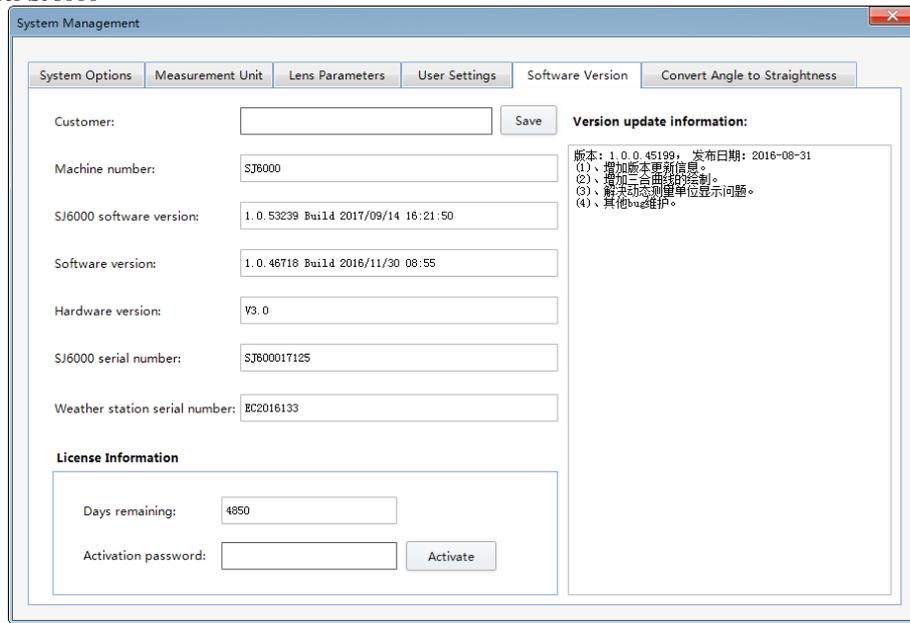

FIGURE3- 1LOGON WINDOW

Select username, type password and then click "OK" to log on. If you just installed the software for the first time, no password is required for the user "Admin", you can directly click "OK" to log on.

After logging on, the main window will appear.

The connection status indication is normal as the laser and the compensation unit are connected well.

3.2 Dynamic measurement software interface
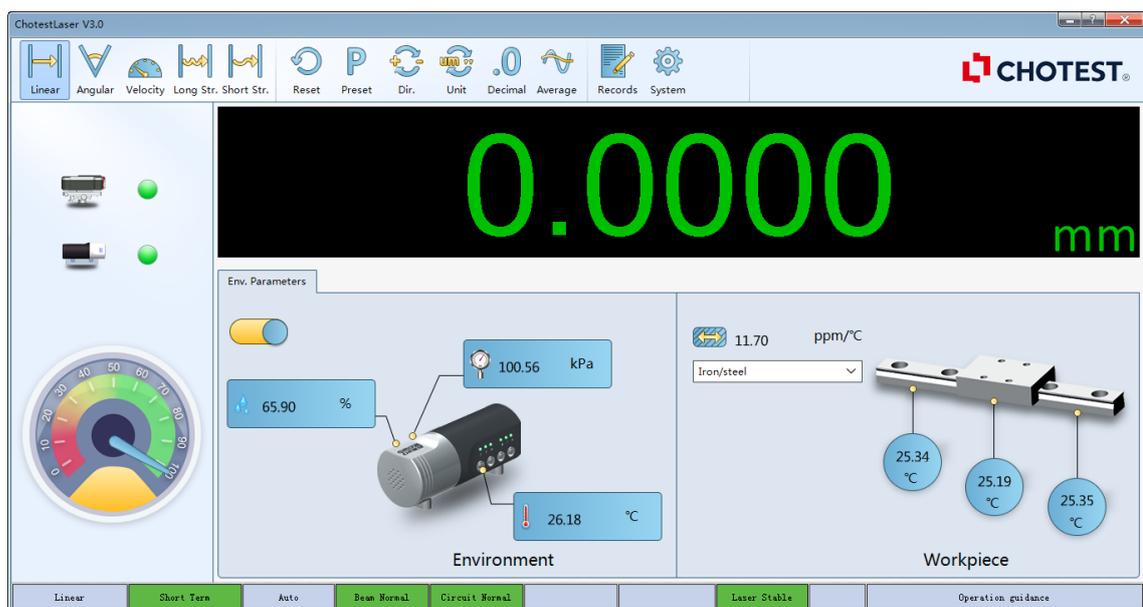
FIGURE3- 2DYNAMIC SOFTWARE INTERFACE
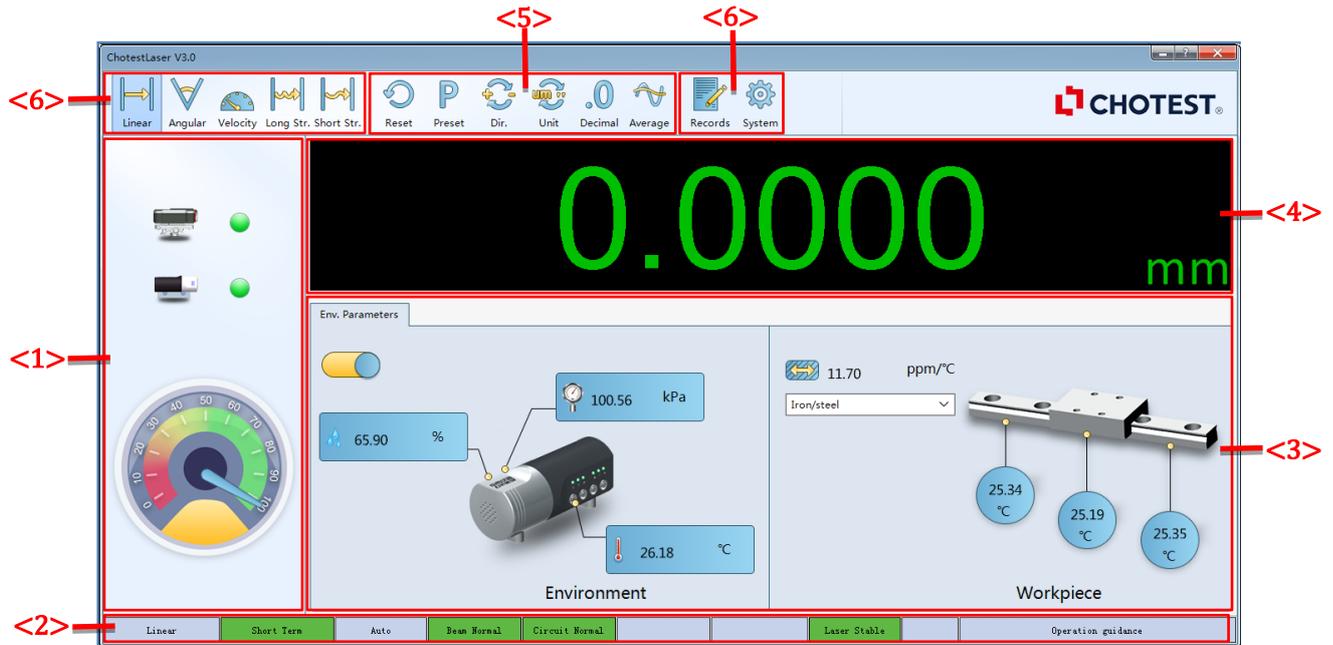
<1> Signal strength field

Indicate the device connection status and the current signal strength.

<2> Status bar

Display the current measurement mode and the measurement status.

<3> Environment window

Display the environment information and the workpiece information.

<4> Data display bar

Display the current measured value.

<5> Tools window

Set the measurement data displayed during measurement.

<6>Menu bar

Set the measurement type and the related information and system.

3.3 Signal strength field

Signal strength meter: indicate the strength of laser beam signal. The higher the meter reading, the stronger the received laser beams.

Connection status: indicate the connection status of PC with the laser head and the environmental compensation unit.

3.4 Status bar

FIGURE 3- 3DYNAMIC-STATUS BAR

Measurement mode: include linear measurement, angular measurement, velocity measurement, long-range straightness measurement, short-range straightness measurement. You can click the button to switch measurement mode.

Averaging type: in dynamic measurement, the default type is "No averaging".

Compensation mode: display environment compensation mode, either the manual compensation or the automatic compensation.

Beam strength: display either "Beam Normal" or "Beam Obstructed". The measurement should be made when it displays "Beam Normal".

Circuit status: display the circuit status.

Laser status: display "Preheating" or "Stabilizing" or "Stable"

3.5   Environment window

The environment window consists of compensation mode, air parameters and workpiece parameters.

Compensation mode: composed of automatic compensation mode and manual compensation mode.

: "ON" status means the automatic compensation mode is turned on.

: "OFF" status means the automatic compensation mode is turned off, it is in

manual compensation mode.

Air parameters: include air temperature, relative humidity and air pressure.

Workpiece parameters: include the material temperature (three temperature points) and the material type. Different material types have different thermal expansion coefficient.

3.6 Data display bar

Display the measured value. In normal measurement, the background colour is green and red when the beam is obstructed or not aligned and a lock icon will appear in the upper right corner.

Double-click the display bar can enter full-screen display mode.

ChotestLaser SJ6000

3.7 Tools window

	Reset the data, keyboard shortcut: Ctrl+C When there is no pre-set value, this command is equivalent to zeroing, otherwise it will reset the value to "a" if "a" is the pre-set value.
	Set the current position displayed as the value "a", keyboard shortcut: Ctrl+P
	Switch the laser reading direction(switch between the plus and minus sign), keyboard shortcut: Ctrl+MIMUS SIGN(-)
	Switch the unit among mm, inch, minch and μm or among degree, μm/mm and arc minute in angular measurement, Keyboard shortcut: Ctrl+U.
	Open resolution dialog box which allows you to set the displayed decimal places, keyboard shortcut: Ctrl+R.
	Switch between averaging OFF, long term averaging ON and short term averaging ON, keyboard shortcut: Ctrl+A.

Note: other keyboard shortcuts.

Previous step: PAGE UP; next step: ENTER; Start: ENTER; unlock: Ctrl+W

3.8 Menu bar

Menu bar consists of linear measurement, angular measurement, velocity measurement, long-range straightness measurement, short-range straightness measurement, record management and system setting.

3.9 Dynamic linear measurement

Click the "Linear" button to switch to linear measurement mode. Click it again to open the "linear measurement guide" window.
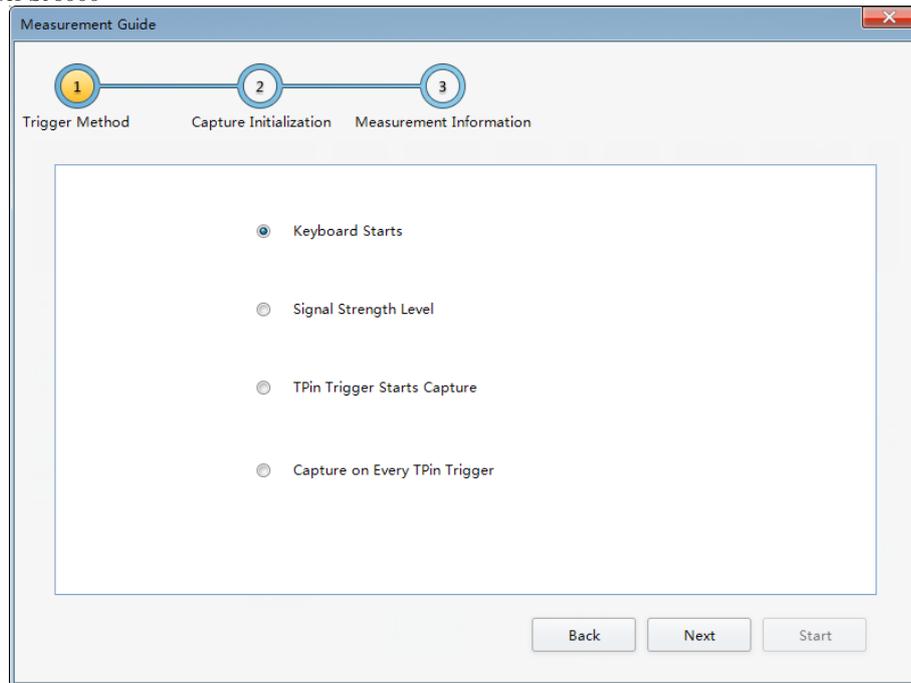
ChotestLaser SJ6000

FIGURE3- 4DYNAMIC MEASUREMENT GUIDE

Trigger method: set the trigger method used for capturing data, "keyboard starts", "signal strength level", "TPin trigger starts capture" and "capture on every TPin trigger" are available.

Trigger type	Setting	Remarks
Keyboard starts		Capture rate: select the number of data points to be recorded per second. You can configure the amount of data collection by setting the capturing time or directly specifying the exact number of data points to be captured. The capture rate is related to the time and the number of data points. If you set the time, and then the number of data point will be calculated automatically, and vice versa.
Signal strength level trigger		Pre-trigger, post-trigger: the software starts capturing data as soon as you select the Capture/Start

50

		menu option and retains the captured data in a circular buffer. Signal strength level: trigger the capture when the signal strength reaches the threshold set during the capturing process.
TPin trigger starts capture	Capture rate : 1 kHz Pre-trigger time : [1310.720] 5 s Post-trigger time : [1310.720] 20 s Total time : [1310.720] 25 s Number of pre-trigger points : [1310720] 5000 Number of post-trigger points : [1310720] 20000 Total points : [1310720] 25000	1. You must select one trigger type for TPin trigger. **TPin Trigger Types** Leading edge trigger ⌄ Do not use edge trigger Leading edge trigger Falling edge trigger Triggered by both edges
Capture on every TPin trigger	Trigger step size : 0 Number of steps : 0 Total distance : 0	2. For "capture on every TPin trigger", you must set trigger step size and the total distance.

The software will automatically save the record and pop up the measurement results after the measurement is completed. For more information about record view and management, refer to "Record management".

📖"Record management" (page 31)

> ▶Important   The set-up procedure of linear measurement applies to the set-up of angular measurement, velocity measurement and straightness measurement in dynamic measurement software.

3.10   Dynamic record management and data analysis

Dynamic record management

The function of "View", "Delete", "Print", "Report setting" and "Export to" on the "Record management" menu also works for the "Record management" in dynamic management software.

📖"Record management" (page 31)

Dynamic data analysis

ChotestLaser SJ6000

Dynamic analysis: dynamic data analysis can process the measured data to generate time-distance plot, time-velocity plot and time-acceleration plot. You can have these plots by clicking the corresponding button.
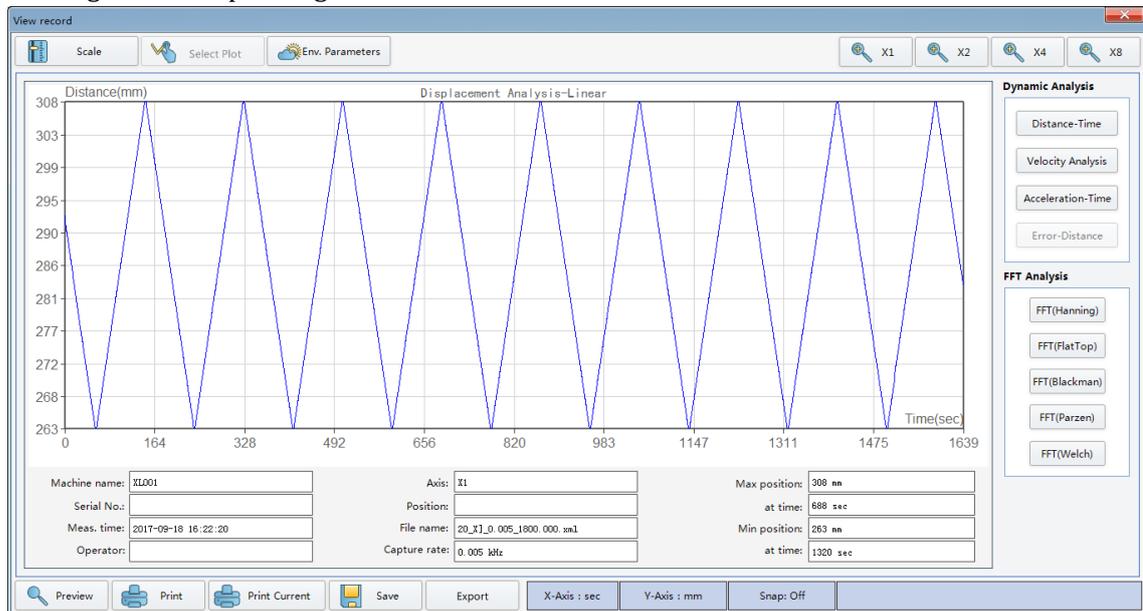

FIGURE3- 5DYNAMIC DATA ANALYSIS WINDOW

FFT analysis: FFT (Fast Fourier Transform) is an effective algorithm used to analyse the relationship between the time domain and the frequency domain.

Energy leakage: when using the computer to process the engineering test signal, it is impossible to test and compute the infinite signal but to analyse the signal in a limited time segment. By intercepting a time interval from the signal, and then perform periodic extension processing with the observed signal time interval to obtain a virtual infinite signal. Because the original signal are truncated, the spectrum distortion occurs and the original concentrated energy is dispersed in two wider frequency band, this phenomenon is called spectral energy leakage. In order to reduce the spectral energy leakage, different truncation functions are used to truncate the signal. The truncation function is called the window function. The leakage is related to the two side lobes of the window, if the height of the side lobes are toward zero and the energy is relatively concentrated in the main lobe, the spectrum is close to the real spectrum, for which different window function are used to truncate the signal in time domain.

Hanning analysis: Hanning window is also known as "raised cosine".   It can be seen as the sum of the frequencies of three rectangular time windows, and the side lobes cancel out each other, eliminating high frequency interference and energy leakage. Thus, it is widely used. From the perspective of reducing energy leakage, Hanning window is better than the rectangular window. But as the main lobe in Hanning window is widened, equivalent to widening the

ChotestLaser SJ6000

analysis band, the frequency resolution is lowered.

FlatTop analysis: the flat top window behaves just like its name in the frequency domain as it has a very small passband fluctuation. And due to the smaller error in amplitude, the FlatTop window could be used for calibration.

Blackman analysis: Blackman window has a wide main lobe and relatively lower side lobes. The equivalent noise bandwidth is a little bigger than that of Hanning window but the fluctuations is smaller than that of Hanning widow. With the lowest accuracy of frequency recognition but the highest accuracy of amplitude recognition for a good selectivity, it is commonly used to detect the signals with similar frequency but different amplitude.

Parzen analysis: Parzen window was introduced in 1960s. The basic idea of the Parzen window method is to estimate a probability density function for the whole body form the mean density of each point in a specified region, also known as kernel density estimation.

Welch analysis: the modification method of periodograph, introduced by Welch, is effectively used in the classical frequency estimation field. In most cases, the frequency resolution and estimation of variance can satisfy the practical application.

> **Important**
>
> When the high frequency resolution is required and the side lobes is smaller, Hanning window is recommended;
>
> When the accurate amplitude is required, FlatTop window is recommended.
>
> When you detect two signals with similar frequency but different amplitude, Blackman window is recommended.
>
> You must set the parameters of Parzen window and Welch window for a high accurate analysis.

Chapter 3   Linear measurement

Linear measurement is the most common form of measurement performed with a laser. The laser system measures linear positioning accuracy and repeatability by comparing the position displayed on the axis read-out with the true position measured by the laser system.
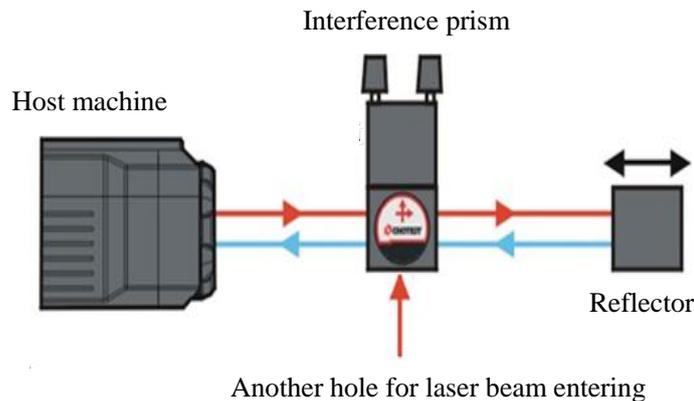
4.1 Principles of linear measurement

FIGURE2- 1SET-UP OF LINEAR MEASUREMENT

To set up for a linear measurement, attach one of the linear reflectors to the beam-splitter with the two screws provided. This combination element is called "linear interferometer". The linear interferometer is positioned in the beam path between the laser and the linear reflector, and its reflected beam forms the reference path for the laser beam. The other beam enters the linear reflector through the beam splitter and the linear measurement is achieved by moving the linear reflector, as shown in the following figure.
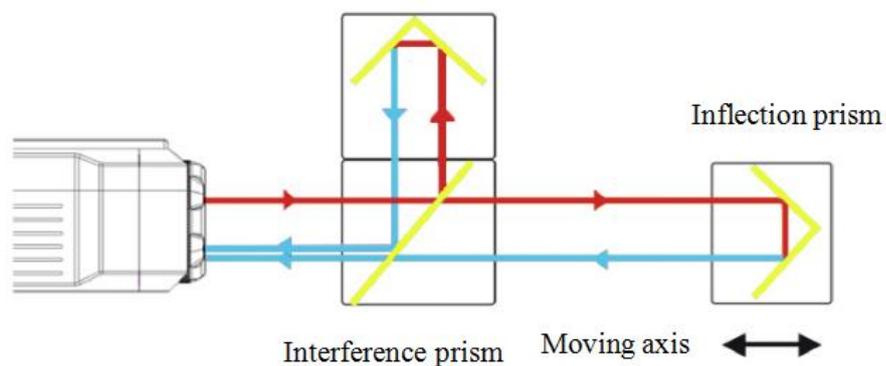

FIGURE4- 2PRINCIPLE OF LINEAR MEASUREMENT

The linear interferometer is positioned in the beam path between the laser and the linear reflector. Two cross arrows are marked on the splitter to indicate the beam direction, and the arrows must be aimed at the two linear reflectors respectively.

During linear measurements, one of the optical components remains stationary, while the other moves along the linear axis. A positional measurement is produced by monitoring the change in optical path difference between the measurement and reference beams. This measurement can be compared to the read-out from the positioning system of the machine under test to establish any errors in the machine's accuracy.

Generally, the reflector is set up as the moving optical component, with the interferometer as the stationary component.

4.2 Configuration of linear measurement

The linear measurement optics can be set up in many different configurations. Most linear measurement configurations fall into one of the following categories:

Horizontal axe measurement: like three-point line, the laser, linear interferometer and linear reflector are located on one axis line.

90° axis measurement: the axis to be measured is perpendicular to the laser head.

Inclined axis measurement: add veering prism.

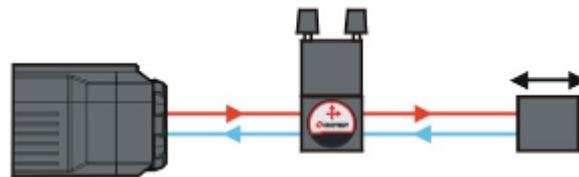Linear measurement components consist of:

1. Laser
2. environmental compensation unit
3. linear measurement optical kit
4. Measurement software

Horizontal axis measurement: three-point line Install the components according to the actual situation.

Beam path of horizontal axis measurement
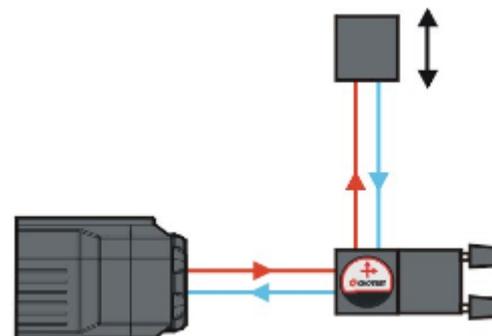
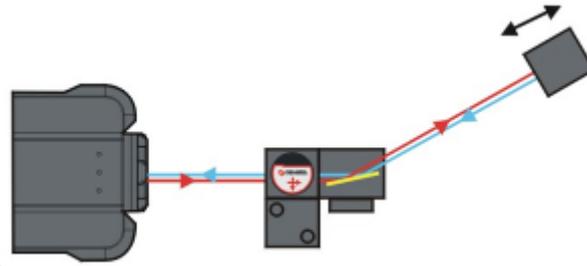90° axis measurement: Horizontal 90° axis measurement and vertical axis measurement.

Beam path of 90° axis measurement

Inclined axis

measurement

Beam path of inclined axis measurement

4.3 Linear measurement procedure

The operation steps of linear measurement are as follows:

① Set the software system in linear measurement mode;

② Align the laser beam with the axis of travel of the machine;

③ Capture data;

④ Select the evaluation standard to analyse the captured data.

4.3.1   Software set-up of linear measurement

A case on the positioning accuracy measurement of steel guide rail, 0~300mm, 40mm interval, 3 runs bidirectional and 1mm overrun.

1.   Double-click   the " ChotestLaser SJ6000 static measurement" icon on the desktop to open the measurement window;

Turn on the automatic environmental compensation;

Select "Iron/steel" as the workpiece material.

2. Click "Linear" to open the linear measurement guide window. Set the parameters under the "Target position", and then click "Next".
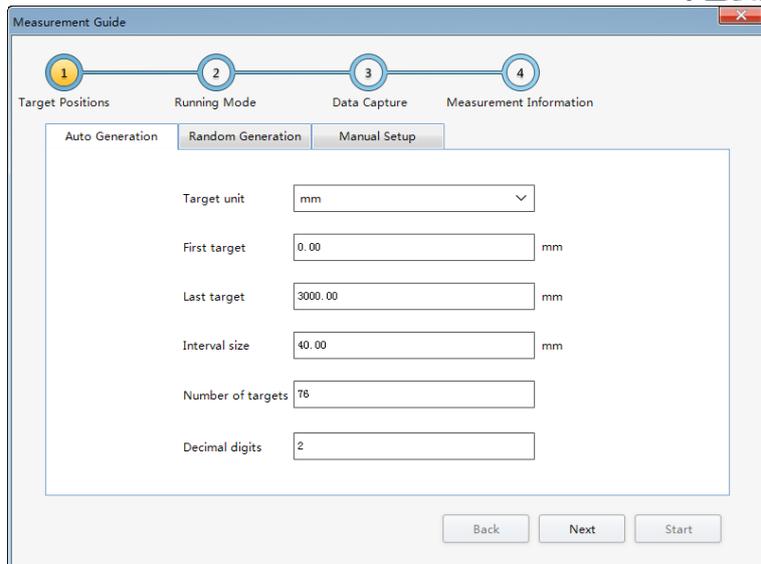
3. Select and set the items in "Running type".

The purpose of the error band is to allow the software to warn you if the rotational error is greater than the width of this band. It has no influence on the analysis results.
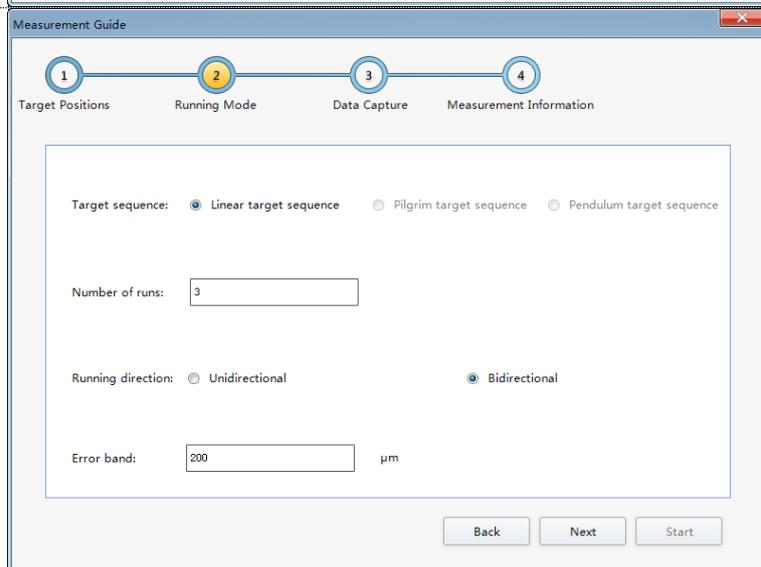
4. Set the items in "Capture data".

"Period halt" and "Stability of reading" are set based on the accuracy of the machine and its settling time.

For full automatic capture, you must select "On move" in the "Overrun action" box.
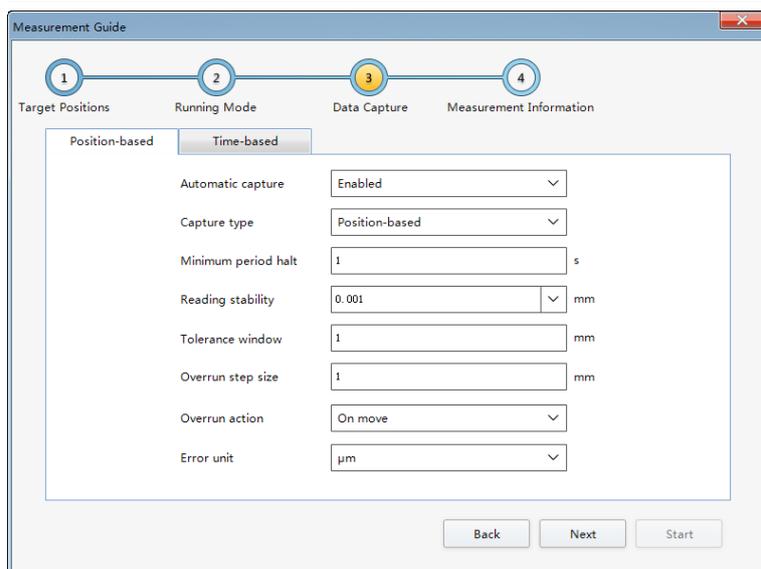
5. Set the items in "Measurement information", and then click "Start" to start the capture.
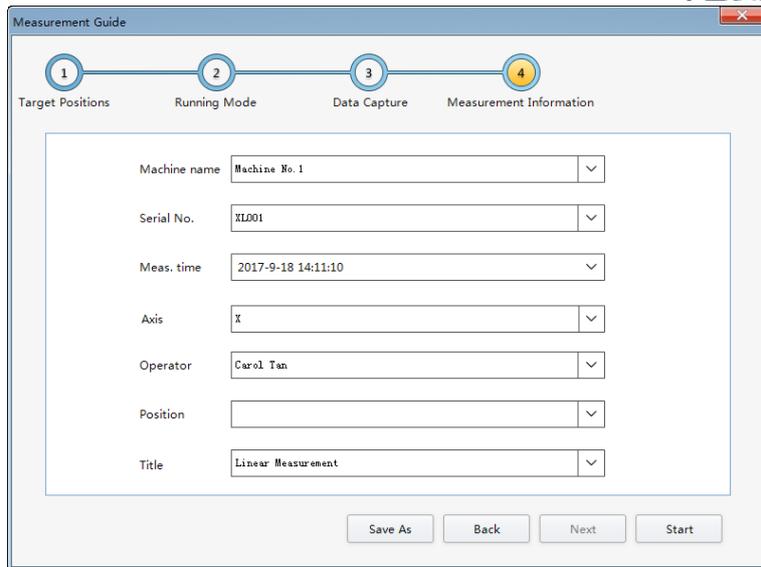
4.3.2 Beam alignment for linear measurement

The purpose of beam alignment

Any misalignment of the laser beam path relative to the axis of motion will result in an discrepancy between the measured distance and the actual distance travelled. To align the beam is to ensure the beam for measurement can accurately return to the laser and get the strongest feedback information for calculating the actual travel values.

⚠ **Caution**	To avoid eye damage, do not stare into the output beam. Do not let the beam pass into your eyes or anyone else's, either directly or by reflection from an optical element or other reflective surface.

Beam alignment requirement

The laser beam for measurement must be parallel to the axis of travel in order to minimise cosine measurement errors.

**Beam alignment procedure-method 1**

| ↘ **Point**	For this method, you should align beam by using linear reflector first, and then mount the linear interferometer.

1. **Coarse adjustment:** roughly align the laser to the axis of travel.

2.   Mount linear reflector: mount the reflector near the laser head as close as possible to the axis of travel, and make sure the prism of the reflector is perpendicular to axis of travel, ensuring the return beam points to the centre of the target spot.
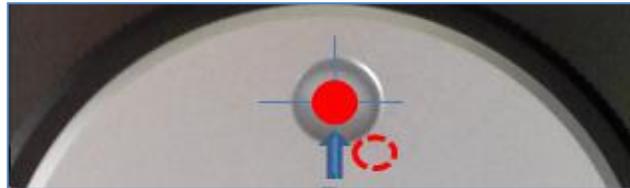

3.   **(Move forward)** move the reflector away from the laser head along the axis of axis until you see the beam start to move away from the target spot on the shutter. Stop moving the reflector as soon as you see half of the beam still points to the white spot. Please observe carefully the distance from the beam to the centre of the white spot.
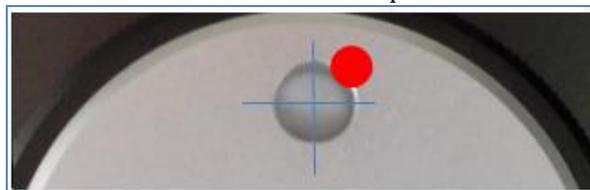

4.   **(Yaw adjustment-symmetrical adjustment)** use the yaw adjustment knob on the left rear of tripod to adjust the rotational pitch of the laser head to make the beam sweep over the white target spot. Continue to move the laser head until the beam is on the opposite position in the horizontal direction with the same distance to the central line of the target.
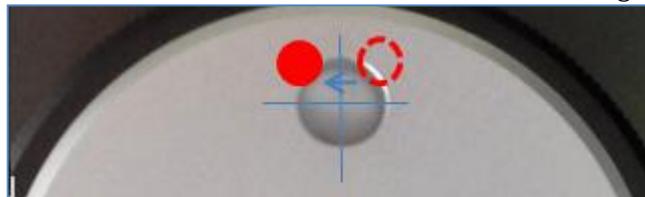
5.   **(Yaw adjustment-translation to the target centre line)** use the translation knob on the left side of the tripod to translate the laser head to bring the beam returns to the vertical centre line of the target spot.
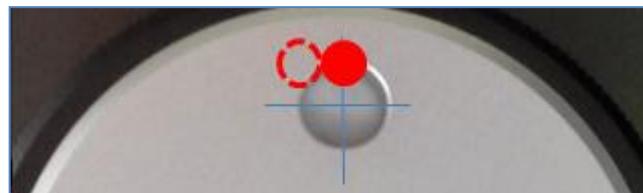
6.   **(Pitch-symmetrical pitch adjustment)** make sure the laser beam is on the vertical position to the target spot.   Use the pitch knob at the rear of the laser head to adjust the beam to sweep the target vertically first. Use the pitch adjustment knob to adjust the laser head until the beam moves to the opposite position across the target spot in vertical direction with the same distance to the centre of the target spot.
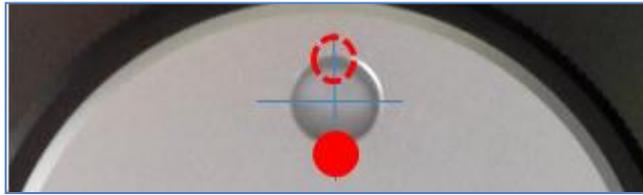
7.   **(Pitch adjustment-back to origin point)** use the height adjustment crank on the tripod to adjust the laser head, up and down until the beam hit the centre of the target spot. Note: during this adjustment, you may need to make a slight yaw adjustment in horizontal direction to ensure the laser beam return to the centre of the target spot.
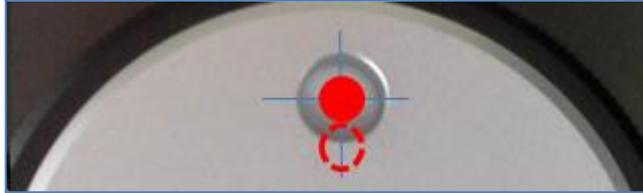
8.   Continue to move the device along the axis of travel, until you see the laser beam starts to move off the target spot. Repeat step3 through step7 until the reflector reaches the end of the axis.

9.   As the reflector reaches the end of the axis, move it back to the start point of the axis. If the beam is no longer located at the centre of the target spot, you can adjust the leaser head by translation or height adjustment to make the beam point to the centre of the target spot.

Tips: if condition permits, you can adjust the position of the reflector to bring the beam back to the centre of the return aperture.

10.   Repeat step3 through setp9 until the beam remains in the centre of the target spot through the entire travel of axis.

| Reference | If you are skilled in the operation, you can align the beam from the far end to the near end. |

The beam alignment of the reflector from far to near is different from that from near to far: the alignment directions are the same;   the adjustment amount is determined according to ratio of the translation distance to the total length of the movement, in general, the value between 1/3 and 1/2 is appropriate.

Beam alignment procedure-method 2

⟍ Point   For this method, you need to install the linear interferometer and the linear reflector before alignment.

1. **Coarse adjustment:** roughly align the laser to the axis of travel.

2. Mount linear optical kit: install the linear interferometer and the linear reflector. Install the two optical sets as close as possible, so that the two beams can go back to the same position in the centre of the beam aperture.

3. Move reflector: move the linear reflector towards the farthest end until you see only a small part of the beam returns back to the centre position.

4. Chase beam: adjust the laser head via the pitch adjustment knob and the yaw adjustment knob to make the beam spot of the linear reflector "chase" the beam spot of the linear interferometer until they overlap. Adjust the laser head by translation and height adjustment to bring the spot to the centre of the target spot.

5. Move the reflector back to check the spot overlapping status. And adjust the linear reflector to make the two beam spots overlap again.

6. Repeat step3 through step5 to make sure the two beam spots overlap anywhere as you move the reflector.

⟍ Point   Beam alignment procedure-method 2 is applicable to any axis measurement and it is an important alignment method for the 90 ° beam path alignment.
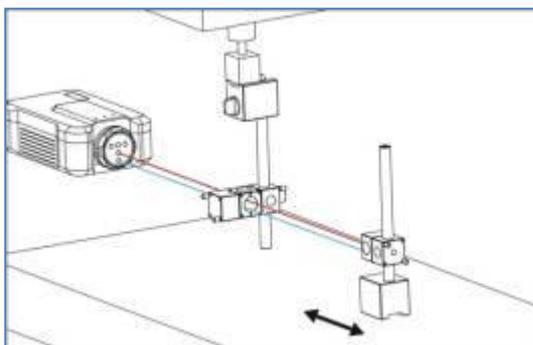
Linear measurement schematic

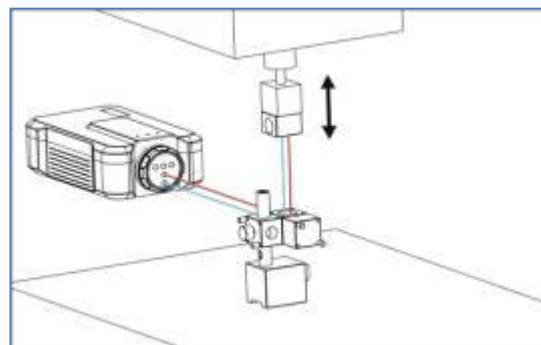FIGURE4- 3 HORIZONTAL AXIS MEASUREMENT   FIGURE4- 4 90 ° AXIS MEASUREMENT

4.3.3 Data capture for linear measurement

In linear measurement, the data are captured automatically and saved as measurement records. the data analysis window will be open automatically after the capture.

During the data capture, some points, which do not meet the capture requirement, may not be collected due to the device is unstable. After the capture of the last point, you will receive a message whether to generate records, and you can manually input the data if necessary.

4.3.4 Data analysis of linear measurement

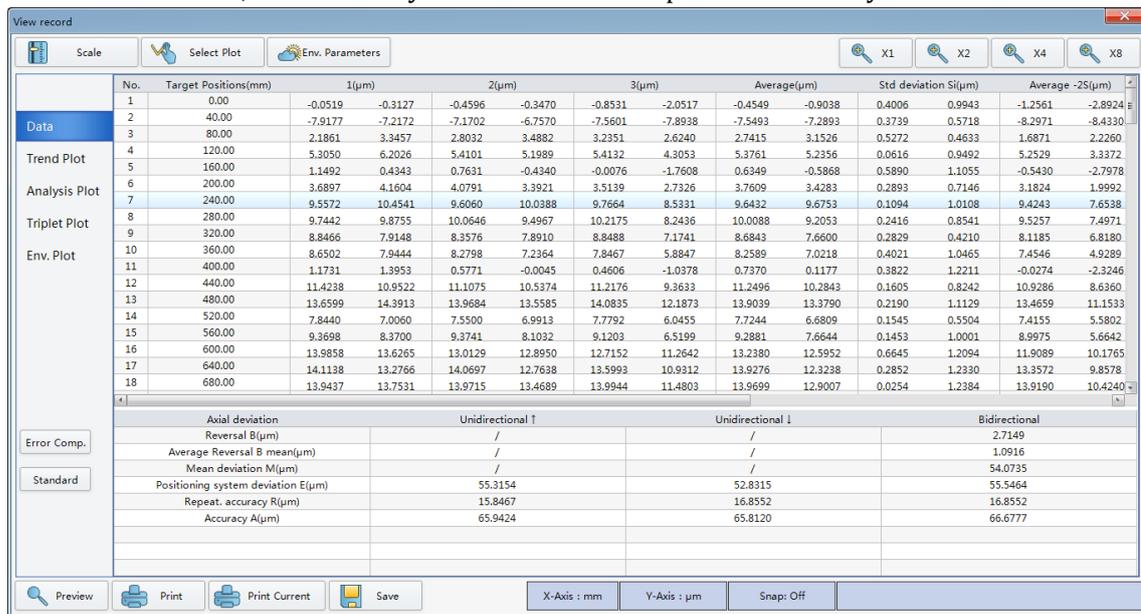After measurement, the data analysis window will be open automatically.

No.	Target Positions(mm)	1(μm)		2(μm)		3(μm)		Average(μm)		Std deviation Si(μm)		Average -2S(μm)	
1	0.00	-0.0519	-0.3127	-0.4596	-0.3470	-0.8531	-2.0517	-0.4549	-0.9038	0.4006	0.9943	-1.2561	-2.8924
2	40.00	-7.9177	-7.2172	-7.1702	-6.7570	-7.5601	-7.8938	-7.5493	-7.2893	0.3739	0.5718	-8.2971	-8.4330
3	80.00	2.1861	3.3457	2.8032	3.4882	3.2351	2.6240	2.7415	3.1526	0.5272	0.4633	1.6871	2.2260
4	120.00	5.3050	6.2026	5.4101	5.1989	5.4132	4.3053	5.3761	5.2356	0.0616	0.9492	5.2529	3.3372
5	160.00	1.1492	0.4343	0.7631	-0.4340	-0.0076	-1.7608	0.6349	-0.5868	0.5890	1.1055	-0.5430	-2.7978
6	200.00	3.6897	4.1604	4.0791	3.3921	3.5139	2.7326	3.7609	3.4283	0.2893	0.7146	3.1824	1.9992
7	240.00	9.5572	10.4541	9.6060	10.0388	9.7664	8.5331	9.6432	9.6753	0.1094	1.0108	9.4243	7.6538
8	280.00	9.7442	9.8755	10.0646	9.4967	10.2175	8.2436	10.0088	9.2053	0.2416	0.8541	9.5257	7.4971
9	320.00	8.8466	7.9148	8.3576	7.8910	8.8488	7.1741	8.6843	7.6600	0.2829	0.4210	8.1185	6.8180
10	360.00	8.6502	7.9444	8.2798	7.2364	7.8467	5.8847	8.2589	7.0218	0.4021	1.0465	7.4546	4.9289
11	400.00	1.1731	1.3953	0.5771	-0.0045	0.4606	-1.0378	0.7370	0.1177	0.3822	1.2211	-0.0274	-2.3246
12	440.00	11.4238	10.9522	11.1075	10.5374	11.2176	9.3633	11.2496	10.2843	0.1605	0.8242	10.9286	8.6360
13	480.00	13.6599	14.3913	13.9684	13.5585	14.0835	12.1873	13.9039	13.3790	0.2190	1.1129	13.4659	11.1533
14	520.00	7.8440	7.0060	7.5500	6.9913	7.7792	6.0455	7.7244	6.6809	0.1545	0.5504	7.4155	5.5802
15	560.00	9.3698	8.3700	9.3741	8.1032	9.1203	6.5199	9.2881	7.6644	0.1453	1.0001	8.9975	5.6642
16	600.00	13.9858	13.6265	13.0129	12.8950	12.7152	11.2642	13.2380	12.5952	0.6645	1.2094	11.9089	10.1765
17	640.00	14.1138	13.2766	14.0697	12.7638	13.5993	10.9312	13.9276	12.3238	0.2852	1.2330	13.3572	9.8578
18	680.00	13.9437	13.7531	13.9715	13.4689	13.9944	11.4803	13.9699	12.9007	0.0254	1.2384	13.9190	10.4240

Axial deviation	Unidirectional ↑	Unidirectional ↓	Bidirectional
Reversal B(μm)	/	/	2.7149
Average Reversal B mean(μm)	/	/	1.0916
Mean deviation M(μm)	/	/	54.0735
Positioning system deviation E(μm)	55.3154	52.8315	55.5464
Repeat. accuracy R(μm)	15.8467	16.8552	16.8552
Accuracy A(μm)	65.9424	65.8120	66.6777

FIGURE4- 5DATA ANALYSIS WINDOW

Click "Analysis standard" to select the standard you want to apply.

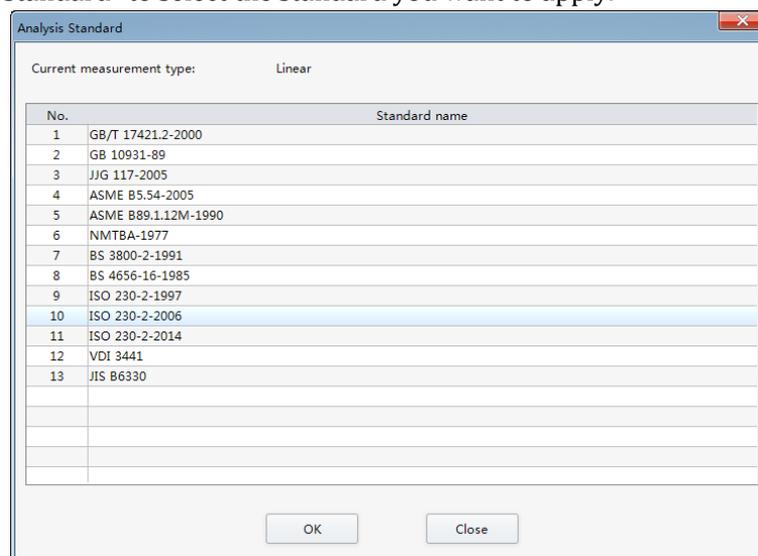| No.	Standard name
1	GB/T 17421.2-2000
2	GB 10931-89
3	JJG 117-2005
4	ASME B5.54-2005
5	ASME B89.1.12M-1990
6	NMTBA-1977
7	BS 3800-2-1991
8	BS 4656-16-1985
9	ISO 230-2-1997
10	ISO 230-2-2006
11	ISO 230-2-2014
12	VDI 3441
13	JIS B6330

FIGURE4- 6STANDARD SELECTION WINDOW

By clicking "OK", the data will be analysed according to the selected standard.

Click "Error compensation", the error compensation table will be generated according to the gain value and absolute value.

4.3.5 Influence factors of linear measurement

Deadpath error

Deadpath error is an error associated with changes in the environment during a linear measurement. It is eliminated by the compensation feature in the automatic compensation unit. Under normal conditions, deadpath error is insignificant and only occurs if the environment changes after a datum and during measurement.

The deadpath error of the laser measurement of path L_2 is related to the distance between the two optical elements when the system is datumed L_1. If there is no motion between the interferometer and the reflector, and the environmental conditions surrounding the laser beam change, the wavelength (in air) will change over the entire path (L_1+L_2) but the laser measurement system will be compensated over the distance L_2 only. Therefore a deadpath measurement error will be introduced due to beam path L_1 not being compensated.

死程 L1   测量光程 L2
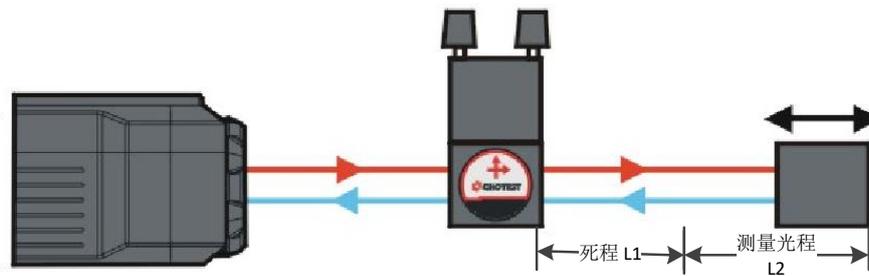
FIGURE4- 7DEADPATH ERROR

	The deadpath error will be reduced if the stationary and moving optic are abutted when the datum is set,
Notice	

测量光程L2
L1=0
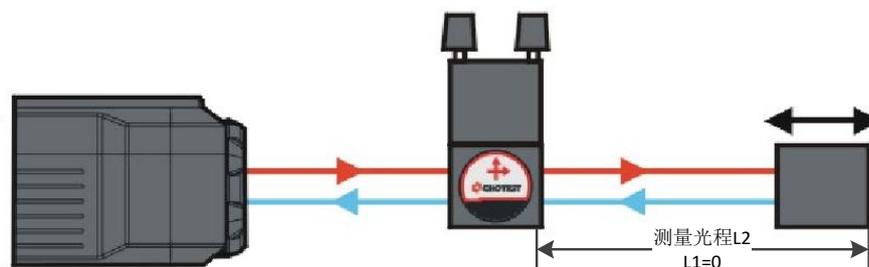
FIGURE4- 8SET-UP FOR REDUCING DEADPATH ERROR

Cosine error

Any misalignment of the laser beam path relative to the axis of motion will result in an discrepancy between the measured distance and the actual distance travelled. This misalignment error is usually referred to as cosine error. The size of this error is related to the angle of misalignment formed by the laser beam and the axis of travel.
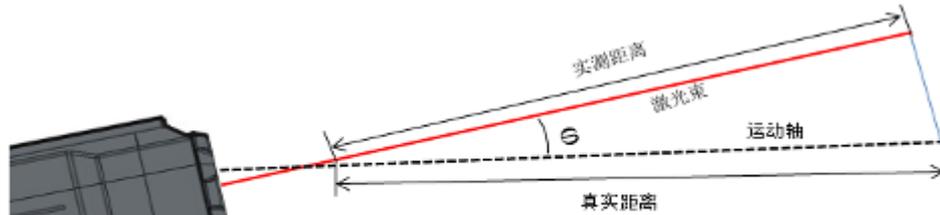
FIGURE4- 9COSINE ERROR

When the laser measurement system is misaligned to the axis of travel, cosine error will cause the measured distance to be shorter than the actual distance. The error increases significantly as the angular misalignment increases, see the following table:

Angle (mm/metre)	Angle (arc minutes)	Error (ppm)
0.45	1.53	0.1
1.00	3.43	0.5
1.40	4.87	1.0
3.20	10.87	5.0
4.50	15.39	10.0
10.00	35.39	50.0

To minimise cosine measurement errors, the laser beam for measurement must be aligned so that is parallel to the axis of travel. On axes longer than a metre, it is relatively easy to achieve using the alignment procedures provided. With shorter axes, it becomes increasingly difficult and 'Maximise the laser measurement reading" can be used to optimise alignment and minimise cosine error.

If there is a cosine error in the laser measurement, the laser reading will be smaller than it should be. Thus, on short axes it is possible to eliminate cosine error by carefully adjusting the pitch and yaw of the laser head until the largest laser reading is obtained. The operation procedure is as follows:

①Align the beam along the axis of travel;

②Move the axis so that the optical kit are close together and datum the laser reading;

③Move the axis so that the optical kit are at their greatest separation;

④Carefully adjust the laser head's pitch and yaw controls to have the largest laser measurement.

Notice	This is a highly effective procedure but needs be very careful. It may be necessary to make a series of small adjustments and to let go of the adjustment controls after each one, before observing the effect on the laser read-out. It may also be necessary to translate the laser head to maintain alignment. It may also be necessary to select the maximum resolution setting on the measurement display and to set "short term averaging" ON. Once completed, it would be much better if you repeat the above steps to confirm alignment.

The use of environmental compensation unit

The environmental compensation unit is the key to laser measurement accuracy. By very accurately and precisely measuring environmental conditions it compensates the wavelength of the laser beam for variations in air temperature, air pressure and relative humidity, virtually eliminating any measurement errors resulting from these variations.

The sensor readings from the compensator are used to compensate the laser readings in linear measurement mode only. Without compensation, the variations in the refractive index of air can lead to significant measurement errors. Although it is possible to manually enter the environmental conditions (using hand-held instruments etc.), the compensation unit can perform the compensation accurately and automatically updated every 7 seconds.

The compensation unit can accept inputs from up to three material sensors, which measure the temperature of the machine or material under test. If you enter the appropriate material thermal expansion coefficient into the measurement software, the measurement can be normalised to a machine (material) temperature of 20 °C (68 °F).

Notice	Make sure the environmental automatic compensation is turned on, the appropriate material thermal expansion coefficient is entered corrected and the material temperature probe is placed in the right place.

Air disturbance

In the process of measurements, the ideal environment is that where the air is still or in the vacuum environment. Therefore, in the high-precision and high-accuracy nano-measurement, it is recommended to use the windshield.

Installation of linear optical kit

The optical kit should be located so that any change in their separation accurately matches the motion of the machine to be calibrated, and is not contaminated by other errors. The following factors should be taken into consideration when mounting the optical kit to ensure any measurement errors are minimised.

➢ Fix the optical kit directly to the point of interest.

The measurement optical kit are usually mounted at the tool or probe holder and workpiece position. Measurements will then accurately reflect the errors that will occur between the workpiece and tool or probe, and will not be affected by other errors.

➢ Fix the optical kit rigidly.

To minimise vibration effects and increase measurement stability, the optical kit should be fixed rigidly to the required measurement points; the mounting pillars should be kept as short as possible and any additional accessories should be of substantial cross section; the magnetic bases should be clamped directly to machine castings instead of clamping to thinner section machine guards or covers; make sure the clamping surfaces are flat and free from oil and dirt.

➢ Bring optics together at one end of axis of travel

Arrange the optical kit so that the linear interferometer and the linear reflector are close at one end of the axis of travel. This will make the beam alignment easier and minimizes the air deadpath for linear measurement.

➢ Avoid localized heat sources.

Avoid positioning the optical kit or laser beam too close to any localized heat sources. The hot air may cause expansion of the optical kit or air disturbances near the laser beam.

➢ Avoid thermal and mechanical creep

If the optical kit have been installed on the machine or moved from one environment to a new environment, it is wise to wait a while for them to stabilise. The length of time required will vary depending on circumstance and measurement accuracy required. It can take a while for the optical kit and their components to get acclimatized.

Do not over-tighten clamping screws and bolts. Excessive stress may cause plastic deformation
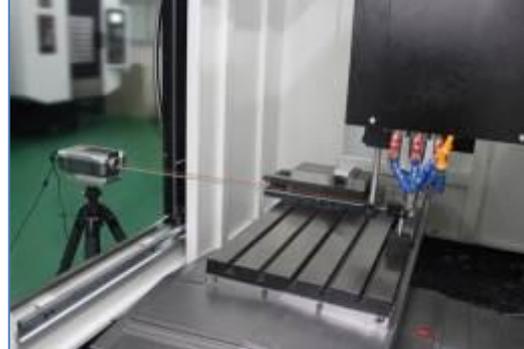
in the threads and a slow creep in position as the stress is relieved.

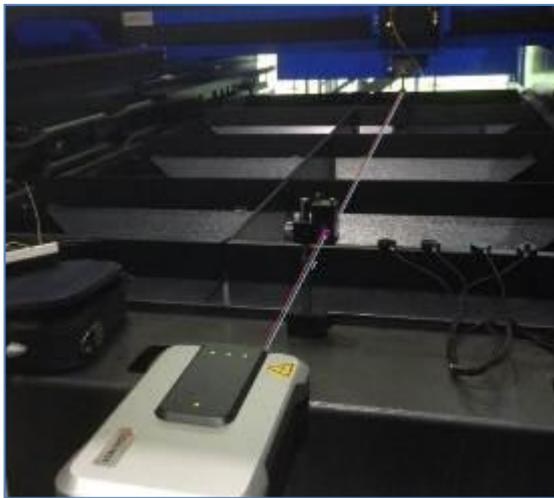# 4.4 Linear measurement application

The linear measurement can be used in linear axis measurement (for coordinate measuring machine, machine tool, X/Y/Z platform, laser cutting machine, etc.)

The measurement on a CMM

The measurement on machine tool

The measurement on laser cutting machine

The measurement on X/Y/Z platform

SJ6000 laser system provides the basis for the correction of positioning error (pitch compensation) and backlash of machine tools.

The machine controller manufacturers allow the positioning error in the machine positioning system to be eliminated by specifying the compensation for each axis. By compensation, the error can be reduced, even to almost zero, which can significantly improve the accuracy and precision of the machine. However, it is necessary to obtain the correct error compensation value when compensating, first, the difference between the expected position and the actual position of

Plot before compensation
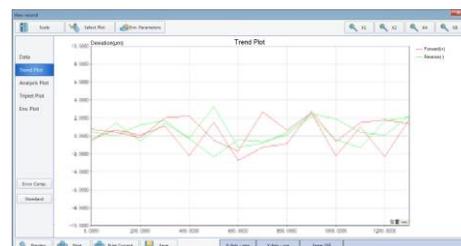
the machine must be measured at different points on the axis.

Using the laser interferometer to measure these errors and the software to record, you can easily get error table of the axis at multiple points. ChotestLaser SJ6000 software provides step-by-step user interfaces to guide the user to complete the operation of the error compensation.

Plot after compensation

4.5 The application of linear accessories

4.5.1 Lightweight linear accessories

Precision instrument measurement-lightweight linear accessories

For the applications where the weight or size of the optical devices may affect the dynamic performance of the machine or the optical devices are difficult to be installed, SJ6000 provides lightweight linear accessories, among which the small retro-reflector is 7g to 8g in weight, it can be magnetically attached onto machine under test and minimise the influence of the weight of the interferometer and its components during the measurement.

Lightweight linear accessories:

Beam reducer   Small retro-reflector
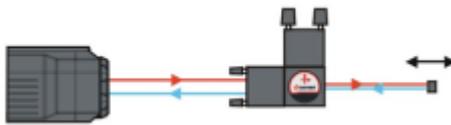
Beam path of small optics kit.

The measurement of thread measuring machine

The beam alignment of lightweight linear accessories

The application of lightweight linear accessories:

① Use the standard linear optical kit to align the beam by applying the"beam alignment procedure-method 2";

② Install the beam reducer in the front of the linear interferometer, the beam goes from the small aperture and return to the small aperture. Rotate the linear interferometer to ensure that the beam completely passes through the beam reducer and returns back.

③ Slightly adjust the small retro-reflector until you see the return beam is round and bright, and

then fix the small reflector.

4.5.2 Veering prism

Inclined axis measurement-veering prism

Veering prism has a built-in plane prism, it can deflect the laser beam in a plane through the range 25° to 90° by rotating the prism, It can be applied in the measurement of a slant-bed lathe or the coordinate measuring machine

Veering prism
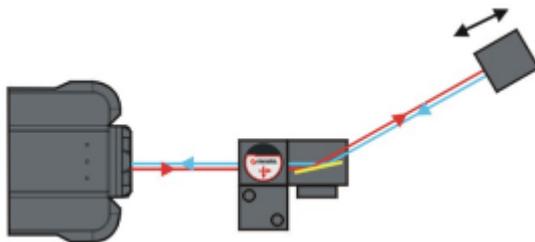
Beam path using veering prism

The measurement of slant machine tool

Beam alignment of veering prism

By using the veering prism, it is recommended to rotate the shutter on laser head to the shape of "⊥" formed by the apertures, the bottom of the aperture if for outward beam and the right aperture is for return beam.
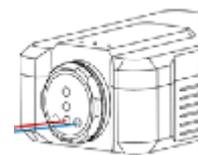
Install the veering prism on the back of the linear interferometer and perform alignment according to "beam alignment procedure-method 2"

4.5.3 Three-coordinate probe holder

Three-coordinate probe holder connectors have different threads, which can be screwed into the corresponding probe heads to fix the linear reflector.

Chapter 4   Angular measurement

Pitch and yaw angular errors are among the largest contributory factors to positioning inaccuracy in machine tools and measurement accuracy errors on coordinate measuring machines. Yaw errors can be caused by a machine moving unevenly along slack guideways, while pitch errors can be caused by bowing effects in these guideways.

The laser system can be used to measure the angular pitch and yaw positioning accuracy and repeatability at target positions along the machine axis of travel and the small angle measurements of rotary axis.

5.1 Angular measurement
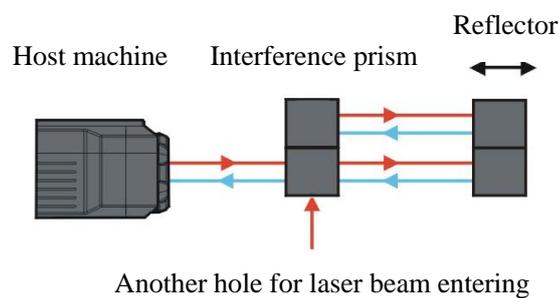
FIGURE5 - 1ANGULAR MEASUREMENT SCHEMATIC

Angular interferometer and angular reflector are applied in the angular measurement, and the angle prism and a relative rotation must be formed between them. The relative rotation can cause the optical path difference between the two beams. This optical path difference will be detected by the SJ6000 laser detector and the software will convert the changes of linear position to angle change.
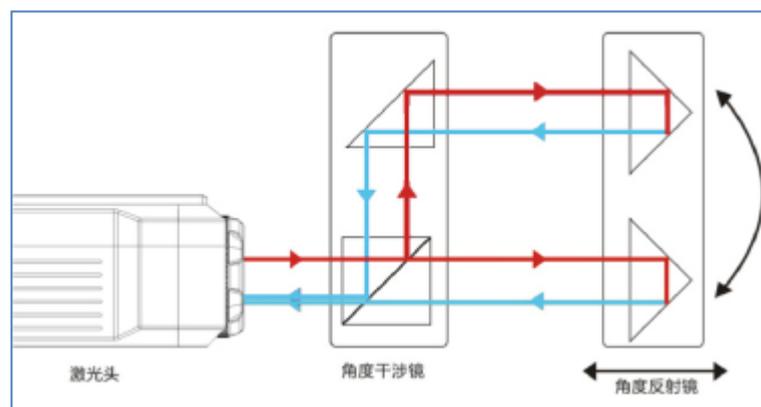
FIGURE5 - 2BEAM PATH OF ANGULAR MEASUREMENT

The angular interferometer is placed in the optical path between the laser head and the angle reflector. The side of the angular interferometer with two optical faces must face away from

the laser head, towards the angular reflector, i.e. the side with two optical faces is the incident plane and the side with one optical face is the outgoing plane.

The installation orientation of the angular optical kit indicates different angle measurement: the vertical installation is applied to pitch angle measurement, while horizontal installation is for yaw angle measurement.

Environmental compensation is not necessary when taking pitch and yaw measurements, as the two measurement beams are both equally affected by environmental changes.

5.2 Configuration of angular measurement

The angular measurement optics can be set up in many different configurations similar with the linear measurement configurations. The configuration of angular measurement falls into one of the following two categories:

Angular measurement components consist of:
1. Laser
2. Angular measurement optical kit
3. Measurement software

Horizontal axe measurement: like three-point line, the laser, angular interferometer and angular reflector are located on one axis line.

90° axis measurement: the axis to be measured is perpendicular to the laser head.

Horizontal axis measurement:
Measure yaw and pitch angle by installing the angular optical kit.
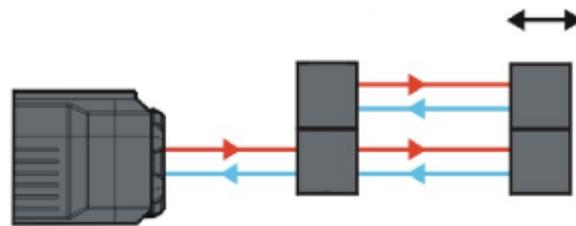
Beam path of horizontal angular measurement

90° axis measurement:
Horizontal 90° axis measurement and vertical axis measurement.
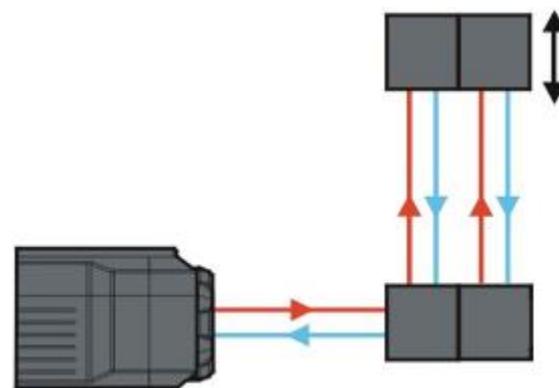
Beam path of 90° axis angular measurement

5.3 Angular measurement procedure

The operation steps of angular measurement are as follows:

① Set the software system in angular measurement mode;

② Align the laser beam with the axis of travel of the machine;

③ Capture data;

④ Select the evaluation standard to analyse the captured data.

5.3.1 Software set-up of angular measurement

A case on the yaw accuracy measurement of steel guide rail, 0~300mm, 40mm interval and 3 runs bidirectional.

1. Double-click the "ChotestLaser SJ6000 static measurement" icon on the desktop to open the measurement window.

\ Point	The environment compensation is not necessary for angular measurement.

2. Click the "Angular" button to open the measurement guide window. Set the parameters under the "Target position", and then click "Next".
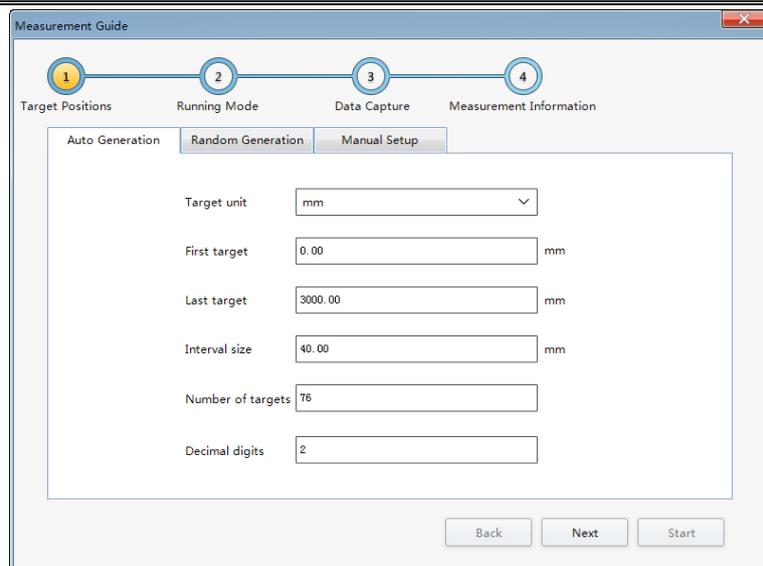
| ✎ Point	For the measurement of small rotary angle, it is wise to select the unit "°" as the measurement unit.

3. Select and set the items in "Running type". The purpose of the error band is to allow the software to warn you if the rotational error is greater than the width of this band. It has no influence on the analysis results.
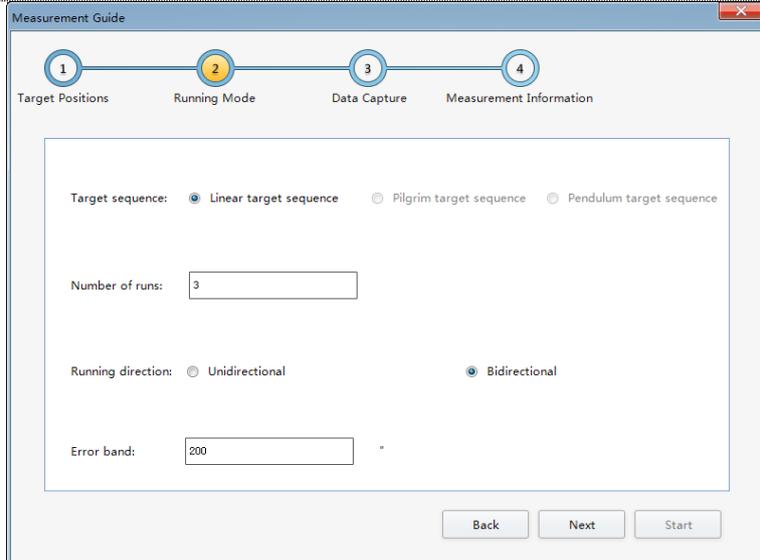
4. Set the items in "Capture data".

In the angular measurement, you must select the "time-based capture". If you cannot confirm the running time of the machine, it is wise to capture the data manually.
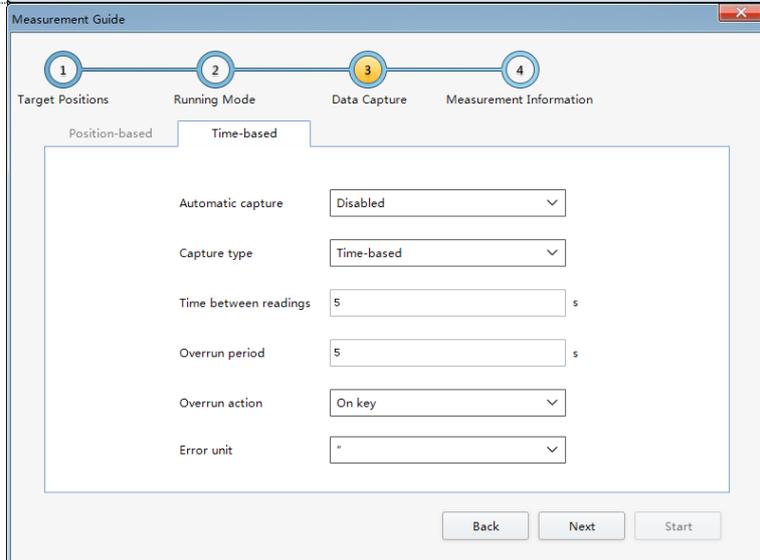
5. Set the items in "Measurement information", and then click "Start" to start the capture.
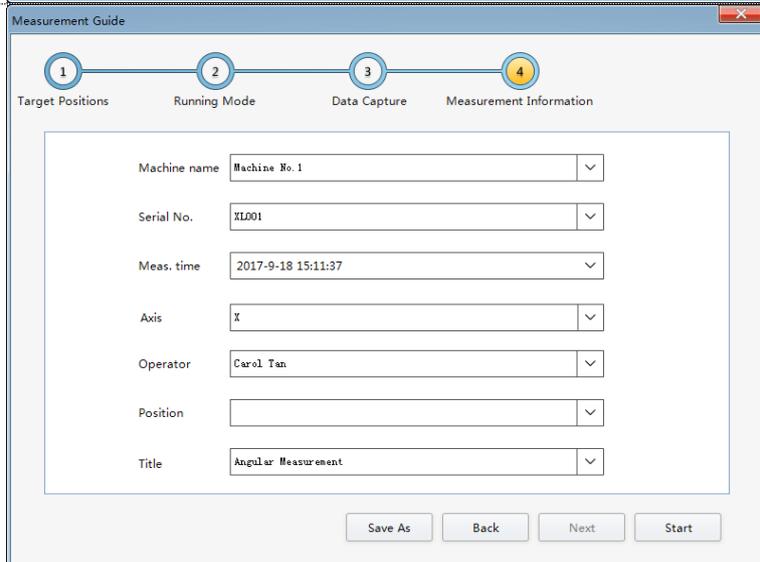
5.3.2 Beam alignment for angular measurement

The beam alignment procedure for angular measurement is the same as the linear measurement.

📖 "Beam alignment for linear measurement" (page 58)
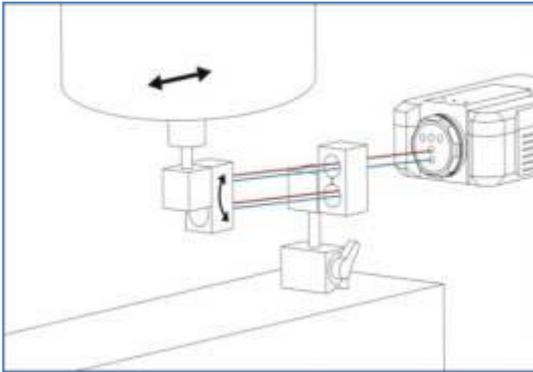
Angular measurement schematics

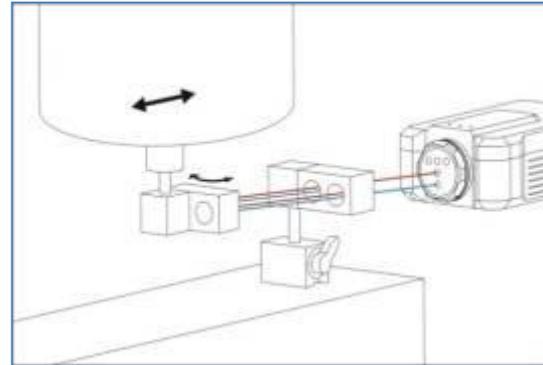FIGURE5- 3PITCH ANGLE MEASUREMENT OF THE AXIS OF TRAVEL

FIGURE5- 4YAW ANGLE MEASUREMENT OF THE AXIS OF TRAVEL

5.3.3 Data capture for angular measurement

The data capture for angular measurement can use the automatic "time-based capture", but it is wise to capture the data by hand.

5.3.4 Data analysis of angular measurement

The captured data will be saved as measurement records automatically, and the data analysis window will be open automatically after the capture.

📖 "Data analysis of linear measurement" (page 62)

5.4 Influence factors of angular measurement

Alignment error

The angular reflector should be aligned perpendicular to the incident beam and parallel to the angular interferometer when the system is datumed.

Angular optics kit error

Angular measurements are derived from the separation between the two reflectors in the angular reflector. The accuracy term is based on the tolerance of the centre-to-centre distance between the two reflectors. Therefore, the accuracy of the angular calibration coefficient directly affects the measurement error.

For more information about the setting of the angular coefficient, see Section 2.2.6 - System setting - Lens parameters.

📖 "System setting-Lens parameters" (page 39)

Installation of angular optical kit

📖 "Influence factors of linear measurement-Installation of linear optical kit" (page 58)

5.5 Angular measurement application

Precision measurement of small angle

The angular optical kit can achieve the precision measurement of small angle within $\pm 10\,°$. The right illustration below is the calibration of small angle test instrument performed by laser system.


The measurement of rotary table

The measurement of angle test instrument

Beam alignment for platform/slant table measurement

ChotestLaser SJ6000

For the measurement of yaw and pitch error of linear axis of a machine. Horizontal installation of the angular optical kit is applied to the yaw angle measurement, while vertical installation is applied to the pitch angle measurement, you can be install the optical kit according to the requirements.
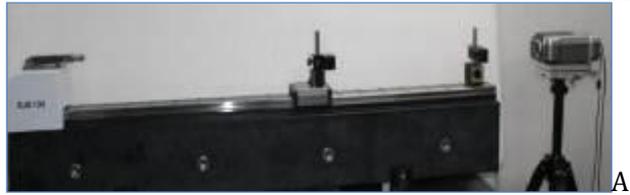
Angular measurement in horizontal direction

Chapter 5

激光器 直线度干涉镜 直线度反射镜

Straightness erro... ...e axis of travel of a machine. The stra... ...ghtness error of the linear axis.
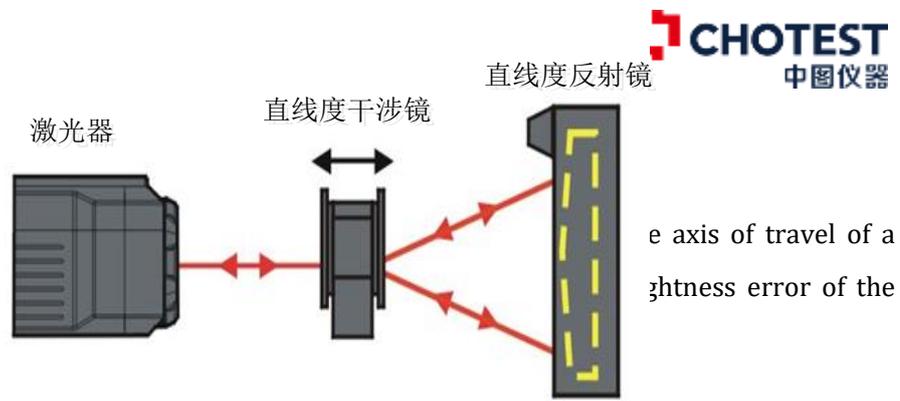
6.1 Principle

FIGURE6 - 1STRAIGHTNESS MEASUREMENT SCHEMATIC

The outgoing beam from SJ6000 laser passes through the straightness interferometer which splits it into two beams which diverge at a small angle and are directed to the straightness reflector. The beams are then reflected from the straightness reflector and return along a new path to the straightness interferometer. At the straightness interferometer the two beams are converged and a single beam is returned to the entry port in the laser head. The record and measurement are performed by photodetector and analyser.

The straightness measurement is performed by detecting the relative lateral displacement change of the optical path between the interferometer and the reflector. The straightness measurement can be in a horizontal or vertical plane depending on the installation orientation of both the straightness interferometer and reflector.
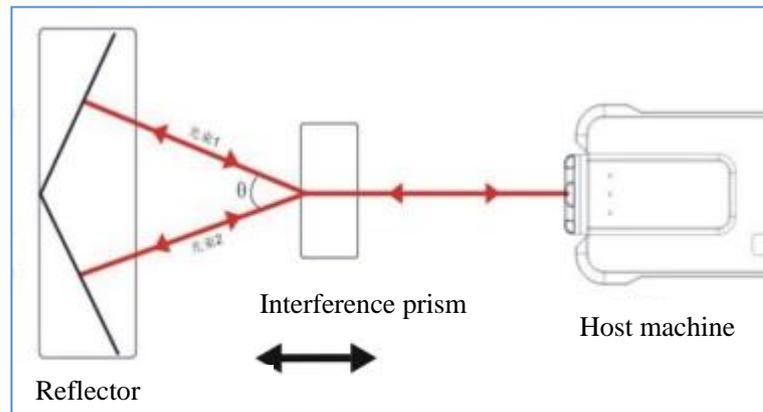
θ

Interference prism

Host machine

Reflector

FIGURE6 - 2BEAM PATH OF STRAIGHTNESS MEASUREMENT

6.2 Configuration of straightness measurement

Different straightness optical kits are available depending on the length of the linear guideway:

Short-range straightness: axial range (0.1 ~ 4.0) m, straightness measurement range ± 3mm;

Long-range straightness: axial range (1.0 ~ 20.0) m, straightness measurement range ± 3mm.

⚠ Caution	Straightness interferometer and reflector are paired with each other and used in pairs. Each straightness interferometer and reflector are marked with unique serial number, please do not use them interchangeably.

The straightness measurement optics can be set up in many different configurations. Most straightness measurement configurations fall into one of the following categories:
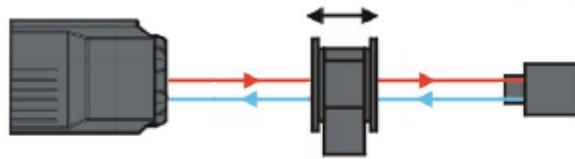
Straightness measurement on a horizontal axis: like three-point line, the laser, straightness interferometer and straightness reflector are located on one axis line.

Straightness measurement on a Z axis: the axis to be measured is the vertical axis, i.e. Z axis. Straightness accessories are necessary for this measurement.

Straightness measurement components consist of:
1. Laser
2. Straightness measurement optical kit
3. Measurement software

Horizontal axis measurement:
The straightness measurement can be on a horizontal or vertical axis depending on the installation orientation of the straightness optical kit.

Beam path of straightness measurement in horizontal direction
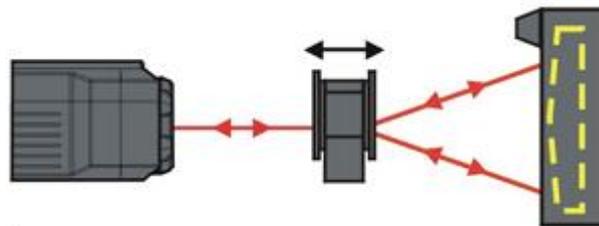
Beam path of straightness measurement in vertical direction

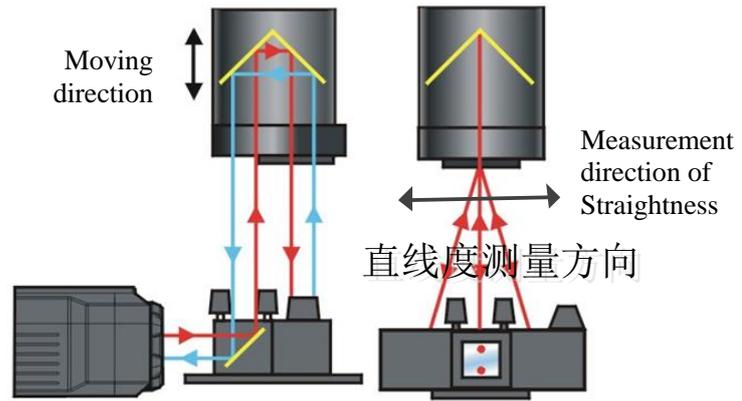Straightness measurement on Z axis: For the straightness measurements involving Z-axis, additional straightness accessories are required, including a large retro-reflector, a vertical veering prism and a straightness base.

Side view-beam path of straightness measurement on Z axis

Front view-beam path of straightness measurement on Z axis

6.3 Straightness measurement procedure

The operation steps of straightness measurement are as follows:

① Set the software system in straightness measurement mode;

② Align the laser beam with the axis of travel of the machine;

③ Install the straightness optical kit and adjust the signal strength;

④ Capture data;

⑤ Analyse the captured data.

## 6.3.1　Software set-up of straightness measurement

A case on the horizontal straightness measurement of steel guide rail, 0~3000mm, 40mm interval and 1 run unidirectional.

1. Double-click the "ChotestLaser SJ6000 static measurement" icon on the desktop to open the measurement window.

\ Point	The environment compensation is not necessary for straightness measurement.

2. Click the "Straightness" button to open the measurement guide window. Set the parameters under the "Target position", and then click "Next".
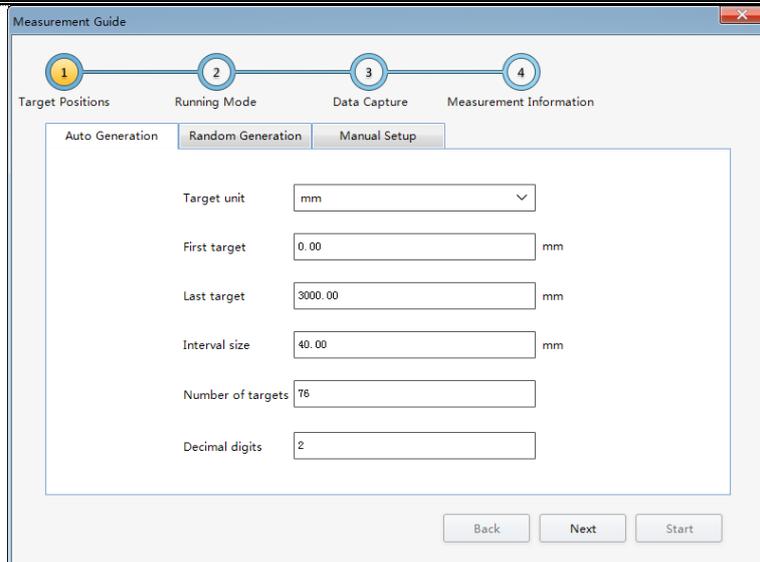

3. Select and set the items in "Running type".
The purpose of the error band is to allow the software to warn you if the rotational error is greater than the width of this band. It has no influence on the analysis results.
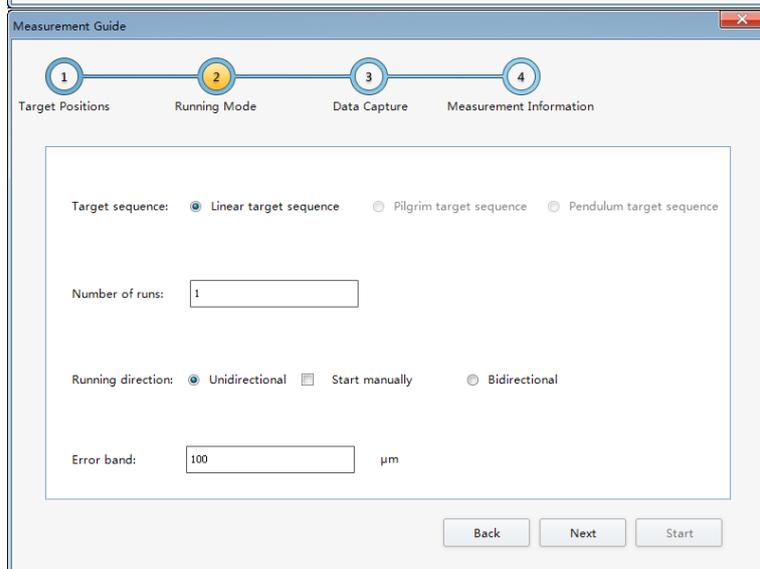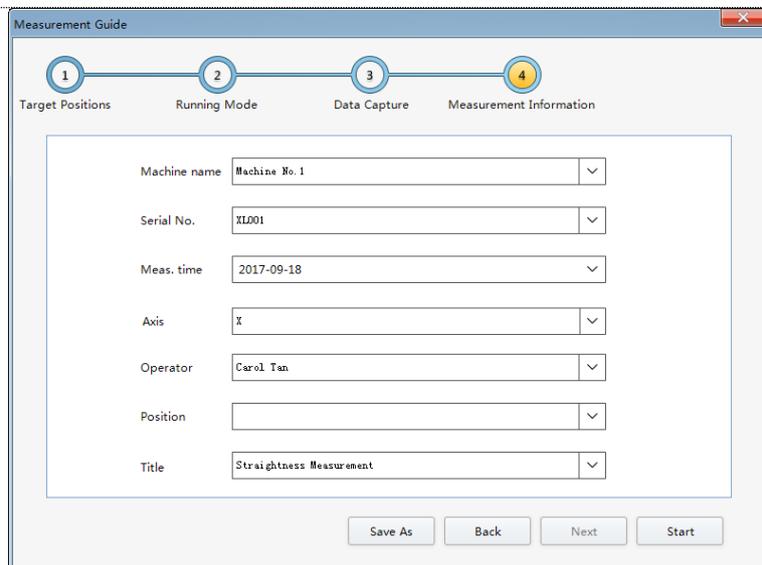
4. Set the items in "Capture data".

In the straightness measurement, you must select the "time-based capture" because the device cannot get the position information. If you cannot confirm the running time of the machine, it is wise to capture the data manually.
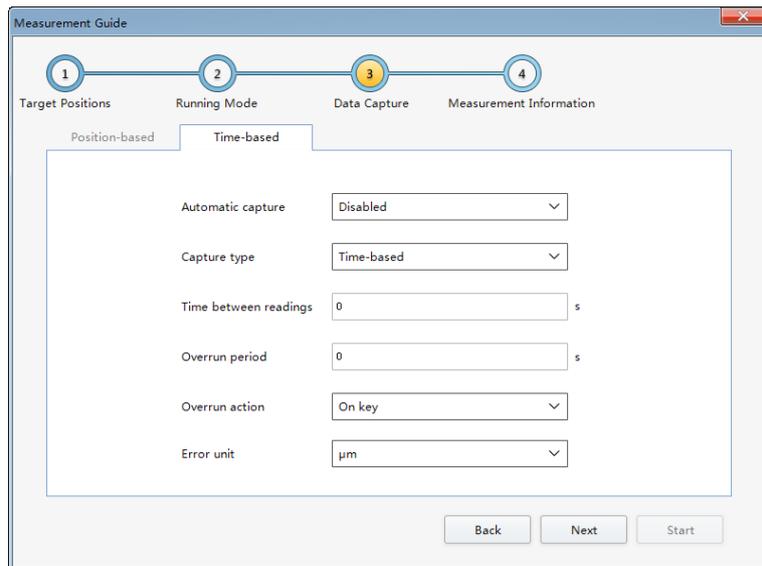
5. Set the items in "Measurement information", and then click "Start" to start the capture.

6.3.2　Beam alignment for straightness measurement

Straightness measurements can be performed on the axis in left-right direction and up-down direction depending on the installation method of the straightness interferometer and reflector. The alignment procedures discussed in this section assume that the optical kit are set up to measure the straightness in horizontal direction.

①Align laser beam

The consistency of the laser beam and the travel path of the axis under test is the basis for the straightness measurement. The preparation work will directly affect the later measurement and results.

Therefore, it is recommended to align the beam with a linear reflector by reflecting the beam to the laser head, so that you can virtually see the alignment state during the whole process of adjustment and improve alignment accuracy.

📖 "Beam alignment for linear measurement" (page 58)

② Install straightness interferometer

After the preparation, replace the linear reflector with the straightness reflector.

Rotate the straightness interferometer to the horizontal direction and adjust its height, so as to let the laser beam pass through the small aperture reaching the back of straightness interferometer.

▶Important	Because the laser has been aligned by linear reflector, do not adjust the laser head, you can only move the interferometer in this step.

③ Install straightness reflector

Coarse positioning: mount the straightness reflector in the proper position where it is at a suitable distance from the moving straightness interferometer, i.e. nearest to the straightness reflector at least 0.1 m for short-range straightness.

▶Important	You can design an extension device outside the guideway to meet the installation requirements of the optical kit and measure the entire travel of the guideway.

Fine positioning: adjust the straightness reflector position by moving left, right, up or down, so that the beam passing through the small aperture on the interferometer reaches the position under the centre mark on the reflector, and return back to the white point on the back of the straightness interferometer.

▶Important	Please make sure the beam is in central symmetry! To ensure the incident beam is in the centre position, an important detection method is applied, i.e. when the incident beam strikes the central position, three reflection spots will appear. Make the middle spot return to the white point on the back of the straightness interferometer.

④ Rotate interferometer

Rotate the interferometer to the measuring position (from the horizontal direction to the vertical direction), so that the beam can pass through the interferometer and be reflected back to the return aperture on the laser head.

Observe if the two spots of the return beam overlap, if not, rotate the interferometer until the two return beams converge.

▶Important

Adjust the reflector according to the return beam spot location, if the return beam strikes above or below the white spot or return aperture, adjust the reflector up and down, if it strikes on the left or right of the white spot or return aperture, adjust the reflector knob.

⑤ Check the tilt angle of interferometer

Open the shutter on laser head and deactivate the magnetic table seat, and then turn the magnetic table seat and simultaneously observe the beam signal meter until the beam signal indication is in the strongest position, and then fix the seat.

⑥ Adjust the gradient

On the prerequisite that that the signal strength over the entire travel meet the requirement of measurement, it is necessary to adjust the angle between the laser beam and the guideway to a sufficiently small level before measurement. This adjustment process is called slope adjustment.

Datum the measurement reading with the straightness reflector and straightness interferometer at their closest approach.

Move the straightness reflector and interferometer until they are at their greatest separation and the measurement reading is R. If R is beyond the requirement of the optical kit, adjust the control knob on the reflector to adjust the reading to a reasonable range.

Adjustment   Zeroing

B   R A
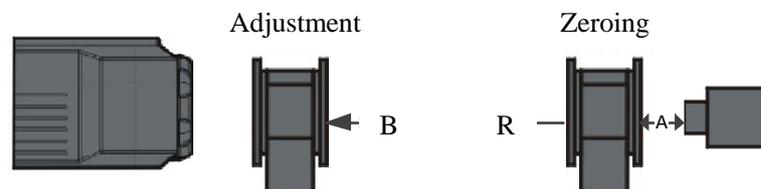
The separation of the two optics at their closest approach recorded is A; the distance travelled by the interferometer is B and the reading is R.

Adjust the tilt control of the straightness reflector so that the displayed reading changes to the value calculated by "-R*B/A".

Check the repeat this procedure for several times until the reading is sufficiently small within the range, Specifically, R value is within 50μm for short-range straightness and within 200μm for long-range straightness.

Straightness measurement schematics

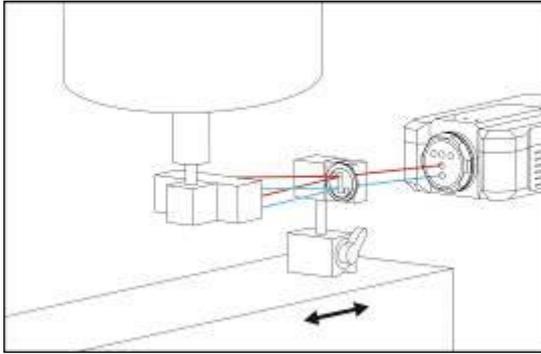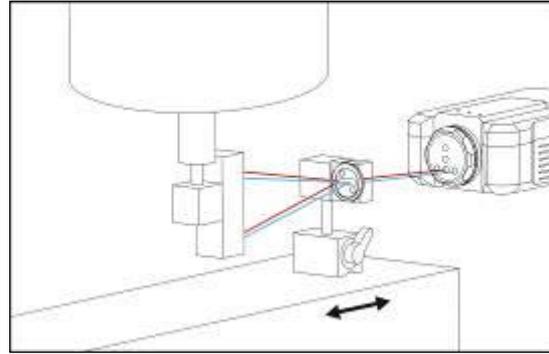**FIGURE6- 3STRAIGHTNESS MEASUREMENT OF TABLE IN HORIZONTAL DIRECTION**

FIGURE6- 4STRAIGHTNESS MEASUREMENT OF TABLE IN VERTICAL DIRECTION

▶ 重 要

Horizontal straightness measurement: straightness interferometer prism is vertical and the apertures on laser shutter are shaped like "T". Vertical straightness measurement: straightness interferometer prism is horizontal and the apertures on laser shutter are shaped like "⊥".

6.3.3　Data capture for straightness measurement

The data capture for straightness measurement can use the automatic "time-based capture", but it is wise to capture the data by hand.

6.3.4　Straightness data analysis

After the capture of data, the data will be automatically saved in measurement records and the analysis window will be open automatically.

Analysis standard: only standard BS 3800-2-1991 is applicable to the straightness analysis.

Trend plot: the trend plot of the original captured data.

Accuracy calibration: a regression line fitted by least squares method, the slope is the regression slope. Straightness error is the straightness deviation of the object under measurement.

6.4 Influence factors of straightness measurement

Air disturbance

The measurement is best performed in very still air at uniform temperature (where there is no turbulence) or in air that is being vigorously stirred. The slow air flow will cause the laser reading to fluctuate.

Installation of straightness optical kit

📖"Influence factors of linear measurement-Installation of linear optical kit" (page 58)

6.5 Straightness measurement application

Straightness error measurement of machine axes (CNC machine tools, coordinate measuring machines, etc.)

Straightness measurements show bending or overall misalignment in the guideways of a machine. This could be the result of wear in these guideways, an accident which may have damaged them, or poor machine foundations that are causing the axis to bow. Straightness error will have a direct effect on the positioning and contouring accuracy of a machine.

Machine spindle/linear motor guideway measurement

For a longer axis, the traditional measurement methods cannot meet the requirements of length or desired accuracy.
In general, it is advised that you use the light-weight straightness interferometer as the moving component.

Straightness measurement of X/Y/Z table

For this measurement, fix the straightness reflector and mount the straightness interferometer on the moving table. The straightness of the table will be recorded according to the movement of the straightness interferometer.
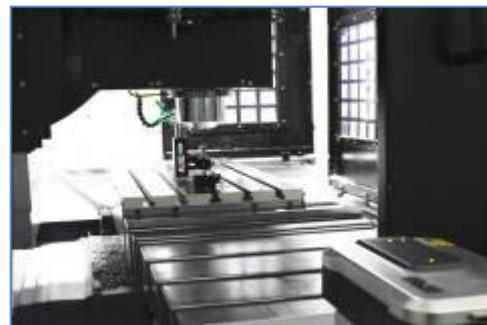
Chapter 6　　Parallelism measurement

Parallelism measurement is based on straightness measurement. The angular relationship between two principal axes is determined by using the common straightness reflector as the reference,

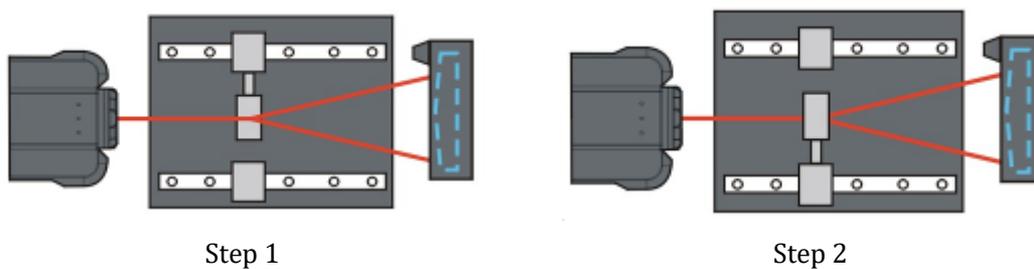## 7.1 Principle of parallelism measurement

Parallelism measurement is based on the straightness measurement, it consists of two groups of straightness measurement with a common straightness reflector as the reference. The parallelism is calculated by the subtracting the slope ($\Theta 2$) of second moving axis from the slope ($\Theta 1$) of first moving axis.

Parallelism= $\Theta 1 － \Theta 2$

7.2 Configuration of parallelism measurement

Parallelism measurement components consist of:

1. Laser
2. Straightness measurement optical kit
3. Measurement software

Measurement procedure:

Step 1　　　　　　　　　　　　　　　　Step 2

7.3 Parallelism measurement procedure

7.3.1　　Software set-up of parallelism measurement

A case on the horizontal parallelism measurement of steel guideway, 0~3000mm, 40mm interval and 1 run bidirectional.

1. Double-click the "ChotestLaser SJ6000 static measurement" icon on the desktop to open the measurement window.

！要点	The environment compensation is not necessary for parallelism measurement.

2. Click the "parallelism" button to open the measurement guide window. Set the parameters under the "Target position", and then click "Next".


！要点	The parallelism measurement applies to two guideways. If the guideways are different in length, select the shorter one to set the related information.

3. Select and set the items in "Running type".

The purpose of the error band is to allow the software to warn you if the rotational error is greater than the width of this band. It has no influence on the analysis results.
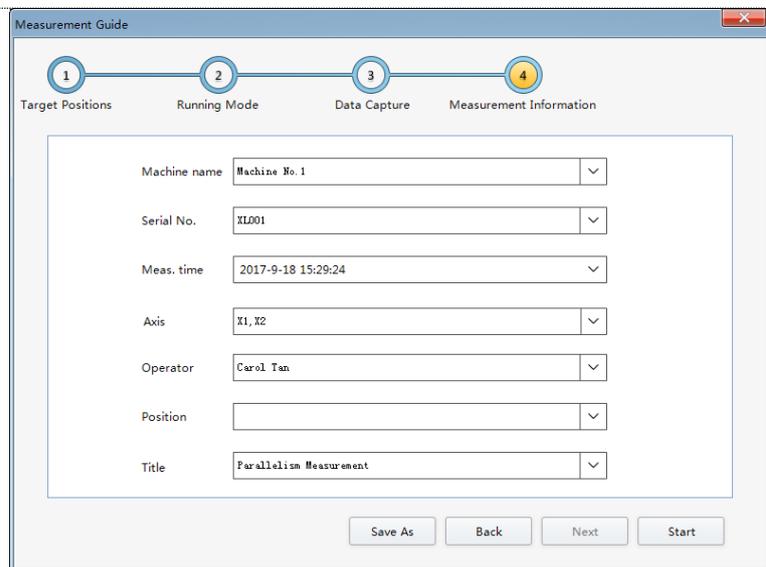
4. Set the items in "Capture data".

In the parallelism measurement, you must select the "time-based capture" because the device cannot get the position information. If you cannot confirm the running time of the machine, it is wise to capture the data manually.
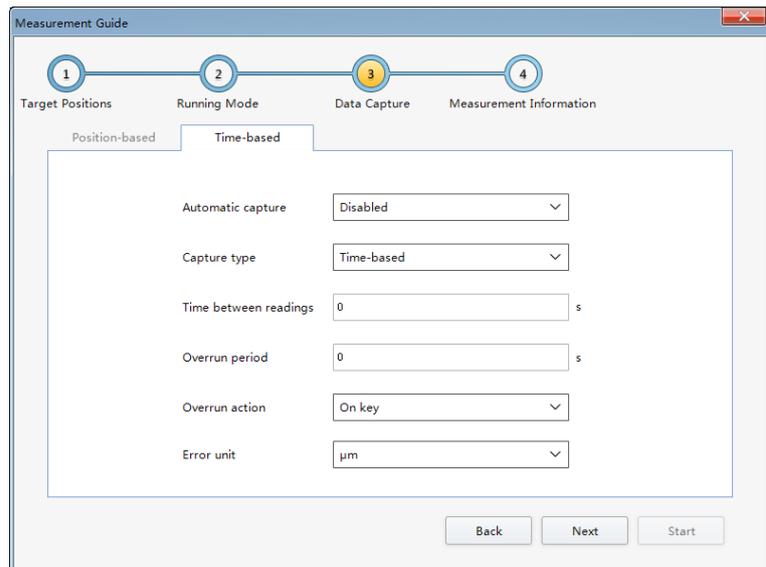
5. Set the items in "Measurement information", and then click "Start" to start the capture.

7.3.2 Beam alignment for parallelism measurement

① Align laser beam

📖 "Beam alignment for linear measurement" (page 58)

② Install straightness optical kit

📖 "Straightness measurement" (page 79)

③ Key to parallelism measurement

Maintain the consistency of the two measurement steps.

- The same moving direction of the interferometer.
- The same incident plane of the interferometer.
- The same sign (＋ or -) on laser reading.
- Keep the straightness reflector stationary in measuring.

7.4 Parallelism measurement application

The parallelism measurement on two guideways (or more).

ChotestLaser SJ6000

Step1   Step 2

PARALLELISM MEASUREMENT APPLICATION

Chapter 7   Perpendicularity measurement

The measurement of perpendicularity is the extension of the straightness measurement in two-dimensional direction. The perpendicularity measurement is performed by measuring the straightness on two nominally orthogonal axes based on the same reference. By comparing the straightness values of the two axes, the perpendicularity is obtained.

8.1 Principle of perpendicularity measurement

The common reference usually refers to the optical alignment axis of the reflector in the two measurements, it is neither be moved nor adjusted between the two measurements. The optical square is used in one of the straightness measurements at least to allow the laser beam to be adjusted to align with the straightness interferometer without moving the straightness reflector.

Perpendicularity error = prism error - ($\theta1 + \theta2$)

8.2 Configuration of perpendicularity measurement

Perpendicularity measurement falls into one of the two categories below:
Horizontal-horizontal perpendicularity measurement;
Vertical-horizontal perpendicularity measurement: use straightness accessories
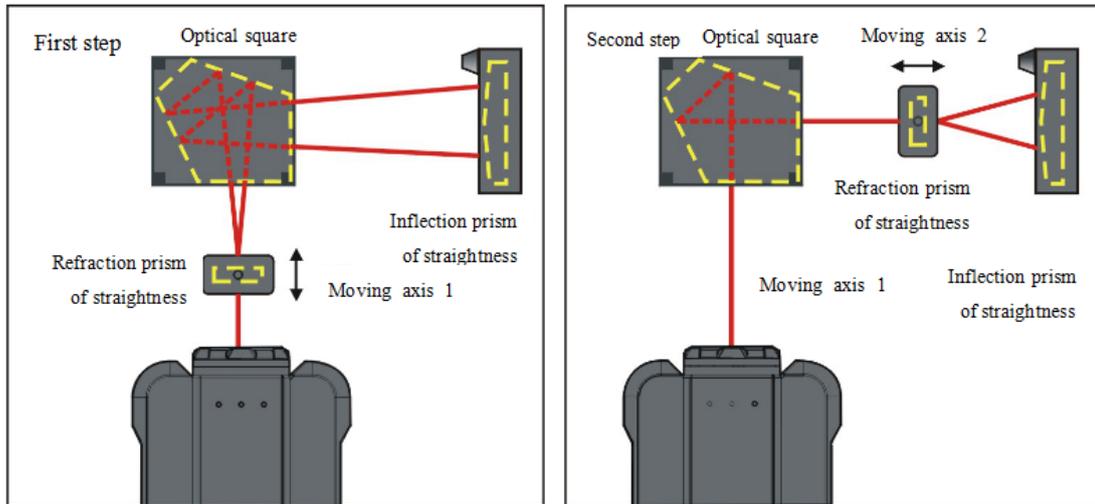
Perpendicularity measurement components consist of:
1. Laser
2. Straightness measurement optical kit
3. Perpendicularity optical kit
4. Measurement software

Horizontal-horizontal perpendicularity measurement:

Step 1, take straightness measurement on the axis of movement 1

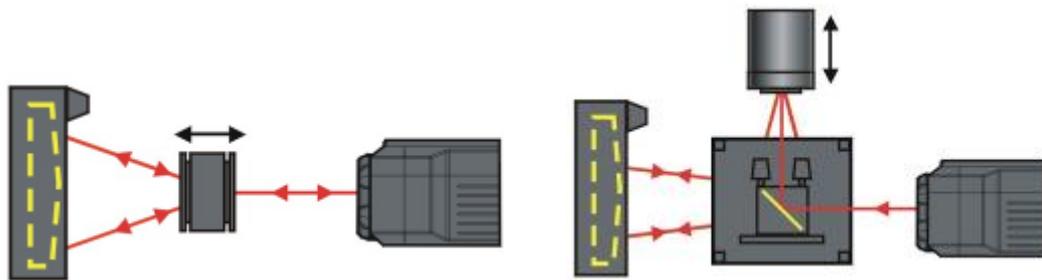Step 2, take straightness measurement on the axis of movement 2

Set-up of horizontal-horizontal perpendicularity measurement

Vertical-horizontal perpendicularity measurement:

Step 1, take straightness measurement on the horizontal axis

Step 2, take straightness measurement on the Z(vertical) axis

Set-up of vertical-horizontal perpendicularity measurement

8.3 Perpendicularity measurement procedure

8.3.1 Software set-up of perpendicularity measurement

A case on the horizontal-horizontal perpendicularity measurement in horizontal plane, 0~1000mm, 100mm interval and 1 run unidirectional.
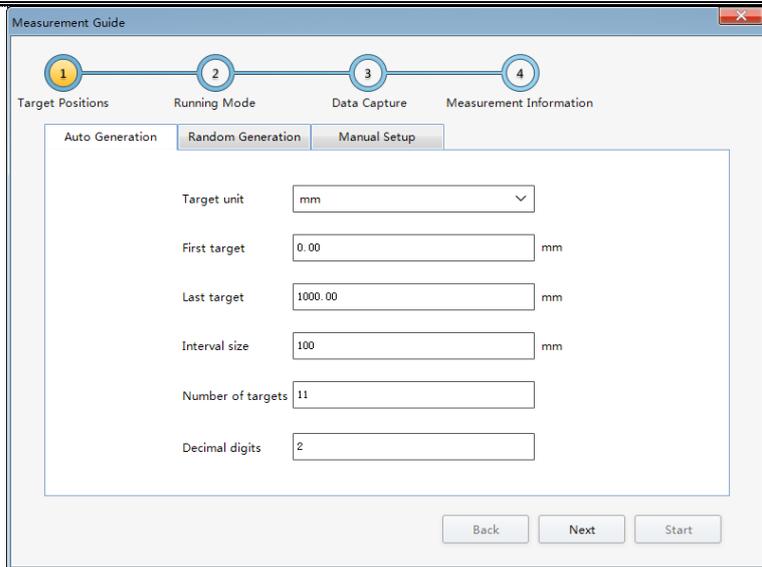
1. Double-click the "ChotestLaser SJ6000 static measurement" icon on the desktop to open the measurement window.
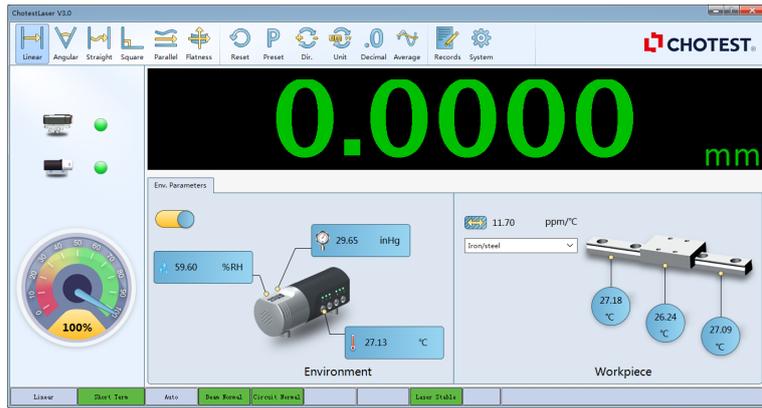
| ! 要 点	The environment compensation is not necessary for perpendicularity measurement.

2. Click the "Perpendicularity" to open the perpendicularity measurement guide window. Set the parameters under the "Target position", and then click "Next".

| ! 要 点	The software performs data capture on the two axes according to the set position information; therefore, you must consider the length of each axis.

3. Select and set the items in "Running type".
The purpose of the error band is to allow the software to warn you if the rotational error is greater than the width of this band. It has no influence on the analysis results.
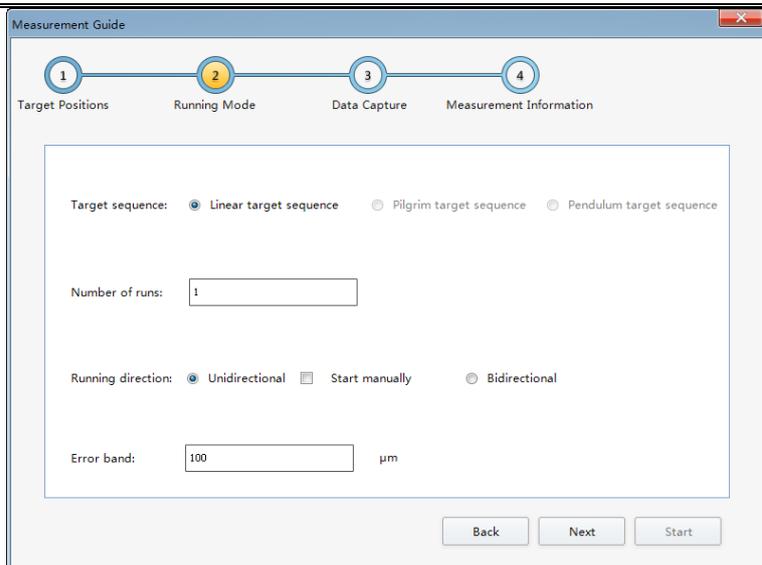
4. Set the items in "Capture data".

In the parallelism measurement, you must select the "time-based capture" because the device cannot get the position information. If you cannot confirm the running time of the machine, it is wise to capture the data manually.
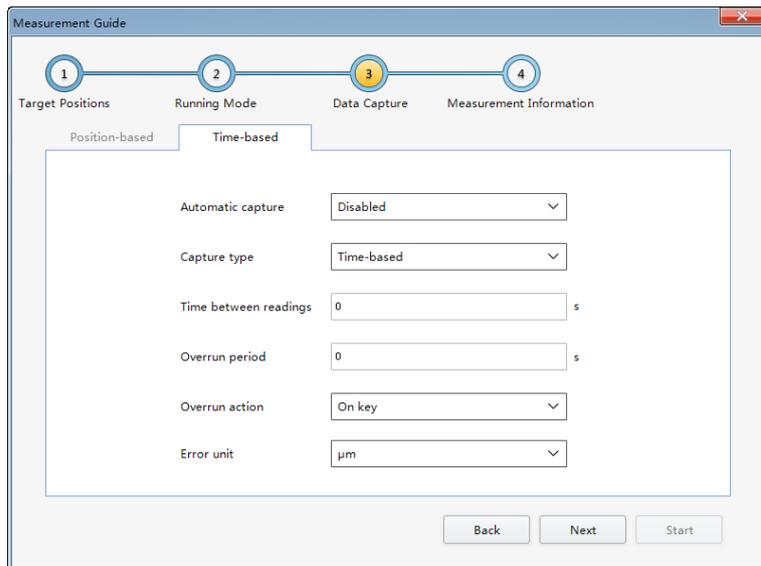
5. Set the items in "Measurement information", and then click "Start".
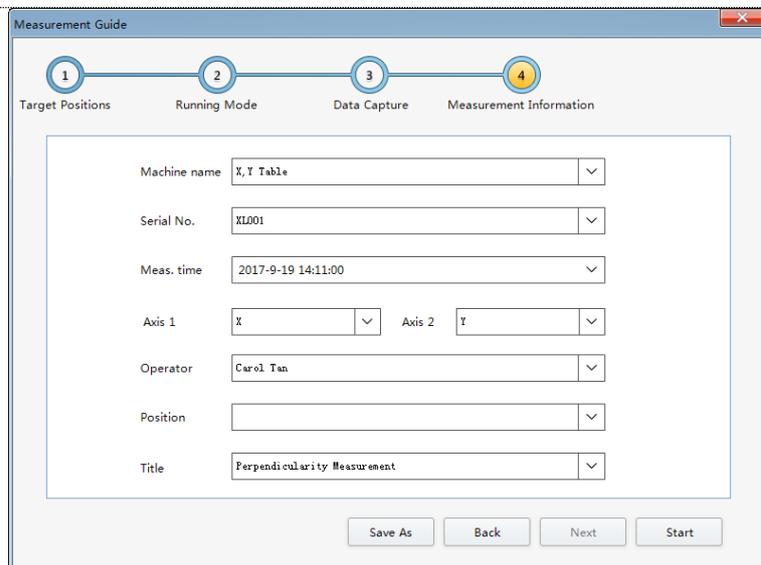
Determine the movement direction of the straightness interferometer and the sign convention（＋or－）of the data in the "Perpendicularity measurement direction". The perpendicularity measurement must follow the convention of the "Perpendicularity measurement direction".
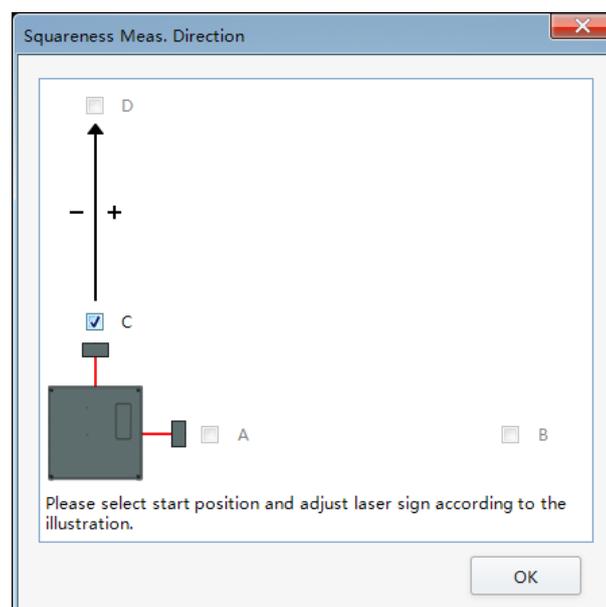
Click "Start" to start the straightness measurement on the first axis.

After the straightness measurement on the first axis, the software will show the measurement direction of the second axis.
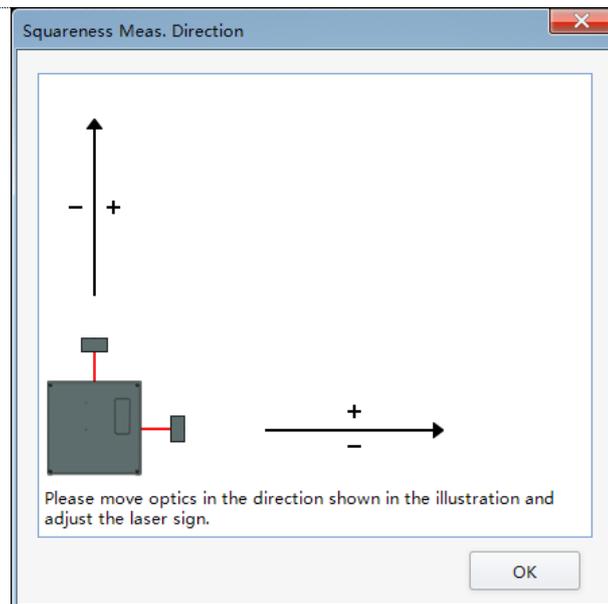
8.3.2 Beam alignment for horizontal-horizontal perpendicularity measurement

① Align with one axis

Determine one axis to perform linear alignment.

📖"Beam alignment for linear measurement" (page 58)

② Mount optical square.
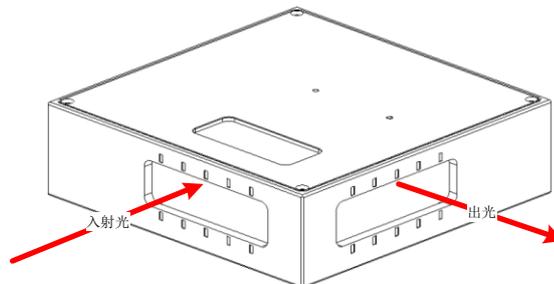
Place the optical square horizontally, so that the incident beam can pass through the centre of upper prism, and then rotate the optical square until it is perpendicular to the incident beam.

③ Install straightness optical kit

📖"Beam alignment for straightness measurement" (page 83)

④ Key to perpendicularity measurement.

- The same incident plane of the interferometer.

- Keep the straightness reflector stationary in measuring.

- The measurement process must follow the guidance from the software.

8.3.3   Perpendicularity measurement and analysis

After measurement, the perpendicularity analysis window will be open automatically.

③ Install straightness optical kit

8.4 Perpendicularity measurement application

Perpendicularity error measurement of machine axes (CNC machine tools, coordinate measuring machines, etc.)

The perpendicularity measurement is performed by determining the perpendicularity by comparing the straightness values of two nominally orthogonal axes. Perpendicularity errors could be the result of wear in machine guideways, an accident which may have caused damage, poor machine foundations or misaligned home position sensors on gantry machines. Perpendicularity error will have a direct effect on the positioning and contouring accuracy of a machine.

Typically, for a machine axis more than 1.5m in length, the optical method, e.g. using a laser interferometer, is the only option for the measurement, because the traditional physical gauges, such as a square (metal or marble, etc.), are generally limited to the length range of 1m.

Perpendicularity measurement of X, Y axes

Perpendicularity measurement of X-Y table and horizontal plane: it is very important to set a common reference for the measurement, whatever the type of X-Y table, including gantry type and hybrid type, and the size of the table. The straightness reflector is kept stationary during the measurement.

PERPENDICULARITY MEASUREMENT OF X-Y TABLE

Vertical-horizontal perpendicularity measurement

Vertical-horizontal perpendicularity measurement is usually used in the measurement of coordinate measuring machine and machine tool.

Vertical-horizontal perpendicularity measurement components consist of:

1. Laser

2. Straightness optical kit

3. Optical square

4. Straightness accessories

5. Measurement software

Additional straightness accessories are required, including a large retro-reflector, a vertical veering prism and a straightness base.

Step 1 is to take straightness measurement on the axis of movement 1; step 2 is to take straightness measurement on the axis of movement 2. The laser head and the straightness reflector are the stationary components while the straightness interferometer is the moving device during the measurement.
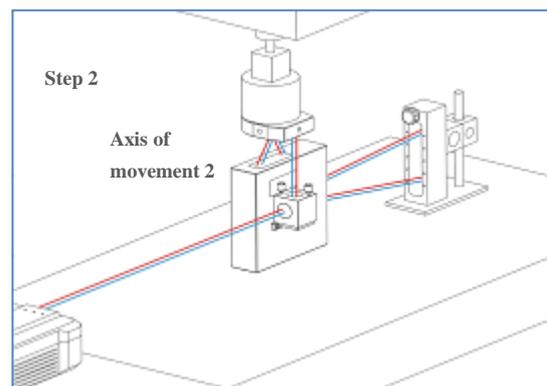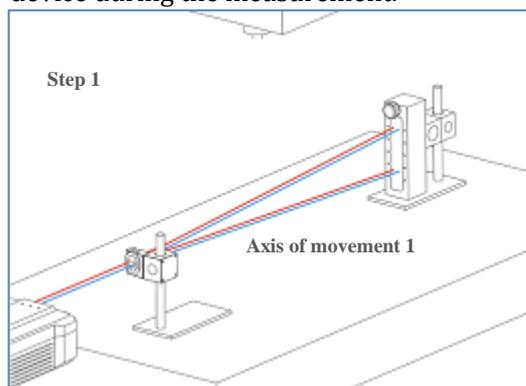
Chapter 8   Flatness measurement
9.1 Principle of flatness measurement

Flatness measurement is the extension of angular measurement by using angular measurement accessories to record a series of plane position angle and then convert them to the changes of height. In most cases, at first, Moody method (diagonal method) is applied to measure the position height change values in the different locations on the platform, and then the software provided will calculate the flatness of the entire platform.

FIGURE9- 1BEAM PATH OF FLATNESS
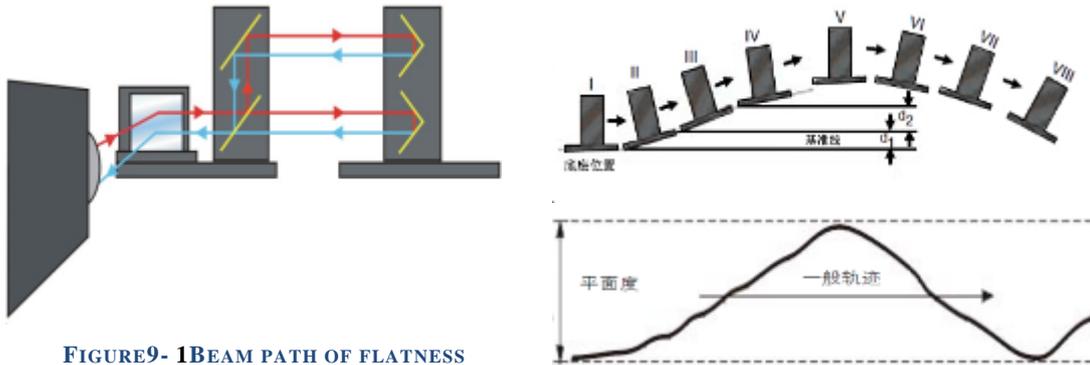MEASUREMENT PRINCIPLE

9.2 Configuration of flatness measurement

Flatness measurement components consist of:	1. Laser
	2. Angular measurement optical kit
	3. Flatness measurement optical kit
	4. Measurement software
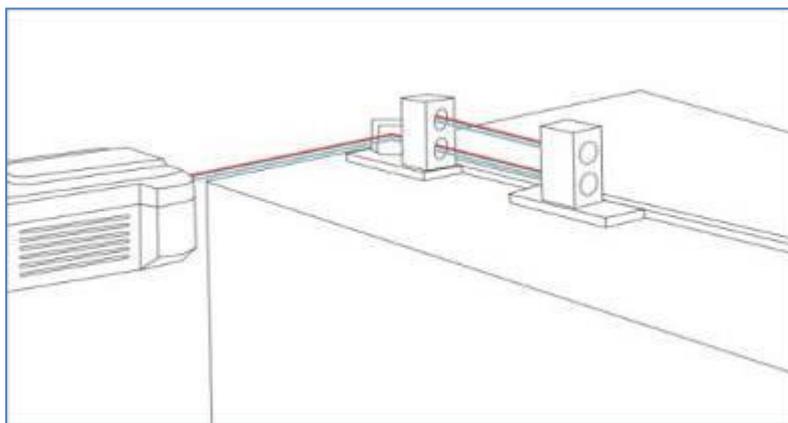
FIGURE 1BEAM PATH OF FLATNESS MEASUREMENT

9.3 Flatness measurement

To measure the flatness of a surface, a number of measurement lines need to be taken over the surface. Moody method, also known as "米" Method in Chinese, is commonly used in flatness measurement.

With Moody method, if the laser is located at point G and the beam aims at point E, it is advised to take the measurement on lines in the order of EA, CA, DH, EG, AG, BF, CE and GC .

For flatness measurement, flatness reflector is applied to adjust the beam and the angular interferometer is fixed on the flatness base as the moving component during the measurement.

Step 1 Take measurement on line AE		Step 5 Take measurement on line AG	
Step 2 Take measurement on line AC		Step 6 Take measurement on line BF	
Step 3 Take measurement on line HD		Step 7 Take measurement on line CE	
Step 4 Take measurement on line GE		Step 8 Take measurement on line CG	
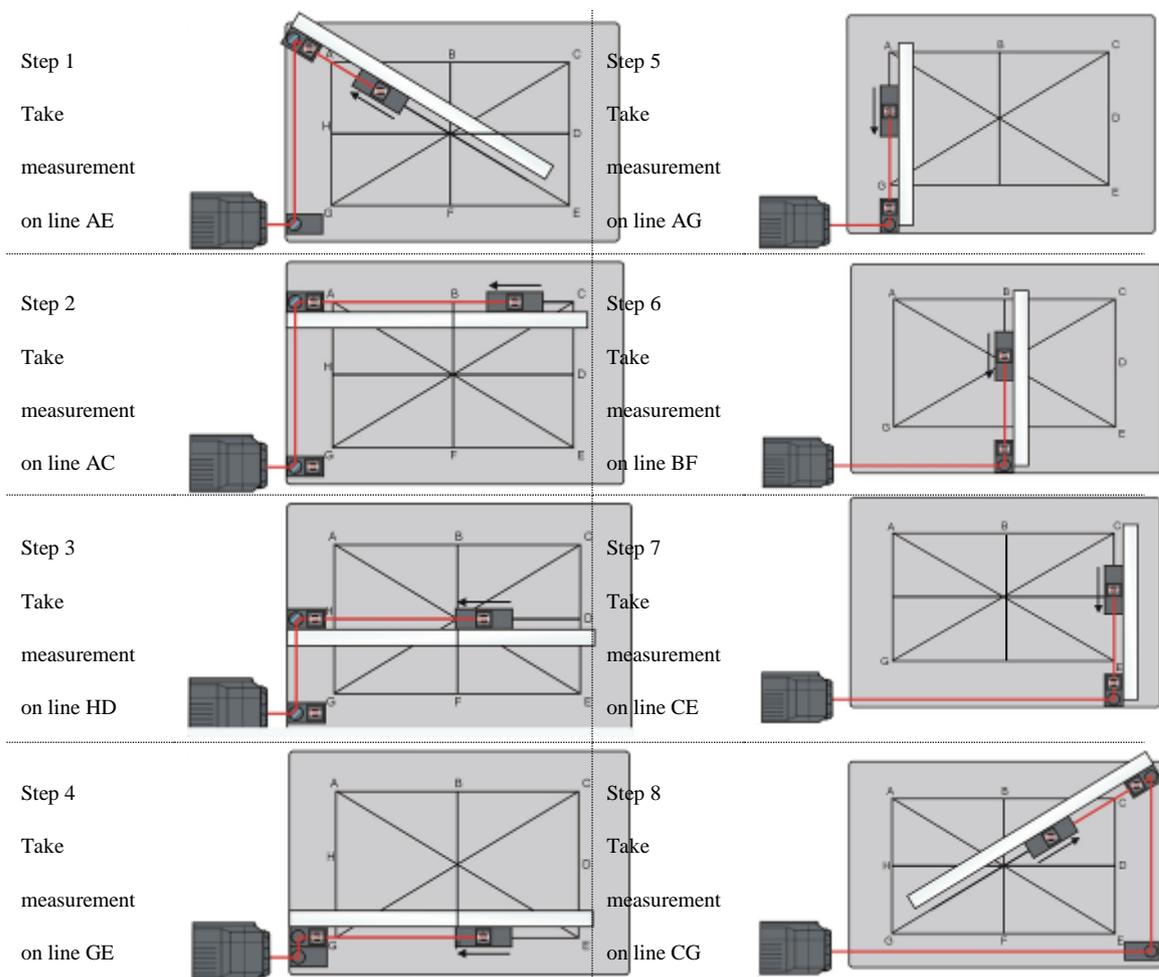
9.4 Flatness measurement application

Flatness measurement can be applied to measure the flatness of marble tablet and plate, etc.

Chapter 9   Rotary axis measurement
10.1   Principle of rotary axis measurement

Using SJ6000 laser system, the rotary axis can be calibrated by applying angular measurement accessories in conjunction with extremely high precision multi-tooth indexer. The indexer can rotate to, and lock its position at, any one of 72 positions in the range 0° to 360° at 5° intervals. It contains a high-precision, automatic controlled toothed plate, which can achieve ± 1″ angle positioning in locked state.
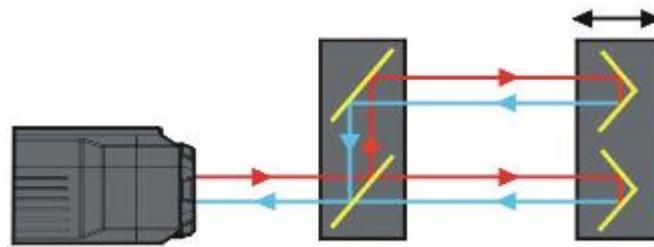
ANGULAR MEASUREMENT SCHEMATIC

The angular positions of the rotary table are measured by using the laser, angular interferometer and angular reflector. The software combines the angular positions of rotary table with the reading from the laser and the angular optical kit, which are the true rotary angle positions of the machine axis to be calibrated. After the measurement, the error of the rotary axis will be automatically calculated according to the selected machine tool standard for the purpose of compensation.

10.2   Configuration of rotary axis measurement

|		
Rotary axis measurement components consist of: 1. Laser 2. Angular measurement optical kit 3. High precision rotary table 4. Measurement software	 Rotary table	High precision rotary table: Height: 165mm Diameter: 125mm Angular measurement range: 0-360° Accuracy of measurement: ±1 arcsecond Highest rotation speed: 10rpm

10.3　Rotary axis measurement application
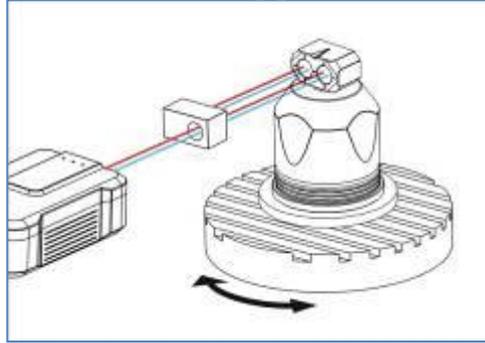
Rotary axis calibration procedure:

①　 Position the rotary table on the axis to be measured and align the laser system (the rotary table can be automatically adjusted to be perpendicular to the optical axis).

②　Set the laser reading to zero at the beginning of the axis, and then start capturing data on computer and run the CNC program.

③　Record the laser reading when the axis returns to the start position (the laser reading is zeroed)　after overrun.

④　The axis move to the second target at a step size of 5 ° and the built-in reflector in rotary table takes a reverse rotation at 5 °.

⑤　The system records the positional error of the axis at 5° by combing the readings of laser with that of the rotary table.

⑥　The all data plot will be generated after the rotary axis moved to the measurement position one by one.

Chapter 10   Dynamic measurement

11.1   Principle of dynamic measurement

Dynamic measurement includes time-based dynamic measurement and distance-based dynamic measurement. Dynamic analysis and FFT analysis can be applied to the captured data by neither method.

The software can be applied to the measurement of linear vibration, angular vibration, dynamic straightness and cutting situation in conjunction with linear, angular or straightness optical kit. It can perform "real-time" data monitoring (e.g. debugging machine parameters) and save the final results for further dynamic analysis.

11.2   Time-based dynamic measurement

Dynamic linear measurement

Click the "Linear" button to switch to linear measurement mode. Click it again to open the "linear measurement guide" window.
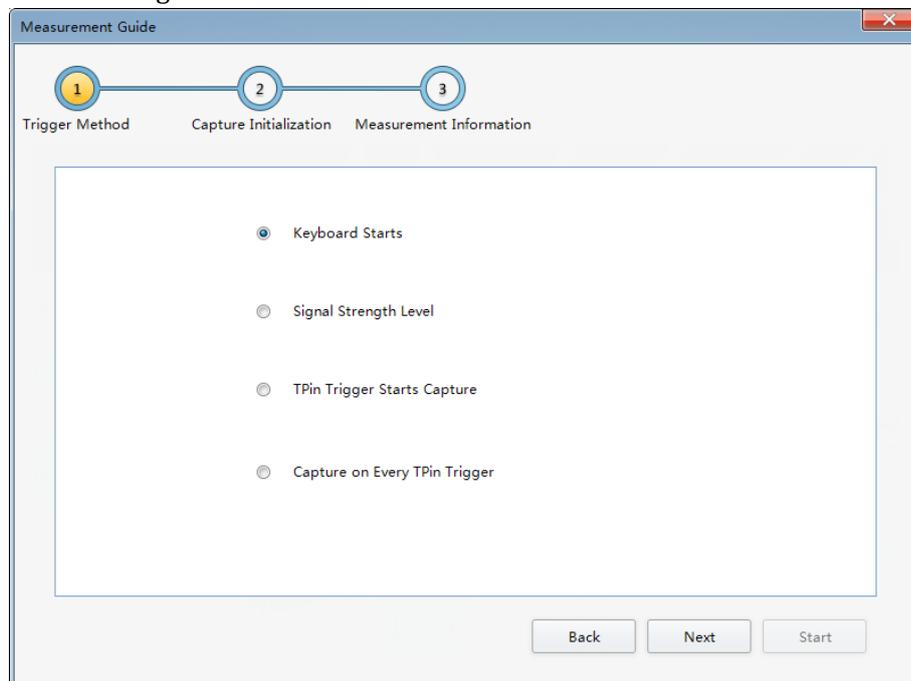

FIGURE11- 1DYNAMIC MEASUREMENT GUIDE

Trigger method: "keyboard starts" and "signal strength level" are available.

Trigger type	Setting	Remarks
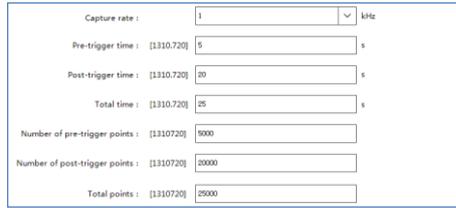
Keyboard starts		Capture rate: set the capture rate value. Pre-trigger, post-trigger: pre-trigger/post-trigger time can take up the software memory; the maximum values are displayed for your reference.
Signal strength level trigger		Signal strength level: trigger the capture when the signal strength reaches the threshold set during the capturing process.
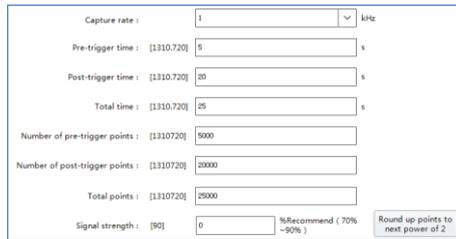
The software will automatically save the record and pop up the measurement results after the measurement is completed.

The software provides several dynamic analysis methods as follows;

✦ Distance-time plot
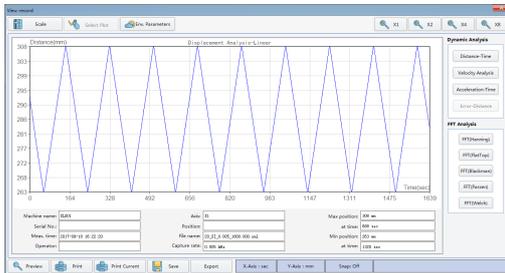
✦ Velocity-time plot
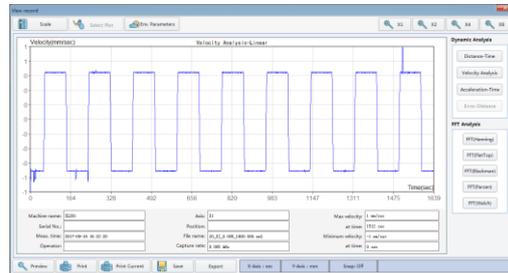
✦ Acceleration-time plot
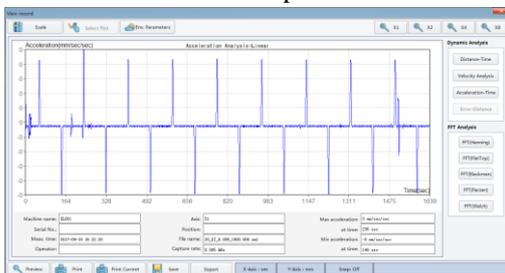
✦ Amplitude vs frequency plot
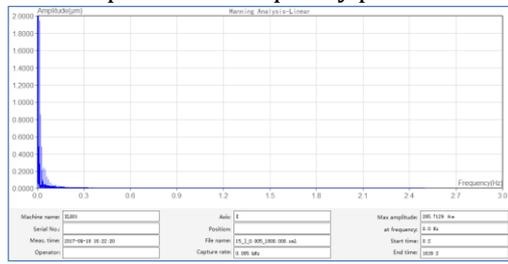
11.3　The application of time-based dynamic measurement

Time-based capture allows the dynamic software to capture relative displacement data within the set time range and save them after capture.

Machine position control

✦ The parameters setting of PID controller.

✦ The stability and the time required for stabilization of the machine after high-speed movement.
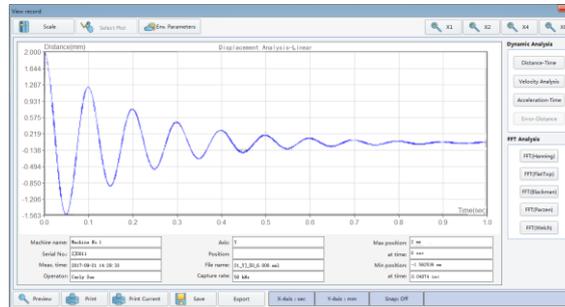
FIGURE 2 TIME-DISTANCE PLOT

✦ The small step (submicron) movement test for high performance motion control.

Vibration monitoring

✦ Application of machine tool: typical applications include high-quality surface finishing that requires slow and smooth contour machining.

Vibration analysis

✦ Analyse the vibration frequency of the target object.

✦ Separate vibration frequency by the method of Fast Fourier Transform (FFT).

▶Important	The set-up procedure of linear measurement applies to the set-up of angular measurement, velocity measurement and straightness measurement in dynamic measurement software.

11.4 Distance-based dynamic measurement

The distance-based dynamic measurement is performed by "flying" along the axis, i.e. the data are captured at user-specified interval without stopping the axis of movement.

Trigger method: TPin trigger starts capture

Trigger type	Setting

Capture on every TPin trigger	1. You must select one trigger type for TPin trigger. TPin Trigger Types Leading edge trigger ⌄ Do not use edge trigger Leading edge trigger Falling edge trigger Triggered by both edges	2. For "capture on every TPin trigger", you must set trigger step size and the total distance. Trigger step size : 1 Number of steps : 21 Total distance : 20

The software will automatically save the record and pop up the measurement results after the measurement is completed. For more information about record view and management, refer to "Record management".

Chapter 11 Product parameters and system components

12.1 Technical specification

System performance

Measurement method: single frequency

Laser frequency accuracy: ±0.05ppm

Dynamic capture frequency: 50 kHz

Preheat time: approximately 8 minutes

Operating temperature range: 0-40 ℃

Storage temperature range: -20-70 ℃

Ambient humidity: 0-95% RH

Environmental compensation unit

Air temperature sensor: ±0.1℃ (0～40) ℃, resolution 0.01℃

Material temperature sensor: ±0.1℃ (0～55) ℃, resolution 0.01℃

Relative humidity sensor: ±5%RH (0～95) %RH

Air pressure sensor: ±0.1kPa (65～115) kPa

Linear measurement

Range: 0-80m

Accuracy: ±0.5ppm (0～40)℃

Resolution: 1nm

Maximum velocity: 4m/s

Angular measurement

Axial range: 0-15m

Range: ±10 °

Accuracy: ±(0.02%R+0.1+0.25M)″ (R is the reading and the unit is ″; M is the measured distance and the unit is m)

Resolution: 0.1″

Flatness measurement

Axial range: 0-15m

Range: ±1.5mm

Accuracy: $\pm(0.2\%R+0.02M^2)$ μm″ (R is the reading and the unit is μm; M is the measured distance and the unit is m)

Flatness base size: 180mm adjustable, 360mm adjustable

Resolution: 0.1μm

Straightness measurement

	Axial range	Measurement range	Accuracy	Resolution
Short-range	(0.1~4.0)m	±3mm	$\pm(0.5+0.1\%R+0.1M^2)$ μm	0.01μm
Long-range	(1.0~20)m	±3mm	$\pm(5.0+2.0\%R+0.05M^2)$ μm	0.1μm
Note: R is the reading and the unit is μm; M is the measured distance and the unit is m.				

Perpendicularity measurement

	Axial range	Measurement range	Accuracy	Resolution
Short-range	(0.1~3.0)m	±3mm	$\pm(0.5+0.1\%R+0.2M)$″	0.01μm
Long-range	(1.0~15)m	±3mm	$\pm(1+0.5\%R+0.04M)$″	0.1μm
Note: R is indicating value of perpendicularity; M is the measured distance and the unit is m.				

High precision automatic rotary table

Model: WR50

Angular range: 0-360 °

Accuracy: ±1″

Resolution: 0.1″

Highest rotation speed: 10rpm

Weight: 1.9kg

Height: 148mm

Diameter: 112mm

Communication: bluetooth transmission

Power supply: lithium battery

Quadrature trigger box

Signal input: differential TTL (RS422) quadrature encoder signal, 10uApp microcurrent signal

Output form: 10μs pulse

Trigger delay: 0.1μs

Power source: 12VDC

Dimension, weight and power supply

Portable case dimension: 613mm×460mm×230mm

Weight (linear configuration loaded): 18kg

Power supply: 100～240 VAC

Safety requirement

The laser safety level meets Class I requirements.

12.2 Configuration list

No.	Name	Description	Remark
1	SJ6000 host machine	1pc with Pan-Tilt	Standard
2	Environmental compensation device	Host device built in Humidity sensor and atmospheric pressure sensor 1pc	Standard
		Air temperature sensor with 5m cable 1pc	
		Material temperature sensor with 5m cable 5pcs	
3	Laptop computer	1 pc with measuring software	Standard
4	Suitcase	1pc with configuration illustration (Size: 613mm×460mm×230mm)	Standard
5	Tripod	1 pc with portable bag	Standard
6	Linear prism (0-80m)	interference prism and reflector 1 pc of each	Standard
7	Supports for prism	Magnetic holder 2pcs	Standard
		Supporting rod 4pcs	
		Auxiliary installing block 1pc	
		Gradienter 1pc	
		Clamping unit with screws for prism 2 pcs	
		Workholder for CMM calibration 1 set	Optional
8	Precision linear prism	Small reflector(8g), interference prism one of each	Optional
9	Veering interference prism	25°~90°Veering interference prism 1pc	Optional
10	Angle prism	interference prism and reflector 1 pc of each	Optional
11	Flatness prism	Turning prism 2pcs 180mm adjustable supporting base, 360mm adjustable supporting base 1 pc of each Remark: need to cooperate with angle prism	Optional
12	Short(1-4m) straightness prism	interference prism and reflector 1 pc of each	Optional
13	Long(1-20m) straightness prism	interference prism and reflector 1 pc of each	Optional
14	Accessories for straightness measurement	Big interference prism, 90°veering interference prism, holder base, M8 connector 1 pc of each	Optional
15	Perpendicularity prism	Optical square, tripod and auxiliary installing block for optical square 1 pc of each	Optional

		Remark: need to cooperate with straightness prism	
16	Precision turntable	Built-in Li battery and bluetooth	Optional
17	Pulse trigger	1 pc	Optional
18	Working uniform	Summer or winter laboratory uniform　1 pc of each	Optional

Chapter 12 Maintenance

Transport requirements:

Notice	✦ **Rotate the shutter on laser head at 90 ° when it is not in use to prevent dust from entering into the laser head.** ✦ **Handle the device carefully and gently to avoid strong shock and vibration.**

Storage requirements:

Notice	✦ **Put all accessories an components in the case and avoid collision and scratch.** ✦ **Store the laser system in special place where the environment is dry, ventilated, shockproof, anti-fog, rustproof and rustproof; keep the devices dry.** ✦ **Keep the devices from pressure, moisture and high temperature, and keep the system case far away from stoves and heating tubes.** ✦ **Keep the optical prisms dry and clean.** ✦ **Do not disassemble or touch the optical prism.**

Optical kit maintenance in ordinary use:

Notice	✦ **Try not to wipe the optical prisms, if they must be wiped, please wipe them carefully and gently with non-abrasive lens tissue or lens cleaning cloth.** ✦ **Use lens cleaner or similar cleaning fluid when cleaning the prism.**

Chapter 13　Troubleshooting

✦　The power indicator does not flash when the instrument is powered on.

（1）The power source is not connected well. Please check the power cable if it works properly.

✦　The connection is off after starting the measurement software.

（1）Make sure the serial port of the instrument is connected to the computer.

（2）Connect USB cable to another computer serial port, if the problem is solved, it indicates that the previous serial port does not work.

（3）Check if the driver is installed properly in "Device Manager" on PC.

If you have checked all items above and no problem is found but the serial port is still not connected, please contact the after sales for help.

✦　Data fluctuates abnormally when measuring.

（1）Make sure you selected the correct measurement mode, e.g. do not select straightness measurement mode for linear measurement.

（2）Make sure the environment is in suitable condition, such as air disturbance. In order to overcome the airflow peristalsis, you can use a fan to enhance the flow of air.

✦　Calibration period

According to JJ G353-2006 633nm *Frequency Stabilized Laser* and JJG739-2005 *Laser Interferometers*, it is recommended to calibrate the laser once a year or once two years at least.

Chapter 14 Software upgrade and technical support

Free technical support, 24 hours a day, 7 days a week.

Free software update during warranty period

One-year warranty for repair and lifetime for maintenance

Response to customer calls within 1 hour

On-site maintenance within 72 hours

Contact information:

Manufacturer: Chotest Technology Inc.

Office address: 2/F, Building B1, Zhiyuan, Xueyuan Road, Xili, Nanshan, Shenzhen, China

Factory address: 1/F, Building No.7, HKC Industry Park, Shiyan, Baoan, Shenzhen, China

Hotline：+86 0755 8331 8191   +86 18129955008

Fax：+86 0755 8331 1192

Appendix A

Error compensation of machine tools

Beam path for machine tool calibration

To calibrate the positioning accuracy of a three-axis machine, the measurements on X, Y and Z axis are required. And this requires that the laser head should not be moved or be moved as necessary and the beam alignment on the three axes are performed by adjusting interferometers and reflectors, by this way, it can save most time for the installation and adjustment of laser system.

FIGURE APPENDIX A- 1LINEAR MEASUREMENT ON X AXIS
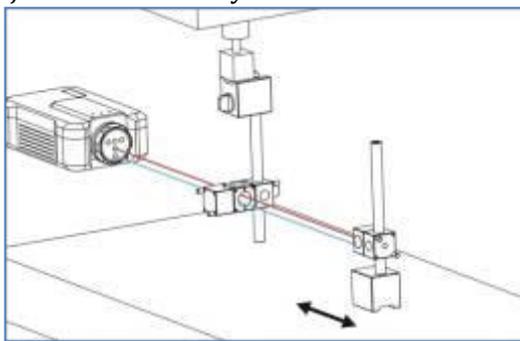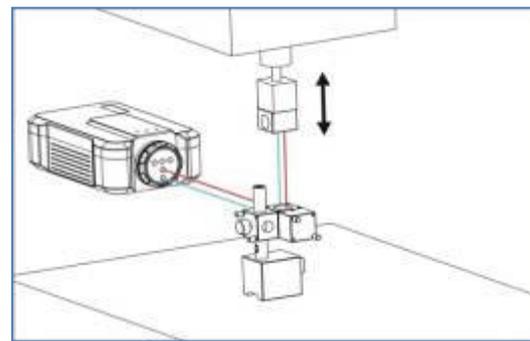
FIGURE APPENDIX A- 2LINEAR MEASUREMENT ON Z AXIS

Mechanical error compensation system for Mitsubishi machine tool

Mechanical error compensation consists of memory type pitch error compensation and memory type relative position compensation.

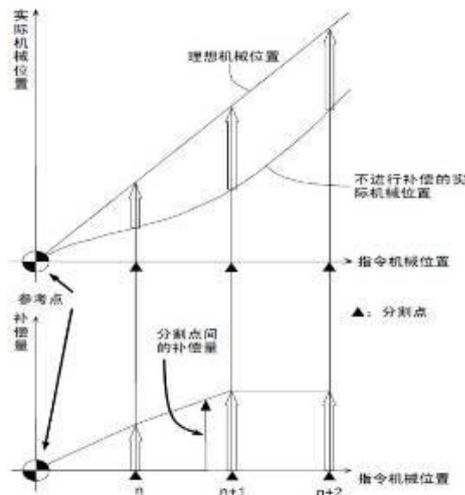(1) Memory type pitch error compensation

FIGURE APPENDIX A- 3THE RELATIONSHIP BETWEEN COMPENSATION AMOUNT AND MECHANICAL POSITION

You can compensate the error of axis feeding caused by the pitch error of the ball screw according to the pre-set parameters. As shown in the figure, the compensation amount is set for each point, which is equally distributed on the machine coordinate, based on the reference point. The compensation amount can be set in the absolute type and the increment type, you can set them by # 4000: pinc. The compensation amount between the division point n and the point n + 1 is determined by the approximate straight line for a smoothing compensation.

(2) Memory type relative position compensation
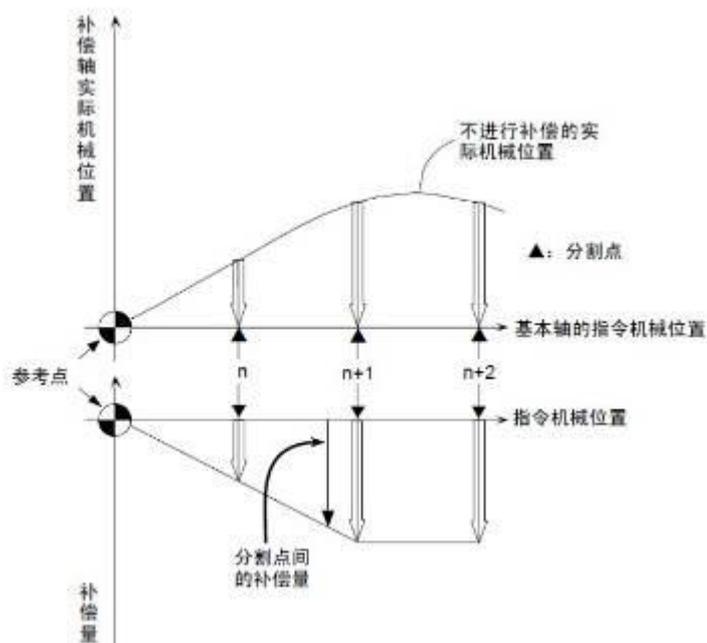
FIGURE APPENDIX A- 4THE RELATIONSHIP BETWEEN COMPENSATION AMOUNT AND MECHANICAL POSITION

You can compensate the relative position error of two axes intersecting at right angle caused by the recess of the moving table etc. according to the pre-set parameters. You can set the compensation amount in compensation axis direction for each point which is equally distributed on the base axis of the machine coordinate. The base axis is one of the two axes intersecting at right angle when the relative position compensation is performed, and it is the reference coordinate axis used for the calculation of relative error, while the compensation axis is the axis intersecting the base axis at right angle and the actual compensation is performed on this axis. The compensation amount between the division point n and the point n + 1 is determined by the approximate straight line for a smoothing compensation.

(3) Machine compensation axis parameter code and description

第 2 轴	第 3 轴	第 4 轴	第 5 轴	第 6 轴	第 7 轴	第 8 轴	第 9 轴	第 10 轴	
4011	4021	4031	4041	4051	4061	4071	4081	4091	分别设定与第 1 轴的 4001~
4012	4022	4032	4042	4052	4062	4072	4082	4092	4007 相对应的参数。
4013	4023	4033	4043	4053	4063	4073	4083	4093	最大控制轴数为 6 轴，但加
4014	4024	4034	4044	4054	4064	4074	4084	4094	上相对位置补偿，最多可设
4015	4025	4035	4045	4055	4065	4075	4085	4095	定 10 轴。
4016	4026	4036	4046	4056	4066	4076	4086	4096	
4017	4027	4037	4047	4057	4067	4077	4087	4097	

#	项目	内容	设定范围
4101		设定各轴的补偿量。	-32768~32767
·			实际的补偿量等于设
·			定值乘以补偿倍率。
·			
5124			

The code parameters closely related to machine calibration:

#4000: pnic, specify whether to use incremental compensation or absolute compensation when setting the machine error compensation data, and 0 indicates the absolute compensation while 1 indicates the incremental compensation.

4003: rdvno the compensation data code on reference point. The reference point is the datum point, and it has no corresponding compensation number and is usually set with a negative number.

4004: mdvno set the compensation data number closest to the negative end.

4005: mdvno set the compensation data number closest to the positive end.

4007: spcdv set the compensation interval of compensation data which is the compensation amount for each interval. This value also determines the step size in machine calibration.

FIGURE APPENDIX A - 1 MACHINE COMPENSATION AXIS PARAMETER CODE AND DESCRIPTION

<第 1 轴>

#	项目		内容	设定范围
4001	cmpax	基本轴	在机械误差补偿中，指定基本轴地址。 （1）设定螺距误差补偿时进行补偿的轴名称。 2）设定在相对位置补偿时作为基准的轴名称。 设定多系统中的"系统编号+轴名称"。 （例）第 2 系统的 Z 轴：2Z	X、Y、Z、U、V、W、 A、B、C 等轴地址
4002	drcax	补偿轴	在机械误差补偿中，指定补偿轴地址。 1）在螺距误差补偿时，与#4001：cmpax 设定相同的轴名称。 2）在相对位置补偿时，设定实际补偿的轴名称。 设定多系统中的"系统编号+轴名称"。 （例）第 2 系统的 Z 轴：2Z	X、Y、Z、U、V、W、 A、B、C 等轴地址
4003	rdvno	参考点位置分割点编号	设定参考点位置相对应的补偿数据编号。实际上，参考点就是基准点，由于不存在对应的补偿编号，所以设定一个负端的编号。	4101～5124
4004	mdvno	最靠近负位置的分割点编号	设定最靠近负端的补偿数据编号。	4101～5124
4005	pdvno	最靠近正位置的分割点编号	设定最靠近增端的补偿数据编号。	4101～5124
4006	sc	补偿倍率	设定补偿量的倍率。	0～99
4007	spcdv	分割间隔	设定分割基本轴的间隔。 各补偿数据是针对各间隔的补偿量。	1～9999999999 （适用控制单位）

第 2 轴	第 3 轴	第 4 轴	第 5 轴	第 6 轴	第 7 轴	第 8 轴	第 9 轴	第 10 轴	
4011	4021	4031	4041	4051	4061	4071	4081	4091	分别设定与第 1 轴的 4001～
4012	4022	4032	4042	4052	4062	4072	4082	4092	4007 相对应的参数。
4013	4023	4033	4043	4053	4063	4073	4083	4093	最大控制轴数为 6 轴，但加
4014	4024	4034	4044	4054	4064	4074	4084	4094	上相对位置补偿，最多可设
4015	4025	4035	4045	4055	4065	4075	4085	4095	定 10 轴。
4016	4026	4036	4046	4056	4066	4076	4086	4096	
4017	4027	4037	4047	4057	4067	4077	4087	4097	

#	项目	内容	设定范围
4101 · · · 5124		设定各轴的补偿量。	-32768～32767 实际的补偿量等于设定值乘以补偿倍率。

Data compensation type

The data compensation includes absolute compensation and incremental compensation.

(1) Absolute compensation

As shown on the left of Figure Appendix A- 5, for the absolute compensation, the compensation amount of each division point from the reference point is:

(Command position - actual machine position) × 2 [output unit]

As shown on the right of Figure Appendix A- 6, if the command position is 100mm while the machine position is 99.99mm, then

（100000-99990）×2 =20[pulse]

is the compensation amount at position +100mm. Similarly, if the command position is -100mm while the actual machine position is -99.99mm, then

$$（-100000+99990）×2 =-20[pulse]$$

is the compensation amount at position -100mm.

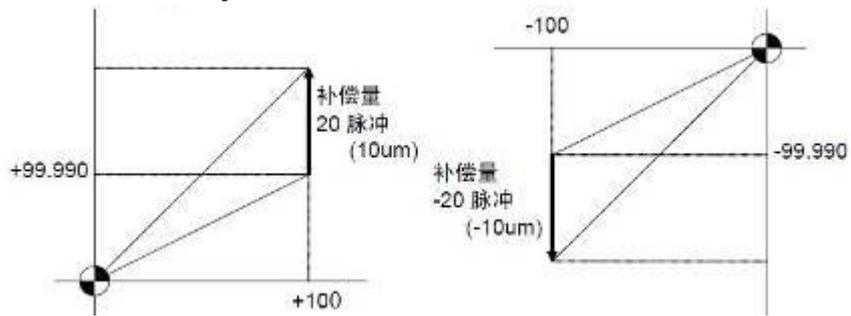FIGURE APPENDIX A- 7ABSOLUTE COMPENSATION

(2) Incremental compensation

As shown in the figure above, when the machine device is located at the positive end to the reference point, the difference between the distance from the division point n-1 to the division point n and the actual moved distance between them

(Division interval-actual movement amount）×2 [output unit]

is defined as the amount of compensation(in fact, the amount of compensation in our laser system is directly defined as (division interval - actual movement amount)).

When the machine is located at the negative end to the reference point, the sum of the distance from the division point n-1 to the division point n and the actual moved distance between them

(Division interval + actual movement amount）×2 [output unit]

is defined as the amount of compensation(in fact, the amount of compensation in our laser system is directly defined as (division interval - actual movement amount)).
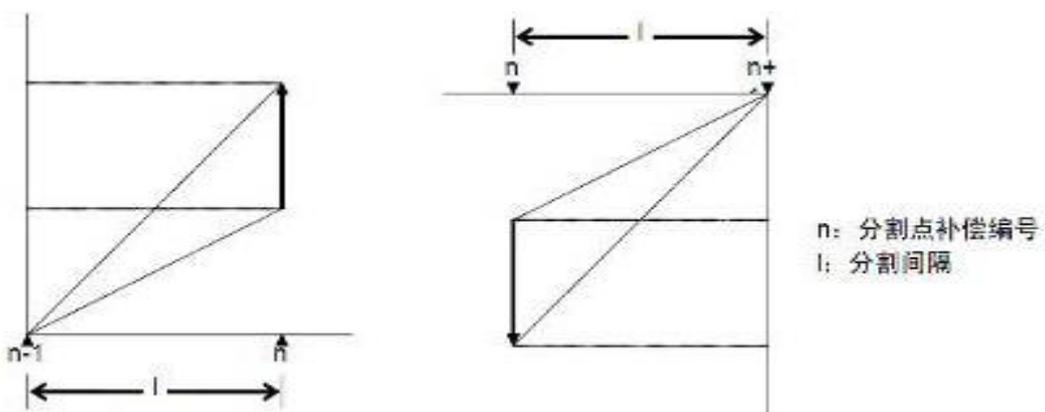

FIGURE APPENDIX A- 8INCREMENTAL COMPENSATION

Example of compensation, the base axis is linear axis

（1）   mdvno (the position number at negative end) and pdvno (position number at positive end) on both

sides of Rdvno (reference point)

分割点编号	#4101	#4102	#4103	#4104	#4105	#4106
指令机械位置	-300.000	-200.000	-100.000	100.000	200.000	300.000
实际机械位置	-299.999	-200.000	-100.003	100.002	200.002	299.999
补偿量 增量式	2	6	-6	-4	0	6
补偿量 绝对式	-2	0	6	-4	-4	2

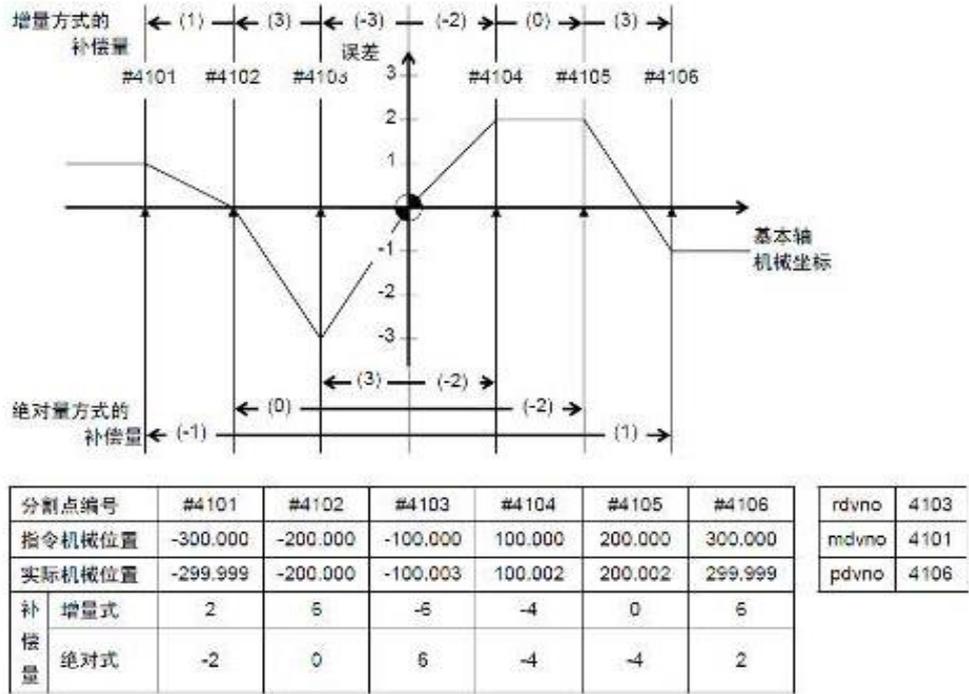|	
rdvno	4103
mdvno	4101
pdvno	4106

FIGURE APPENDIX A- 9INCREMENTAL COMPENSATION 1

The rdvno (reference point) number is 4103, 4101 for mdvno (at negative end) and 4106 for pdvno (at positive end). The compensation out of the set range (mdvno and pdvno) is performed based on the compensation amount of mdvno or pdvno.

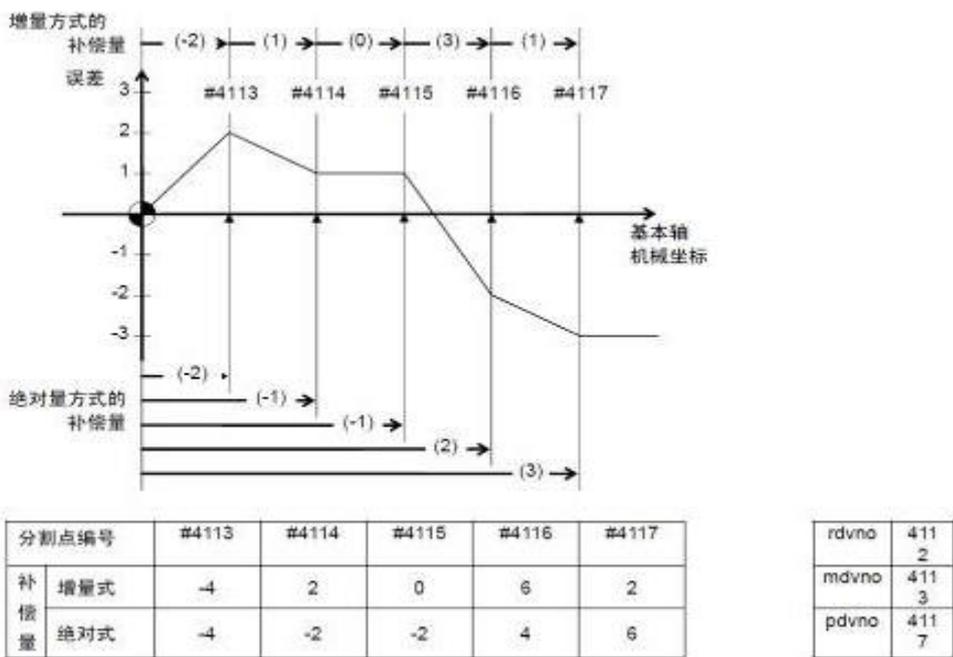⑵   Compensation range is on the positive side only (common compensation range, on X axis in general)

分割点编号	#4113	#4114	#4115	#4116	#4117
补偿量 增量式	-4	2	0	6	2
补偿量 绝对式	-4	-2	-2	4	6

rdvno	4112
mdvno	4113
pdvno	4117

FIGURE APPENDIX A- 10INCREMENTAL COMPENSATION 2

The rdvno (reference point) number is 4112, 4113 for mdvno (at negative end) and 4117 for pdvno (at positive end). The machine position exceeding pdvno is compensated based on the compensation amount of pdvno, and no compensation for the machine position in the negative direction.

（3）　Compensation range is on the negative side only (common compensation range, on Y axis and Z axis in general)
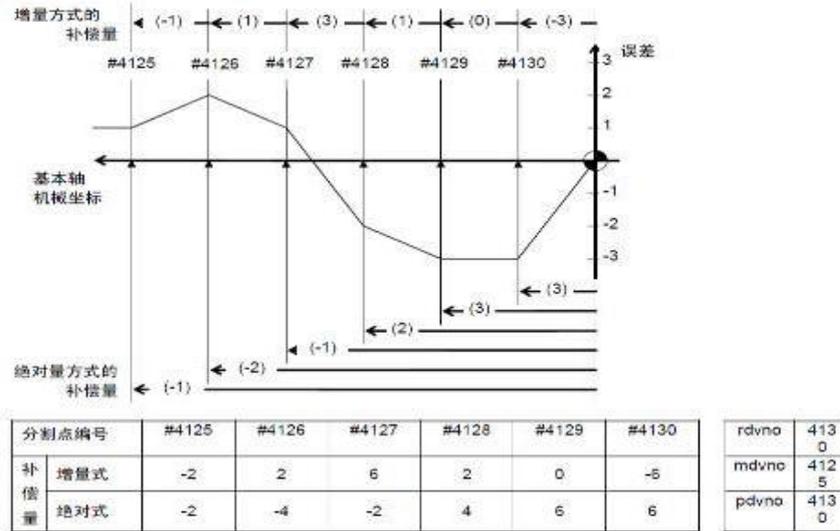

FIGURE APPENDIX A- 11 INCREMENTAL COMPENSATION 3

The rdvno (reference point) number is 4130, 4125 for mdvno (at negative end) and 4130 for pdvno (at positive end). The machine position exceeding mdvno is compensated based on the compensation amount of mdvno.

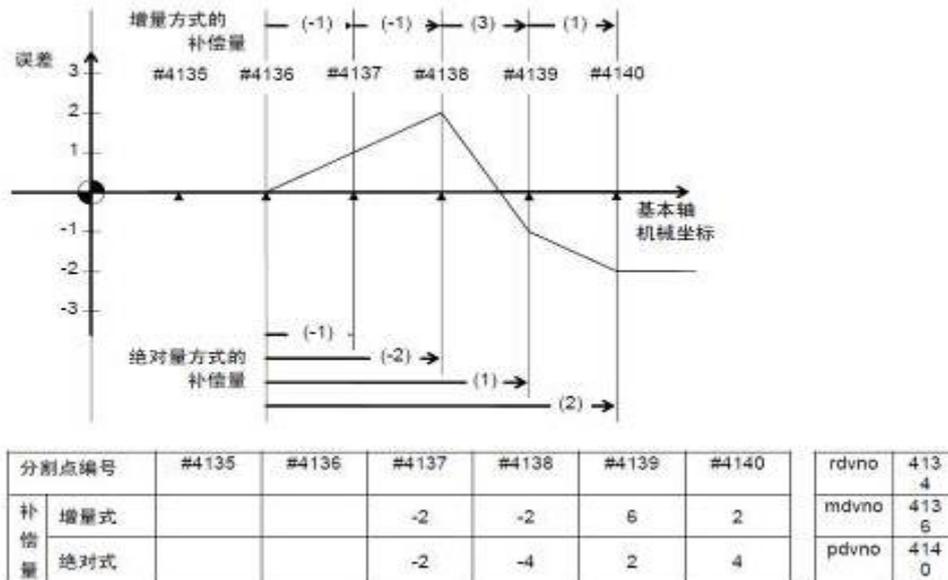（4）　The compensation range does not includes the reference point

FIGURE APPENDIX A- 12 INCREMENTAL COMPENSATION 4

The rdvno (reference point) numbere is 4134, 4126 for mdvno (at negative end) and 4140 for pdvno (at positive end). Because the reference point is not within the section form the positive number to negative number, at this time, the compensation is performed form mdvno to pdvno. If the machine position is in the negative direction without the reference point, the compensation is set in the similar way.

ChotestLaser can perform calibration and compensation for various machine tools, e.g. the machine tools form Mitsubishi, Fanuc, Mazak, Simens, Bosch Rexroth, Heidenhain, Schneider, Fagor, Syntec, LNC-Bao-yuan, Bai Chu, Wuhan Huazhong, GSK, Nanjing Kaitong, For more information, please contact Chotest.