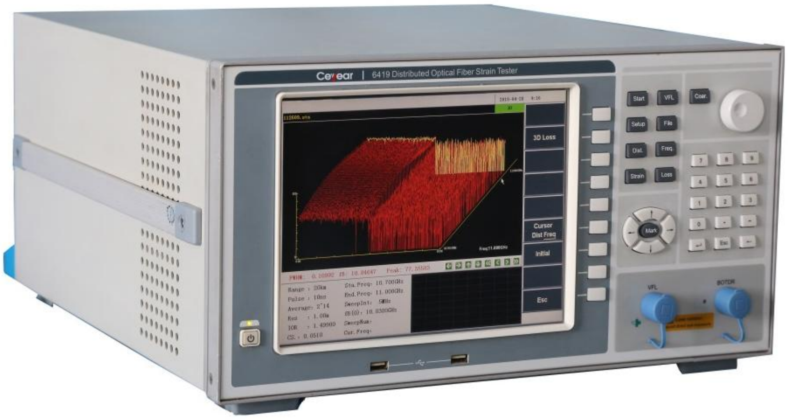
6419 Distributed Optical Fiber Strain Tester

User Manual



China Electronics Technology Instruments Co., Ltd

January 2018

Foreword

Thank you very much for choosing and using the 6419 distributed optical fiber strain tester produced by China Electronics Instrument Co., Ltd. The company produces high-grade, high-precision and advanced products, with the highest quality cost-effectiveness among similar products. We always comply with the ISO9000 standard during the production process, and we're customer-oriented and consider the quality as the enterprise's life. Please read this manual carefully for your convenience. We will make our best efforts to meet your needs, provide you with the most cost-effective control equipment, and bring you first-class after-sales service. With the consistent purpose of "good quality, considerate service", it's our commitment to provide satisfactory products and services to you. We sincerely hope to bring convenience and speed to your work, and welcome your inquiries through calls:

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This manual describes the purpose, performance characteristics, basic principles, application methods, maintenance, and precautions of the 6419 distributed optical fiber strain tester to help you become familiar with and master the operating methods and key points of the controller. In order to make better use of this product and create more economic benefits for you, please read this manual carefully.

Due to the tight time and the limited capability of the author, it is inevitable that there are errors and omissions in this manual, please criticize and correct! We apologize for the inconvenience caused by the mistakes we made.

Statement:

This manual is the third edition of the user manual of 6419 distributed optical fiber strain tester, the version number is D.2.

The contents of this manual are subject to change without notice. The right of interpretation to the contents and the terms used in the manual belongs to China Electronics Technology Instruments Co., Ltd.

Table of Contents

Safety requirements

The following general safety precautions must be taken at any stage of operating the instrument. Failure to take these safety precautions or to follow the warnings and precautions described elsewhere in this manual will violate the safety standards for the design, manufacture, and use of the instrument. China Electronics Technology Instruments Co., Ltd assumes no responsibility for the consequences arising from users' violation of these requirements.

Use environment

For the working environment and storage environment of this instrument, please refer to the description of the technical parameters in Chapter XI.

Power supply

For the requirements of the working power of this instrument, please refer to the description of the technical parameters in Chapter XI. The working power of this instrument must range from $198V_{ac}$ to $242V_{ac}$. Be sure to use the dedicated three-wire power cord shipped with the instrument or the three-wire power cord of the regular manufacturer's specifications, and ensure that the grounding is good, so as to avoid inducting voltage generated by the enclosure. The fuse of the same specification shall be used when replacing the fuse in the fuse holder.

Do not use the instrument in an explosive or flammable environment

Do not use the instrument in the presence of flammable gases or fumes.

Do not disassemble any parts of the instrument

Do not disassemble any parts of the instrument except those that are authorized to be replaced by the users. Replacement of parts and internal adjustments can only be carried out by the maintenance personnel authorized by or entrusted by China Electronics Technology Instruments Co., Ltd.

Safety terms used in this manual

Warning! : Remind users to pay attention to a process, operation method, or similar situation. Failure to operate properly or in accordance with the rules may result in personal injury or damage to the instrument.

Caution! : Remind users to pay attention to a process, operation method, or similar situation. Failure to operate properly or in accordance with the rules may result in partial or whole damage to the instrument.

Note! : Information that aids in the use and maintenance of the instrument.

Warnings for the use of instrument

Requirements for power supply

Warning!

: The power supply used in this instrument must meet the following requirements: $220V_{AC}$ ± 10%, 1.5A, 50 ~ 60Hz. Using a power supply that is too high/low or unstable will cause damage to the instrument. Using a power supply that is too high/low or unstable will cause damage to the instrument.

Laser safety

The safety standards for the lasers used in this instrument are in accordance with IEC65 and IEC348.

Warning!

Although the output intensity of the laser used in this instrument is within the safety standard, it may damage the visual acuity, so the output of the laser should be prevented from directly shooting into the eye. Do not look directly into the light output connector of the instrument with your eyes, and do not look directly at the end of the fiber during testing. When the VFL function of the instrument is turned on, do not look directly at the VFL's output port or the end of the fiber connected to the VFL output port.

Use of distributed optical fiber strain tester (BOTDR)

Warning!

(1) It is absolutely not allowed to connect an optical fiber with any optical signal to the test port of the 6419 distributed optical fiber strain tester. This may result in inaccurate measurement results and even permanent damage to the instrument. Please ensure that all fibers tested by this instrument are in a no-signal state.

(2) It is absolutely not allowed to connect and disconnect the optical fiber during the test of the 6419 distributed optical fiber strain tester. This will cause the instantaneous increase of echo of the optical fiber tested by the instrument, which may cause permanent damage to the instrument.

(3) It is absolutely not allowed to connect the fiber interface that does not match the optical interface of the 6419 distributed optical fiber strain tester to the test port of the 6419 distributed optical fiber strain tester. This will not only increase the insertion loss due to the mismatched optical interface and result in no inaccurate test results, but will also cause permanent damage to the optical interface.

Transportation and packaging

Warning!

(1) Please pack the 6419 distributed optical fiber strain tester with the original standard aluminum alloy box during transportation, and ensure that the 6419 distributed optical fiber strain tester does not move in the aluminum alloy box. **Special note: When placing the instrument in an aluminum alloy box, no filler is allowed in front of the LCD display to avoid damage to the LCD display during transportation.**

(2) Care should be taken during transportation to avoid damage to the 6419 distributed optical fiber strain tester caused by severe shock and vibration.

Notes for the use of instrument

LCD display

Caution!

(1) Do not use a sharp object to click on the LCD screen, and do not impact the LCD screen with big power. This will damage the LCD screen.

(2) Do not drop or splash organic solvents or contaminants on the LCD screen, such as acetone, oil, antifreeze, grease, etc., otherwise the LCD screen will not work properly.

(3) Wipe the LCD screen with silk cloth or soft fabric. Do not wipe the LCD screen with organic solvent, otherwise, this may damage the LCD screen.

Use of distributed optical fiber strain tester (BOTDR)

Caution!

(1) The light output connector of the instrument has a delicate and fragile ceramic positioning core inside. When the fiber is connected, be sure to insert the fiber plug in parallel and screw it tightly after aligning the positioning pin.

(2) When using this instrument for measurement, the inside of the light output connector of the instrument and the end face of the light output connector of the instrument must be kept clean to prevent the grease and other contaminants from contaminating the light output connector. Otherwise, it will cause measurement error of the instrument, and may cause the instrument not be able to test the fiber.

(3) If possible, when testing the instrument, point the end of the fiber under test to a non-reflective object.

Maintenance and service

Note!

(1) Please use the original packaging materials when carrying the instrument to avoid severe shock and vibration.

(2) The instrument should be stored under the ambient temperature range between 0°C and 50°C, and it should be kept ventilated and dried without direct sunlight.

(3) When storing the instrument, the dust cover on each optical port of the instrument should be covered.

Calibration requirements

The validity of the technical parameters is related to the operating environment of the instrument. The duration of the calibration can be extended or shortened depending on the use intensity, the operating environment and the maintenance of the instrument. You should determine the appropriate calibration period based on your needs.

In the case of normal use of the instrument, it is recommended that the 6419 distributed optical fiber strain tester be calibrated once a year. For details, please call the service number.

Warranty and repair of instrument

Note!

(1) The warranty period of the whole machine (except for the light output connector and consumables) is 18 months. Items offered during product promotions are not within the scope of the warranty.

(2) The light output connector and optical fiber output contact of the instrument are consumables, which are not within the scope of the warranty.

(3) Damage or deterioration of the instrument due to irresistible force and human factors is within the scope of the warranty.

(4) The instrument shall be maintained by China Electronics Technology Instruments Co., Ltd or its designated authorized maintenance unit. It is illegal for any other unit or individual to disassemble and repair the instrument. The instrument will lose its warranty qualification and the China Electronics Technology Instruments Co., Ltd reserves the right to pursue legal liability for violators.

(5) The instrument will lose its warranty qualification once it is dismantled and disassembled in an unauthorized manner. The instrument will lose its warranty qualification once the fastening screws or sealing strip is removed.

Description:

China Electronics Technology Instruments Co., Ltd reserves the right to make any changes to the design and structure of the 6419 distributed optical fiber strain tester at any time, but has no obligation or responsibility to freely modify or replace the products sold for free. Accessories of this product, including but not limited to fiber end face tester, optical fiber patch cords and mice, are not subject to the warranty of this manual.

Caution!

When the instrument needs to be returned for repaired, calibration or maintenance, the following points shall be noted:

(1) If the test data is stored in the instrument, please back up the data to avoid loss.

(2) Please use the original packaging box for packaging and transportation.

(3) If other packaging box is used, please make sure there is at least soft filler of 3 cm around the instrument.

(4) To reduce the impact of external forces.

(5) Please indicate the contact address, contact number, description of the situation, etc. when the instrument is returned.

(6) Please seal the packaging box with tape before shipping.

(7) Damage caused by improper packaging is not within the scope of the warranty when the instrument is returned.

Chapter I Overview

1 Overview of instrument

The 6419 distributed optical fiber strain tester (hereinafter referred to as 6419 BOTDR can test the strain distribution, loss distribution and Brillouin scattering spectrum of fiber optic cable simultaneously. It can simultaneously display the 3D and multiple distribution parameters, and has the advantages of high strain test accuracy, good repeatability and single-ended non-destructive testing, which is an indispensable test instrument in the field of Optical Fiber Communications and Optical Fiber Sensing.

The product can be widely used in the development, production and testing, construction and acceptance of fiber optic gyro, fiber optic hydrophone and submarine cable, and line maintenance and support.

The product can also be widely used in the detection of health status of bridges, dams, tunnels, tall buildings, oil rigs, oil pipelines, etc., as well as the prediction of geological disasters such as landslides, debris flows and earthquakes. It also has important applications in the detection of intelligent structural health status of large-scale marine vessels and aerospace vehicles.

The main functions and features of the instrument are as follows:

1. **Brillouin scattering distribution test function**
2. **Distributed optical fiber strain test function**
3. **Distributed optical fiber loss test function**
4. **Distributed Brillouin scattering spectrum width test function**
5. **Multiwindow display function**
6. **File management function**
7. **Remote control function**
8. **Timing test and data saving functions**
9. **3D display function of loss distribution**
10. **Test curve comparison function**
11. **Large screen color LCD display, touch screen operation**
12. **Built-in VFL (visual fault location) function**
13. **Upgrade of application software system without need to return to the original factory**

2 Components of instrument

2.1 Basic components

The basic components of the 6419 BOTDR are shown in Table 1-1.

Table 1-1 Basic components of 6419 BOTDR

ITEM	Name	Qty
Host	6419 distributed optical fiber strain tester	1
Standard accessories	Power cord	1
	User Manual	1
	CD or USB	1
	Aluminum alloy box	1
	Standard edition of 6419 data analysis software	1

2.2 Optional components

Table 1-2 6419 List of optional components of BOTDR

Serial number	Name	Qty
001	Fiber end face tester	1
002	Advanced lens paper	1
003	Optic optical fiber patch cord (FC/APC to FC/UPC)	1
004	Professional edition of 6419 data analysis software	1
005	SC fiber optic adapter	1
006	FC fiber optic adapter	1

3. Description of instrument panel

3.1 View of instrument front panel

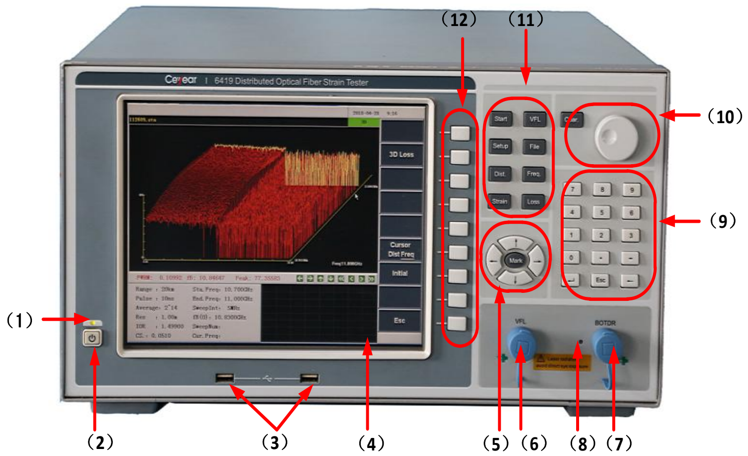


Figure 1-1 Schematic diagram of the front panel of the instrument

Table 1-3 Descriptions of the functions of each part of the front panel

No.	Name	Function description	Remarks
(1)	Power indicator	When the power is off, the indicator is off; when the power is on but the instrument is not turned on, the indicator is orange; when the instrument is turned on, the indicator is green.	
(2)	On/Off button	Used to turn the instrument on and off.	
(3)	USB interface	Used to connect USB devices such as USB keyboard, USB mouse and USB flash drive.	
(4)	Touch LCD screen	Used to display measurement information and perform touch screen operation.	
(5)	Navigation button	Including arrow keys and cursor keys, used to scale the test curve in the test state and move the cursor during test conditions and system settings.	Detailed in Section 3.1.1
(6)	VFL optical interface	FC/APC interface.	
(7)	BOTDR optical interface	FC/APC interface.	
(8)	Laser indicator	Used to indicate whether the laser inside the instrument is running.	
(9)	Numeric key area	Used to enter or modify the number, “.” and “-” characters in the input box of the cursor in the test condition, file operation or system setting interface.	
(10)	Knob keypad	Used to move the cursor for the test curve.	Detailed in Section 3.1.2
(11)	Function keypad	Including 8 common function keys, which can directly and quickly perform the functions corresponding to the function keys	Detailed in Section 3.1.3
(12)	Menu button	The nine menu buttons correspond to the nine function menus in the software interface, and the corresponding menu functions can be executed by pressing the buttons.	Detailed in Section 3.1.4

3.1.1 Description of navigation button functions

(1) In the test state, the test curve in the window is scaled around the position of the curve where the cursor is located:

▲ and ▼ are used to expand and compress the vertical coordinate of the test curve in the window display area respectively. This function is invalid in the "multiwindow" state;

◀ and ▶ are used to expand and compress the horizontal coordinate of the test curve with the distance as the abscissa in the window display area respectively. This function is invalid in the "Brillouin spectrum" state; in the "multiwindow" state, the cursor in the multiwindow sub-menu is set as the "distance/frequency", and the two buttons are used for synchronous expansion and compression of the horizontal coordinates corresponding to the curves of the strain distribution, the distribution of Brillouin scattering spectrum width, and the loss distribution, respectively.

(2) In the test condition and system setting interface, the cursor button [Cursor] is used to move the cursor in different parameter setting boxes, if the cursor moves to the drop-down menu, ▲ and ◀ are used to display the previous item of the current menu option; and ▼ and ▶ are used to display the next item of current menu options. If the cursor is in the radio button or progress bar, ▲ and ◀ are used to control the single option or the progress bar to move forward, and ▼ and ▶ then control the single option or progress bar to move backward.

3.1.2 Description of knob keypad functions

Knob: It’s used to move the cursor on the test curve in the window display area. When the knob rotates clockwise, the cursor on the test curve moves right; when the knob rotates counterclockwise, the cursor on the test curve moves left.

Coar. : Coar. button is used to switch between the normal movement mode and the fast movement mode of the knob. If the knob is in the normal movement mode, the distance the cursor moves each time is 1 unit horizontal coordinate; if the knob is in the fast movement mode, the distance each time the cursor moves is 10 unit horizontal coordinates.

3.1.3 Description of function keypad functions

Test : Perform/stop the average processing test. When the instrument is performing an average processing test, using this button will stop the average processing test; when the instrument is in the non-average processing test state, using the test button will start the averaging processing test.

VFL : Pop-up VFL control dialog box, providing fault location function of visual cable for users to select among four VFL working states of OFF, CW, 1Hz and 2Hz.

Setup : Press this button to enter the test condition setting interface (this button is invalid when system setting or file operation is in progress).

File : Press this button to enter the file operation sub-menu (this button is invalid when the test condition setting or system setting is in progress).

Dist. : Switch the corresponding mode of the current horizontal cursor to the distance mode.

Freq. : Switch the corresponding mode of the current horizontal cursor to the frequency mode.

Strain : Switch the current window to the "strain distribution" state automatically, showing only the "strain distribution" window.

Loss : Switch the current window to the "comprehensive loss" state automatically, showing only the "comprehensive loss" window.

3.1.4 Description of menu button functions

The menu button corresponds to the function menu button on the right side of the 6419 BOTDR software interface. If you want to execute the menu item of the function menu being displayed on the software interface, just press the menu button of its corresponding position.

3.2 View of instrument back panel

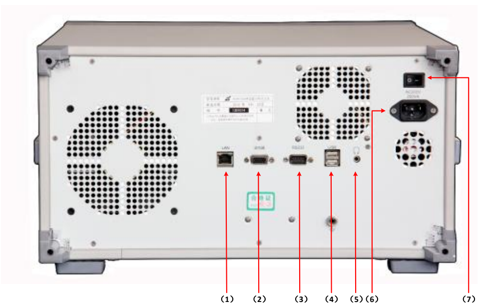


Figure 1-2 Schematic diagram of the back panel of the instrument

(1) LAN interface (2) VGA interface (3) RS232 interface (4) USB interface (5) Headphone jack (6) Power interface (7) Power switch. The description of corresponding functions of each part of 6419 BOTDR back panel are shown in Table 1-4 (The picture is for reference only, the actual products shall prevail).

Table 1-4 Descriptions of the functions of each part of the back panel

No.	Name	Function description	Remarks
(1)	LAN interface	A network cable can be used to connect the instrument to the network or directly to other computers.	
(2)	VGA interface	The VGA cable can be used to connect the instrument to external display.	
(3)	RS232 interface	The RS232 serial cable can be used to communicate with other computers or serial devices.	

(4)	USB interface	Used to connect USB devices such as USB keyboard, USB mouse, and USB flash drive.	
(5)	Headphone jack	Used to connect to headphones.	
(6)	Power switch	Used to turn the power of the instrument on/off.	
(7)	Power interface	Used to connect the power cord. Power cord	

Chapter II Description of Operation Interface

1 Main operation interface

The main operation interface of the 6419 BOTDR is shown in Figure 2-1.

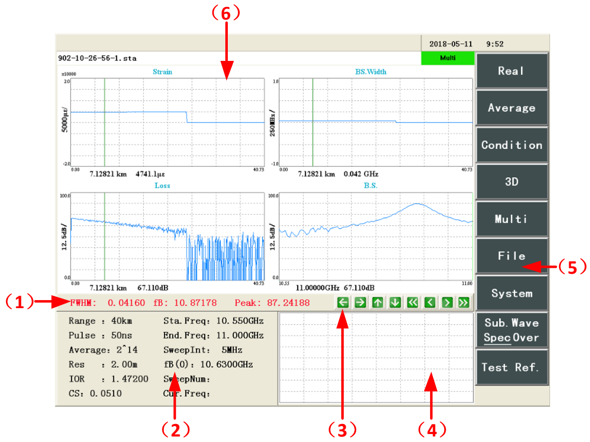


Figure 2-1 Schematic diagram of the main operation interface

The operation interface of 6419 BOTDR instrument is divided into six areas: (1) Test result area, (2) Test condition area, (3) Waveform operation area, (4) Sub-waveform window, (5) Function menu area and (6) Window display area, the specific information is described as below.

1.1 Test result area

This area is used to display some results of the 6419 BOTDR test, which has the following meanings:

FWHM: Indicates the Brillouin spectrum bandwidth of the current distance point;

fB: Indicates the center frequency of the Brillouin spectrum fitting curve of the current distance;

Peak: Indicates the peak relative power of the Brillouin spectrum at the current distance point.

1.2 Test condition area

This area is used to display the test conditions or Marker information of the instrument. When the software is in the Marker sub-menu, the Marker information will be displayed in this area. In other cases, the test condition of the instrument will always be displayed in the area. See Section 2 in **Chapter 3** for details.

1.3 Waveform operation area

The waveform operation area includes buttons, with the following functions:

and : In the "strain distribution" state, the "spectral width distribution" state, the "loss distribution" state, and the "comprehensive loss" state, it's used to compress or expand the horizontal coordinate of the test curve with the cursor as the center in the window display area. When the [cursor] in the in the multiwindow sub-menu is set as the "**distance/frequency**", the two buttons are used for synchronous expansion and compression of the horizontal coordinates corresponding to the strain distribution, the spectral width distribution, and the loss distribution curves, respectively.

and : It's used to expand and compress the vertical coordinate of the test curve with the cursor as the center in the window display area respectively. This function is invalid in the "multiwindow" state;

and : It's used to control the cursor to move left or right on the measurement curve of the window display area, moving 1 horizontal unit at a time.

and : It's used to control the cursor to move left or right quickly on the measurement curve of the window display area, moving 10 horizontal units at a time.

The [Cursor] button setting in the function menu determines whether the horizontal coordinate controlled by the waveform operation button control is the distance or frequency mode, and other corresponding operations will be triggered according to the operation for the selected horizontal coordinates (for details, see "Chapter IV

"Description of Window Display") .

1.4 Sub-waveform window

When the window display area is in the "strain distribution" state, the "spectral width distribution" state, the "loss distribution" state, and the "comprehensive loss" state, the sub-waveform window displays the Brillouin spectrum curve on the cursor of the global curve or curve of the measurement curve according to the setting of the [Sub.Wave] function button in the main function menu.

The sub-waveform window in the Brillouin spectrum state is displayed as a strain distribution global curve.

1.5 Function menu area

This area is used to display the function menu of the software. Each function menu button has a one-to-one correspondence with the menu buttons on the front panel of the instrument. The corresponding function menu buttons can be selected by pressing the front panel menu button of the instrument to realize the functions, or the corresponding functions can be performed by clicking the function menu buttons with the mouse or through the touch screen.

1.6 Window display area

In the "multiwindow" state, "strain distribution" state, "spectral width distribution" state, "Brillouin spectrum" state, "loss distribution" state, "comprehensive loss" state, and "3D" state, this area is used to display the measurement curve in the corresponding state; the corresponding setting interface is displayed when setting the test condition, file operation and system.

2 Structure and function of main menu

The function menu displayed by default in the main operation window after the instrument is turned on is the main function menu, including [Real-time Test], [Average], [Test condition], [3D display], [Multiwindow], [File], [System] and [Sub.Wave].

[Real-time Test]: The instrument starts/stops testing the real-time loss distribution curve at the selected sweep frequency. The real-time test allows the sweep frequency of the test to be changed at any time during the test, which is convenient for quickly determining the optimal start frequency condition for the average processing test. This function does not stop automatically after execution. If the real-time test is not stopped, the test will continue until the instrument is turned off. Figure 2-2 shows the loss distribution curve under real-time test. The knob button on the front panel of the instrument is used to change the sweep frequency of the real-time test.

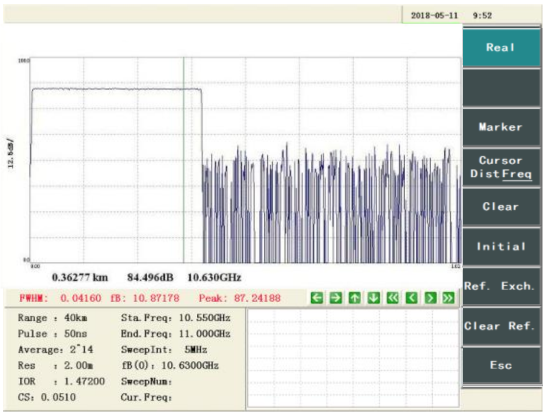


Figure 2-2 Loss distribution curve under real-time test

[Average]: The instrument starts/stops the average processing test function to test the loss distribution curve of the fiber under test. The average processing test function calculates the strain distribution curve of the fiber under test by testing the loss distribution curve at the sweep frequency point from the start frequency to the cut-off frequency, so the function will automatically stop after the test is completed after execution. Figure 2-3 shows the loss distribution curve under the average processing.

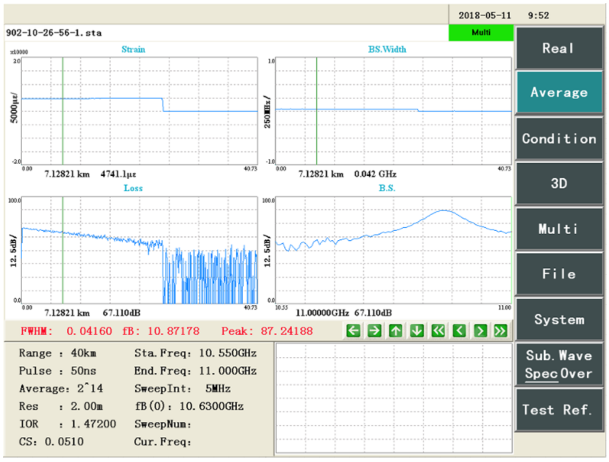


Figure 2-3 Loss distribution curve under average processing

[Test condition]: After entering the test condition setting interface shown in Figure 2-4, the measurement conditions and parameters related to the 6419 BOTDR measurement process can be set, and the function menu area will display the test condition sub-menu (for details, see **"Chapter III Description of Test Conditions"**).

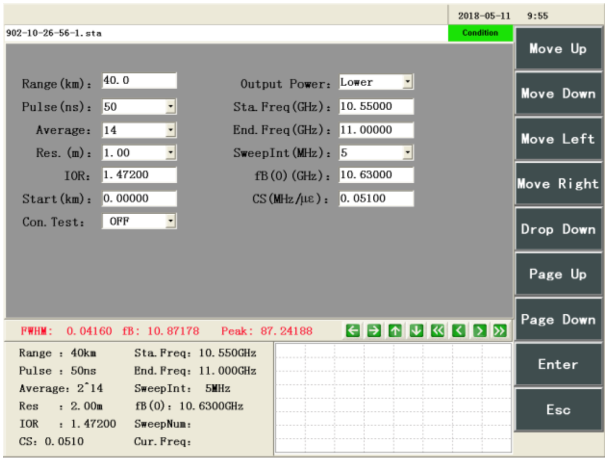


Figure 2-4 Interface of test condition

[3D display]: The window display area will enter the “3D” status interface shown in Figure 2-5. Only the “3D” window will be displayed. The function menu area will display the sub-menu in the 3D state (for details, see **“Chapter V Description of 3D Display Functions”**).

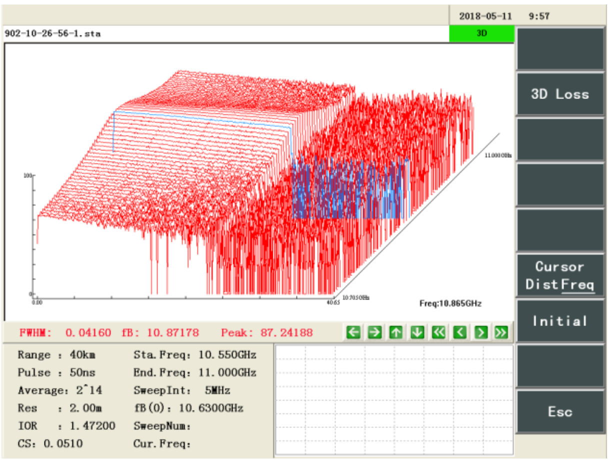


Figure 2-5 Interface of 3D state

[Multiwindow]: The window display area will enter the "multiwindow" state shown in Figure 2-6, and the "strain distribution" window, the "spectral width distribution" window, the "Brillouin spectrum" window, and the "loss distribution" window will be displayed. The function menu area will display the sub-menu in the multiwindow state (for details, see "**Chapter IV Description of Window Display**").

Figure 2-6 Interface of multiwindow state

[File]: After entering the file operation interface, the function menu area will display the file sub-menu to can open the file, save the file and open the reference file, as shown in Figure 2-7 (for details, see **"Chapter VI Description of File Functions"**).

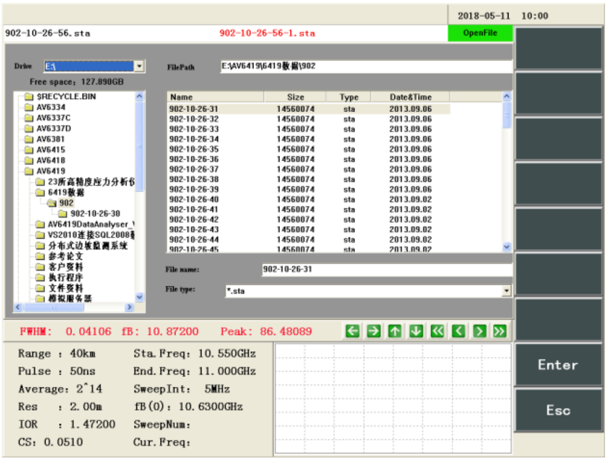


Figure 2-7 Interface of opening file

[System]: The function menu area will display the system sub-menu (as shown in Figure 2-8). The 6419 BOTDR system function can be used and set according to the menu function provided (for details, see **“Chapter VII Description of System Menu”**).

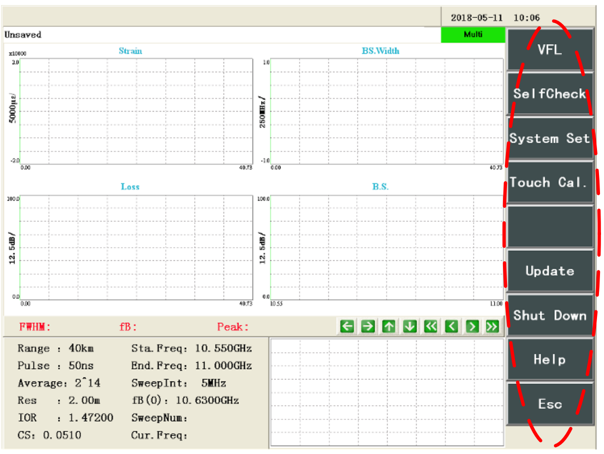


Figure 2-8 Function menu area showing the system sub-menu

[Sub.Wave]: It is used to set the display contents in the sub-waveform window (as shown in Figure 2-9). If the button is displayed as “**global** Brillouin spectrum”, it indicates that the sub-waveform window will display the global test curve; if the button is displayed as “global **Brillouin spectrum**”, it indicates that the sub-waveform window will display the spectrum curve at the distance point where the cursor is located. In the “Brillouin spectrum” state, the sub-waveform window only displays the global strain curve (for details, see **“Chapter IV, Section 2, Description of Sub-waveform Window”**.

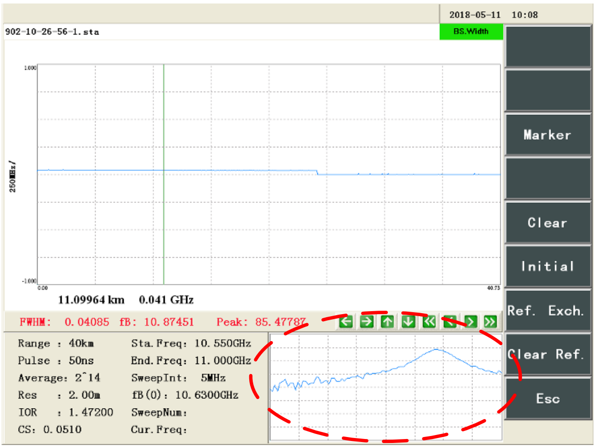


Figure 2-9 Sub-waveform window

Chapter III Description of Test Conditions

Press the [Test condition] button to enter the test condition setting interface. As shown in Figure 3-1, the window display area displays the test condition setting interface, and the function menu area displays the test condition sub-menu.

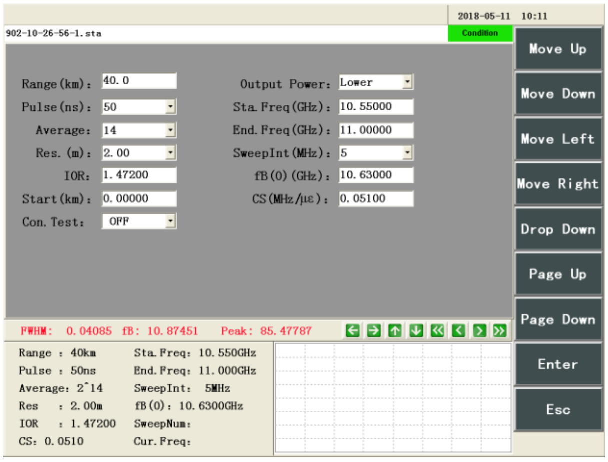


Figure 3-1 Test condition setting interface

1 Description of test condition sub-menu

The test condition sub-menu is shown in Figure 3-1 and has the following functions:

[Move Up]: Move the focus to the parameter box directly right above the parameter box where the current focus is located. If the current focus is already at the top, move to the parameter box at the bottom of the other side.

[Move Down]: Move the focus to the parameter box directly right below the parameter box where the current focus is located. If the current focus is already at the bottom, move to the parameter box at the top of the other side.

[Move Left]: Move the focus to the parameter box on the left of the parameter box where the current focus is located.

[Move Right]: Move the focus to the parameter box on the right of the parameter box where the current focus is located.

[Drop Down]: If the parameter box where the current focus is located is a drop-down box, a drop-down list will pop up.

[Page Up]: Display the test condition setting interface of the previous page.

[Page Down]: Display the test condition setting interface of the next page.

[Enter]: Save the current test condition parameters and return to the main operation interface.

[Back]: Don’t save users’ modification to the current test condition parameters and return to the main operation interface.

2 Description of test condition parameters

2.1 Range

The range parameter is used to set the distance range of the scanning curve of the instrument. The user can set an integer from 0.5 to 127km with double-click of the input box. If the decimal is entered, it will be rounded up by default, as shown in Figure 3-2.

The parameter should be set according to the length of the fiber to be tested. The test range value shall not be lower than the length of the fiber to be tested to avoid the secondary reflection of the fiber end affecting the test result. The length of the fiber can be given either by the fiber/cable manufacturer or measured by the OTDR or the instrument.

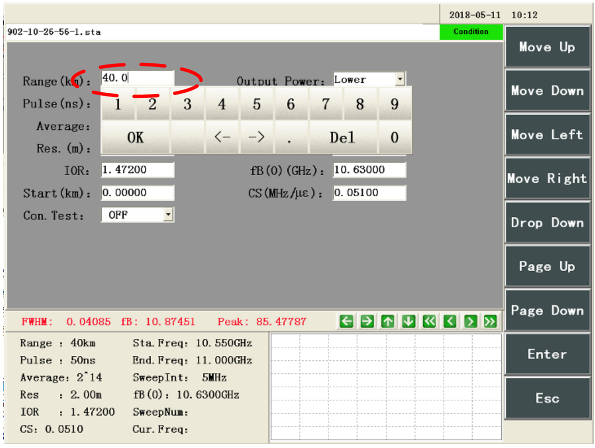


Figure 3-2 Range setting interface

2.2 Pulse width

The instrument can be set to 10, 20...200ns with an increment of 10ns, there are 20 pulse widths to choose from, which can be selected by touch screen or mouse, or can be selected by "↑" or "↓" on the navigation keys. As shown in Figure 3-3.

The pulse width parameter determines the spatial resolution of the test, and its correspondence relation is shown in Table 3-1. In general, the wider the pulse width, the longer the detection distance and the higher the strain test accuracy, but the lower the spatial resolution, in the actual test, the pulse width should be properly selected according to the test requirements.

Table 3-1 Correspondence relation between pulse width and spatial resolution

Pulse width	Spatial resolution	Pulse width	Spatial resolution	Pulse width	Spatial resolution	Pulse width	Spatial resolution
10ns	1m	60ns	6m	110ns	11m	160ns	16m
20ns	2m	70ns	7m	120ns	12m	170ns	17m
30ns	3m	80ns	8m	130ns	13m	180ns	18m
40ns	4m	90ns	9m	140ns	14m	190ns	19m
50ns	5m	100ns	10m	150ns	15m	200ns	20m

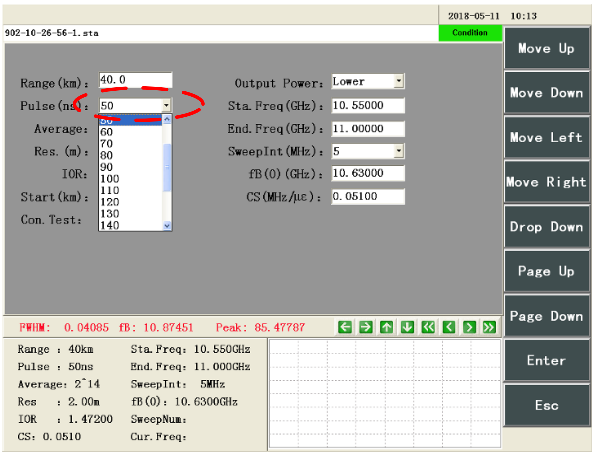


Figure 3-3 Pulse width setting interface

2.3 Average times

It is used to set the average times when the instrument is sampling, with a value of 2^n, n is the selected parameter value, and the average times is 2^{10} to 2^{24}, and there are fifteen optional values. According to the test time and test results, comprehensive consideration can be made to set the appropriate average times.

Increasing the average times can improve the signal-to-noise ratio and improve the strain test, but it will increase the test time. For double increase in the average times, the test time will also be doubled. When the average times is increased to a certain extent, the effect of suppressing noise will no longer be obvious, and the test time will increase greatly, so the average times should not be too large. **The default value of the instrument is 2^{14}.**

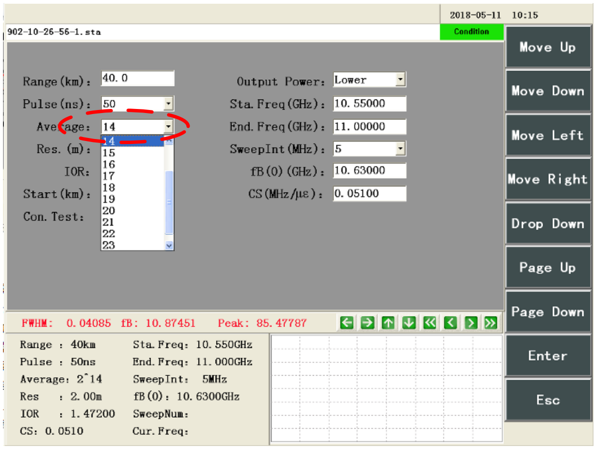


Figure 3-4 Setting interface of average times

2.4 Resolution

It is used to set the sampling resolution of the instrument, also called the sampling interval. There are various resolutions to choose, from 0.05m, 0.1m, 0.2m, 0.5m, 1m to 2m (as shown in Figure 3-5), the lower the sampling resolution value (the higher the corresponding resolution or the smaller the sampling interval), the higher the distance measurement accuracy of the instrument, the finer distribution of fiber strain along the distances can be detected, but test time will extend accordingly.

In actual use, due to the limitation of the maximum number of sampling points of the instrument (currently, the maximum number of sampling points is 80,000 points), different sampling resolutions are selected, and the range of the fiber strain curve that can be detected and displayed is different. The calculation method is: The product of 80,000 and sampling resolution corresponds to the maximum distance of the strain distribution of the displayable fiber. For example, if the selected resolution is 0.05m, the maximum distance of the fiber strain distribution that the instrument can display is 4km at the highest 80,000 sampling point; if the resolution is chosen to be 0.5m, the longest distance of the fiber strain distribution that the instrument can display is 40km theoretically. Therefore, if a longer distance sensing fiber is tested, but a higher resolution is chosen, the instrument can only display the strain distribution curve of a certain distance in the fiber, because the product of the highest sampling point and the selected resolution is less than the length of the fiber (see "Setting of Starting Point"). If it's hoped to display the complete strain distribution of the fiber, it's necessary to reduce the resolution so that the product is larger than the length of the fiber.

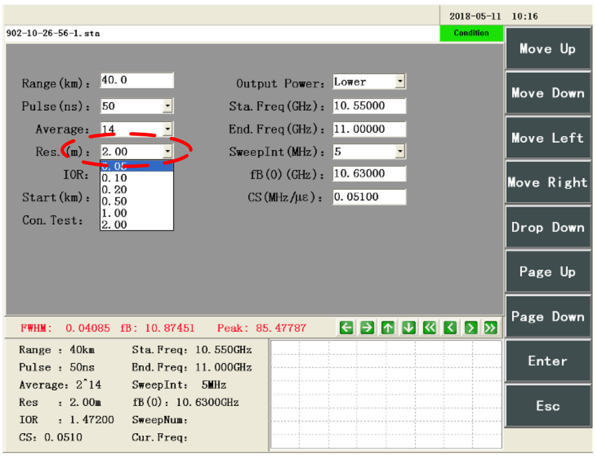


Figure 3-5 Resolution setting interface

Table 3-2 Relationship between sampling resolution and maximum test length

Resolution (m)	Maximum test length (km)
0.05m	4
0.1	8
0.2	16
0.5	40
1	80
2	128 (maximum range)

It should be pointed out that the singular point measured in the case of high sampling resolution can be presented in the partial display, but may not be presented in the global display due to the screen resolution. The singular point can be presented in the display of 6419 BOTDR.

2.5 Refractive index

It is used to set the refractive index of the fiber under test. The setting of the refractive index will directly affect the distance of the instrument test fiber. **In general, it can be set to 1.468.** As shown in Figure 3-6, the refractive index can be input in the input box, or input with the soft keyboard by double-clicking the input box.

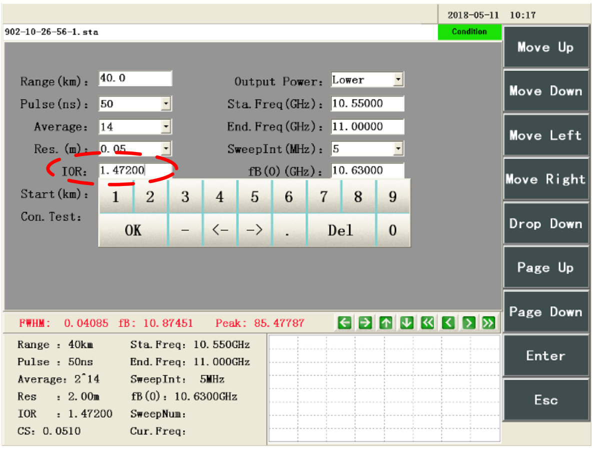


Figure 3-6 Setting interface of refractive index

2.6 Starting point

The starting point parameter is used to set the starting distance of the instrument to test the measured fiber, and the setting range is from 0 to the selected range. The user can set the parameters to observe the details of the fiber strain distribution after the test of the starting point. The setting interface of starting point is shown in Figure 3-7. **The default value is 0**.

The significance of this parameter is that high-resolution testing can be performed on any segment of the fiber under test to observe the details of the distribution of the strain along the distance of any segment of the fiber. It should be noted that it is valid and meaningful to set the starting point parameter only when the product of the maximum number of sampling points and the resolution is greater than the test range. For example, for a 70km sensing fiber, if you want to observe the complete strain distribution of a 70km fiber, the resolution must be greater than 0.5m, because 80,000 (maximum sampling points) × 0.5m (resolution) = 40km, when the starting point is 0, it can only observe the fiber strain distribution in the range of 40km. However, the starting point can be set to 40km at this time, so that the strain distribution of the latter segment of the fiber can be observed.

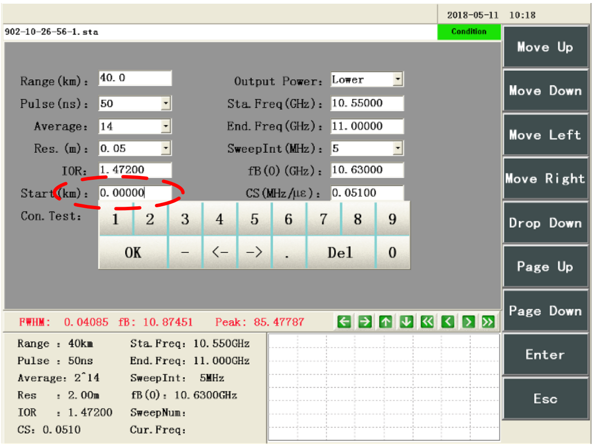


Figure 3-7 Setting interface of starting point

2.7 Output optical power

The input box of output optical power is shown in Figure 3-8. There are four optional values of relatively low, low, medium and high. It's used to set the intensity of the optical pulse signal used in the instrument test, and the increase of the output optical power can improve the quality of the test signal and the accuracy of the instrument when the optical fiber under test is long or the test signal is poor.

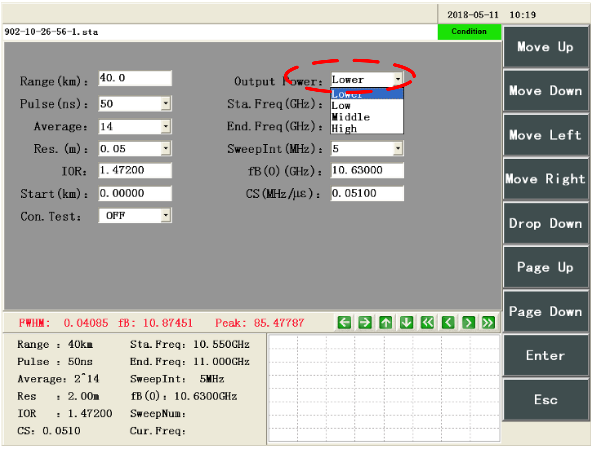


Figure 3-8 Setting of the output optical power

2.8 Start frequency

The Start frequency refers to the Start frequency of the scan. As shown in Figure 3-9, the Start frequency can be entered through the numeric keys of front panel or the digital screen keyboard after double-clicking the input box. The setting value cannot be higher than the ending frequency. The Start frequency should not be set to too small value, otherwise the scanning frequency points will be increased, and the test time will be extended; and the setting value should not be set to too large value, otherwise, the complete Brillouin spectrum cannot be obtained, and the strain of the optical fiber cannot be tested.

The setting of the Start frequency is directly related to the budget value (fy) of the minimum strain of the fiber. Generally, a trial Start frequency can be set first. Then the strain distribution of the fiber can be tested to observe whether there is a jump change of zero strain point in the small strain distribution along the fiber. If there is a zero strain point, the Start frequency is set too large, and it can be appropriately reduced. The frequency of the starting point should be offset from the center frequency with no less than 100MHz. In general, the starting scanning frequency set should be less than 100MHz above the center frequency of the Brillouin spectrum in order to be able to obtain a complete Brillouin scattering spectrum and facilitate curve fitting. Table 3-4 shows the recommended values for the starting scanning frequency setting. Assuming that the fiber fB(0) is 10.64GHz, the test pulse width is 20ns, and it is expected to withstand an axial compressive strain of 1,000με, the Start frequency should be set to fB(0) - 0.1 - 1,000/20,000 = 10.49GHz.

Table 3-4 Correspondence relation between the recommended value of the Start frequency and the pulse width

Pulse width (ns)	Recommended value of the Start frequency (GHz)
10	fB(0)-0.2-fy/20000
20	B(0)-0.1-fy/20000
50	B(0)-0.05-fy/20000
100	B(0)-0.05-fy/20000
200	B(0)-0.05-fy/20000

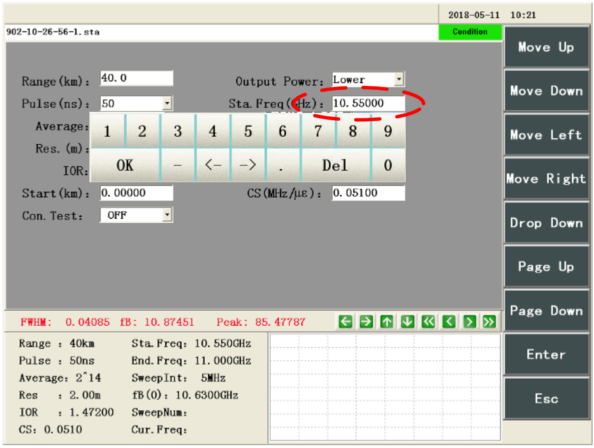


Figure 3-9 Setting of the Start frequency

2.9 Ending frequency

The ending frequency refers to the ending frequency of the scan. As shown in Figure 3-10, the ending frequency can be entered through the numeric keys of front panel or the digital screen keyboard after double-clicking the input box. The setting value cannot be higher than the Start frequency. The ending frequency should not be set to too large value, otherwise the scanning frequency points will be increased, and the test time will be extended; and the setting value should not be set to too small value, otherwise, the complete Brillouin spectrum cannot be obtained, and the strain of the optical fiber cannot be tested.

The setting of the ending frequency is directly related to the budget value (fy) of the maximum strain of the fiber. Generally, a trial ending frequency can be set first. Then the strain distribution of the fiber can be tested to observe whether there is a jump change of zero strain point in the large strain distribution along the fiber. If there is a zero strain point, the ending frequency is set too small, and it can be appropriately increased. The frequency of the starting point should be offset from the center frequency with no less than 100MHz. In general, the ending scanning frequency set should be less than 100 MHz above the center frequency of the Brillouin spectrum in order to be able to obtain a complete Brillouin scattering spectrum and facilitate curve fitting. Table 3-5 shows the recommended value set for the ending scanning frequency. Assuming that the fiber fB(0) is 10.64GHz, the test pulse width is 20ns, and it is expected to withstand an axial compressive strain of 5,000 με, the ending frequency should be set to fB(0) + 0.1 + 5,000/20,000=11.04GHz.

Table 3-5 Correspondence relation between the recommended value of the ending frequency and the pulse width

Pulse width (ns)	Recommended value of the ending frequency (GHz)
10	fB(0) + 0.2 + fy/20,000
20	fB(0) + 0.1 + fy/20,000
50	fB(0) + 0.5 + fy/20,000
100	fB(0) + 0.5 + fy/20,000
200	fB(0) + 0.5 + fy/20,000

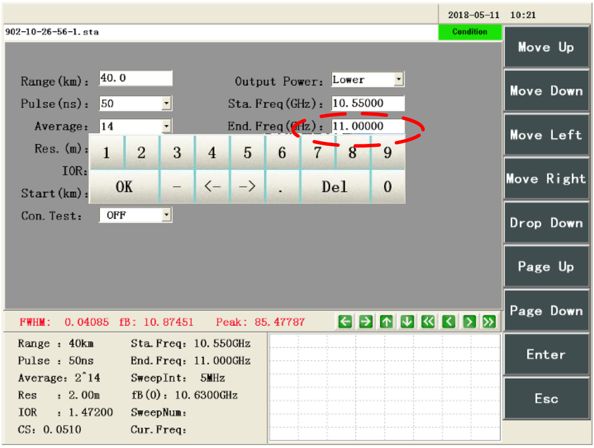


Figure 3-10 Setting of the ending frequency

2.10 Frequency interval

The frequency interval is the step value of the scanning frequency change, as shown in Figure 3-11. Users can choose 1MHz, 2MHz, 5MHz, 10MHz, 20MHz and 50MHz frequency interval through the touch screen or double-click of the mouse, or the "↑" or "↓" of the navigation keys after clicking the setting item area. The frequency interval, the Start frequency and the ending frequency determine the number of sweep points tested together. The formula is:

The number of frequency scanning points = (ending frequency - start frequency) / frequency interval

The maximum number of frequency scanning points of the instrument is 500. The smaller the frequency interval, the more the number of sweep points, and the longer the test time. **It is generally recommended to set it to 5MHz or 10MHz.**

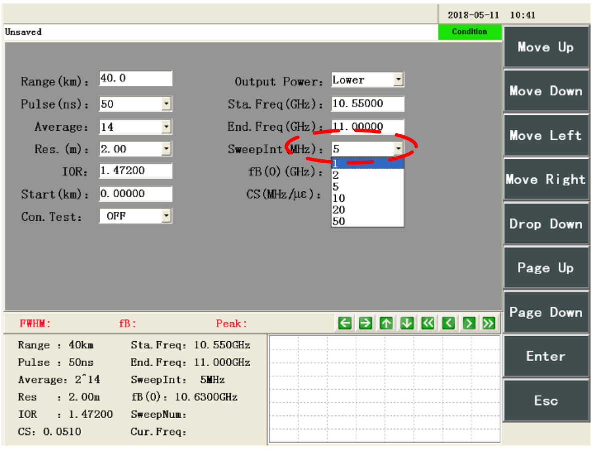


Figure 3-11 Setting interface of frequency interval

2.11 fB (0)

This parameter is the center frequency of the Brillouin scattering spectrum of the fiber under test without strain. It is related to the material of the fiber and is one of the important parameters for calculating the strain distribution of the fiber. If absolute strain test is required, the parameter needs to be calibrated (It needs to be obtained by means of a specific device), otherwise, only relative testing can be performed. The specific test methods are as follows:

Step 1: Connect the fiber under test without strain to the BOTDR optical interface of front panel, and test the strain curve according to the method described in **Chapter VIII, Section 2.1**. Click [Multiwindow] → [Strain Dis.] to enter the strain distribution window.

Step 2: Click [Marker] to enter the marker function menu. Use the touch screen or waveform operation button to move the cursor to the vicinity of 10% of the length of the fiber under test. Click [Marker 1] to set the marker point 1; move the cursor to the vicinity of 90% of the length of the fiber under test, click [Marker 2] to set the marker point 2;

Step 3: Click [Strain Frequency] to switch the marked calculation data in the test condition area to frequency data, then the average center frequency value displayed in the Ave item is the initial frequency shift of Brillouin spectrum fB (0) of this segment of fiber, as shown in Figure 3-12.

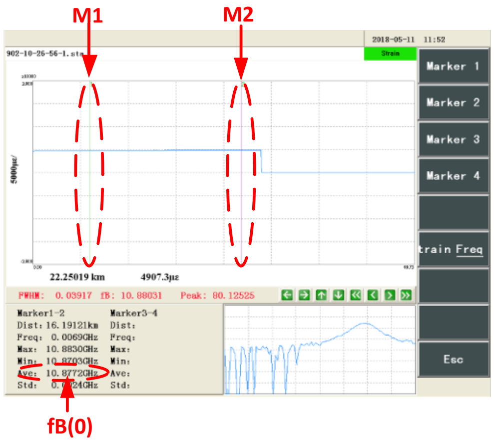


Figure 3-12 Initial frequency shift of Brillouin spectrum fB (0) test

Note! **By setting marker 1 and marker 2, the maximum value, minimum value, average value and standard deviation of the fiber strain (or frequency) between the two markers can be automatically calculated, and the strain and Brillouin center frequency can be converted. For detailed operation, see the description of the function of the marker points in Chapter IV, Section 1.1.3.**

Through the above test, fB (0) can be input through the numeric keys of front panel or the digital screen keyboard pop up after double-clicking the input box, as shown in Figure 3-13.

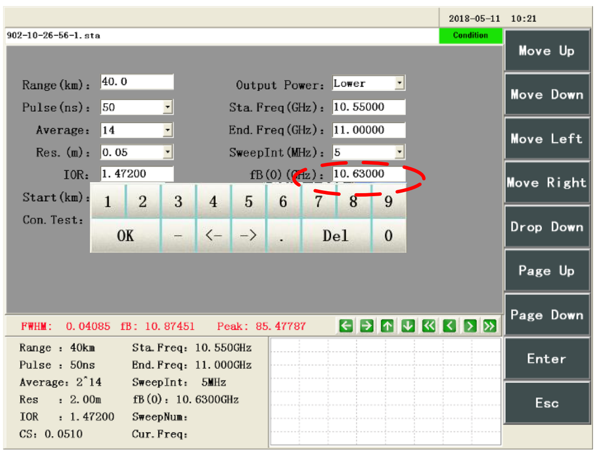


Figure 3-13 fB (0) setting interface

2.12 CS

The parameter is the strain coefficient of the fiber, that is, the relationship between the strain of the fiber and the center frequency of the Brillouin spectrum. Like the Start frequency shift parameter of the fiber, this parameter is one of the important parameters for calculating the strain distribution of the fiber, and is related to the fiber material. If an absolute strain test is required, the parameter needs to be calibrated (it needs to be obtained by means of a specific device), otherwise, only relative testing can be performed. As shown in Figure 3-14, the CS parameter can be entered through the numeric keys of front panel or the digital screen keyboard after double-clicking the input box. **The default value is 0.05MHz/με**.

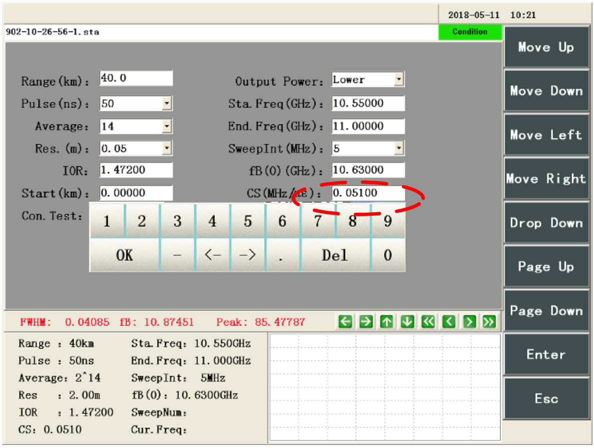


Figure 3-14 CS. setting interface

2.13 Continuous test

The continuous setting parameter is used to set the timing test of the instrument and opening and closure of automatic saving function.

The continuous test is in the "off" state by default in the system as shown in Figure 3-15. Continuous test can be enabled by selecting “enable” from the continuous test drop-down menu, and continuous test options will appear in the test condition setting interface: **Time interval, Autosave** options, as shown in Figure 3-16.

When the continuous test option is enabled, the instrument will time and test according to the time interval settings until the user stops the average processing test.

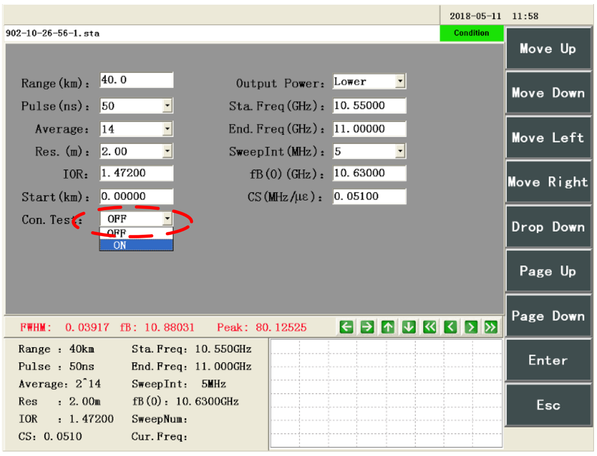


Figure 3-15 Disable the test condition setting interface of continuous test

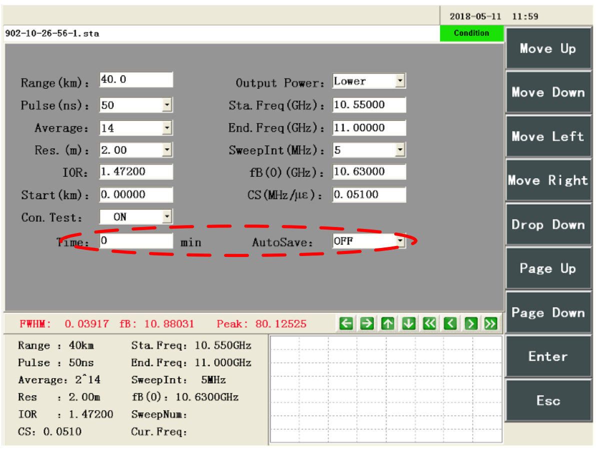


Figure 3-16 Enable the test condition setting interface of continuous test

2.14 Time interval

The time interval is used to set the time interval between two start-up tests in minutes. If the time interval set value is less than the single test time, the instrument will test at the minimum time interval of a single test.

2.15 Autosave

Auto saving sets the auto saving function of measurement data through the drop-down menu, it is in “OFF” sate by default. When auto saving is set to OFF, the instrument will not save the data automatically in the continuous test state, and the current measurement result will only be displayed in the window display area. When auto saving is set to ON, the test condition setting interface increases the **File Type, File No. and SavePath** options, as shown in Figure 3-17.

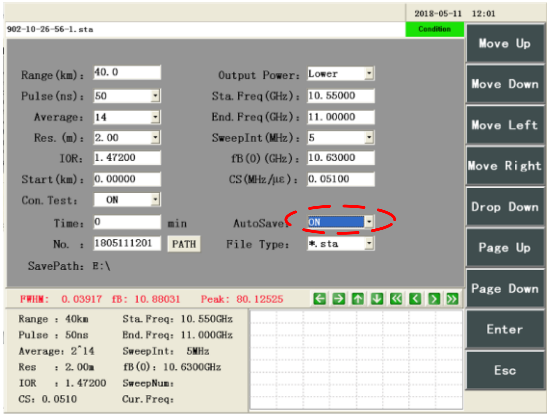


Figure 3-17 Enable the test condition setting interface of auto saving

2.16 File serial number

The file serial number is the file name when the data file name is automatically saved, which can be entered through the mouse or the soft keyboard pop out after double-clicking the text box on the touch screen, or the numeric key area of the front panel of the instrument, as shown in Figure 3-18. After enabling the auto saving, the data file will be automatically stored in the selected path in the form of "file serial number _XXXX. file type" once the test is completed. XXXX is the file order saved after starting continuous test, if the file serial number is set to 1602251025, the file type is sta file, then the first saved file name is: 1602251025_0000.sta, the second saved file name is: 1602251025_0001.sta, and the third saved file name is 1602251025_0002.sta, ……, and so on.

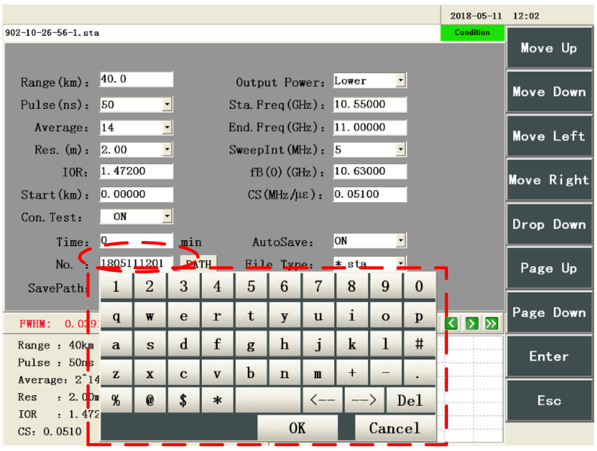


Figure 3-18 File serial number setting and soft keyboard interface

2.17 File type

The file type is used to set the type of the file saved automatically. The drop-down menu has two data types "*.sta" and "*.eis" to choose from, and the "*.sta" type data stores all measurement results of the instrument, "*.eis" type data only contains data of strain. For the description about the type of the 6419 distributed optical fiber strain tester, see **Chapter VI, Section 4**.

2.18 Autosave path

The autosave path display is located directly below the file serial number, as shown in Figure 3-19. The path button is used to set the save path of the data during continuous test. It is located on the right side of the file serial number input box. After clicking the path button with the touch screen or mouse, the sub-window of path setting will be displayed in the test condition area at the lower left of the screen.

In the sub-window of path setting, the partition and directory of file saving can be set by mouse or touch screen.

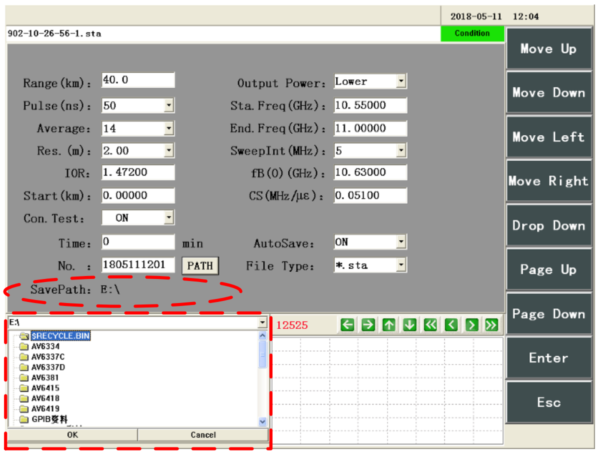


Figure 3-19 Save path setting interface

3 Description on operation of test condition interface

The parameter boxes in the 6419 BOTDR test condition interface are divided into two categories. One is the input box that can be freely input by the user; the other is the drop-down box where the user can only select the parameter among the given parameters.

3.1 Description of operation of input box

The parameter boxes of the refractive index, test starting point, Start frequency, ending frequency, fB(0) and CS under the test condition interface are input boxes. The user can change the parameter values in the input box by operation on touch screen, mouse or front panel keys.

(1) Use the touch screen or mouse to change the parameters in the input box. The steps are as follows:

① Use the touch screen or left mouse button to click the input box that needs to change the parameters, and move the focus to the corresponding parameter input box;

② Double-click the input box to pop out the numeric keypad as shown in Figure 3-20;

③ Click the clear key, number key and decimal point in the numeric keypad to change the value in the box. The “->” and “<-” keys can control the cursor in the parameter box to move forward or backward character by character;

④ Click the "OK" button to complete the input of the parameter values.

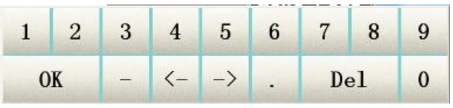


Figure 3-20 Schematic diagram of numeric keypad

(2) Use the buttons on the front panel to change the parameters in the input box. The steps are as follows:

① Use the buttons on the menu keypad of front panel to run [Move Up], [Move Down], [Move Left] and [Move Right] in the function menu. The cursor buttons on the navigation keypad can also be used to move the focus of the test condition interface to the input box that needs to change the parameters;

② Enter the parameters using the numeric keys in the numeric key area and delete the parameters using the backspace key;

③ Use the Enter key to confirm the entered parameters or use the ESC key to cancel the modification of the parameters in the selected parameter box.

3.2 Description of operation of drop-down box

The parameter boxes such as range, pulse width, average times, sampling resolution, output optical power, automatic scanning, and frequency interval under the test condition interface are drop-down boxes.

(1) Use the touch screen or mouse to change the parameters in the drop-down box. The steps are as follows:

① Use the touch screen or left mouse button to click the part of the drop-down box that needs to change the parameters, and pop out the list;

② Select the desired parameter value to complete the input.

(2) Use the buttons on the front panel to change the parameters in the drop-down box. The steps are as follows:

① Use the function keys of [Move Up], [Move Down], [Move Left] and [Move Right] in the function menu. The cursor buttons on the navigation keypad can also be used to move the focus of the test condition setting interface to the drop-down box that needs to change the parameters;

② Use the [Drop Down] function key in the function menu to pop out the list of selected drop-down boxes;

③ Use the arrow button on the navigation keypad of front panel to move the focus in the drop-down list and move the focus to the parameter you want to select;

④ If you did not perform step ② and step ③, the arrow button  or  can select the previous option of currently displayed menu item in the drop-down menu option,  or  can select the next option of the currently displayed menu item. Then use the function keys of [Move Up], [Move Down], [Move Left] and [Move Right] in the function menu, or the cursor buttons on the navigation keypad to move the focus of the test condition setting interface to the parameter boxes of other parameters to complete the input in the drop-down box.

Chapter IV Description of Window Display

1. Description of the state of window display area

There are seven states in the 6419 BOTDR window display area, which are “multiwindow” state, “strain distribution” state, “spectral width distribution” state, “Brillouin spectrum” state, “loss distribution” state, “comprehensive loss” state and, "3D" state.

1.1 Multiwindow state

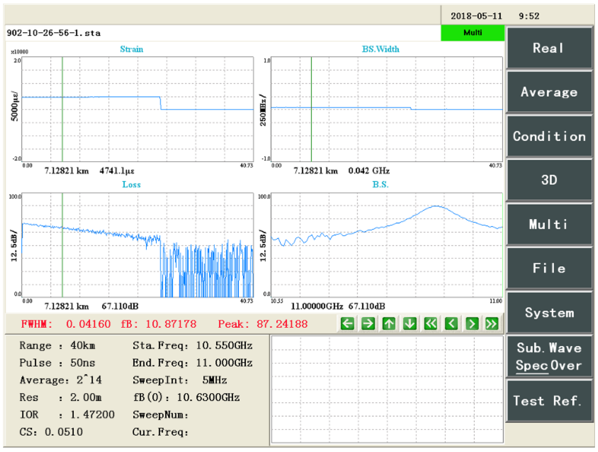


Figure 4-1 Multiwindow state

1.1.1 Overview

The “multiwindow” state is the default state of window display area of the instrument software. When the instrument software is started, the window display area will automatically enter the “multiwindow” state; the user returns to the multiwindow sub-menu from the tertiary menu under the multiwindow sub-menu and returns to the main menu from the secondary menu, the window display area will automatically enter the "multiwindow" state.

In the "multiwindow" state, the window display area will display the "strain distribution" window, the "spectral width distribution" window, the "Brillouin spectrum" window, and the "loss distribution" window. The upper right corner of the window display area displays the state as "multiple-window", the window display area is shown in Figure 4-1.

In the "multiwindow" state, the "strain distribution" window, the "spectral width distribution" window, the "Brillouin spectrum" window, and the "loss distribution" window will all display curves according to the test results in the instrument, if the window has no corresponding data to display, this window will be empty and the curve will not be displayed.

1.1.2 Description of sub-menu

Click the [Multiwindow] function button in the main function menu to enter the multiwindow sub-menu. The multiwindow sub-menu is a secondary menu. The structure is shown in Figure 4-2. The function of the menu button is as follows:

[Strain Dis.]: The function menu area displays the sub-menu of strain distribution, and the window display area enters the “strain distribution” state.

[Spectral width distribution]: The function menu area displays the sub-menu of spectral width distribution, and the window display area enters the "spectral width distribution" state.

[Brillouin spectrum]: The function menu area displays the sub-menu of Brillouin spectrum, and the window display area enters the "Brillouin spectrum" state.

[Loss Dis.]: The function menu area displays the sub-menu of loss distribution, and the window display area enters the “loss distribution” state.

[Comprehensive Loss]: The function menu area displays the sub-menu of comprehensive loss, and the window display area enters the “comprehensive loss” state.

[Cursor]: It is used to select distance mode or the frequency mode of cursor movement in the "multiwindow" state.

[Global Display]: It initializes the curves of all windows in the "multiwindow" state, and returns to the initial state of the test so that each window can display the full view of the curve.

[Back]: Return to the main function menu, and the status of the window display area remains in the "multiwindow" state.

Figure 4-2 "Multiwindow" sub-menu

1.1.3 Description of operation

In the "multiwindow" state, the curves displayed in the "strain distribution" window, the "spectral width distribution" window, the "loss distribution" window, and the "Brillouin spectrum" window can be operated through the touch screen, the mouse, and the front panel keys, but the result of the operation will change due to the setting of the [Cursor] function button in the multiwindow sub-menu.

(1) In the "multiwindow" state, after setting the [Cursor] function button in multiwindow sub-menu to "**distance/frequency**", the cursor can be moved or the curve can be scaled in the "strain distribution" window, the "spectral width distribution" window, and the "loss distribution" window.

① The curves displayed in the “strain distribution” window, the “spectral width distribution” window, and the “loss distribution” window can be compressed along the horizontal coordinate after clicking the button in the waveform operation area through the left mouse button or the touch screen. The curves displayed in the “strain distribution” window, the “spectral width distribution” window, and the “loss distribution” window can be expanded along the horizontal coordinate after clicking the button in the waveform operation area through the left mouse button or the touch screen. The curves displayed in the “strain distribution” window, the “spectral width distribution” window, and the “loss distribution” window can be compressed along the vertical coordinate after clicking the button in the waveform operation area through the left mouse button or the touch screen. The curves displayed in the “strain distribution” window, the “spectral width distribution” window, and the “loss distribution” window can be expanded along the vertical coordinate after clicking the button in the waveform operation area through the left mouse button or the touch screen. The cursor moves in the above window through clicking the buttons. The button indicate fast movement. The button moves the cursor to the left by ten units at a time. The button moves the cursor to the right by ten units at a time. indicate normal movement, and the button moves the cursor to the left by one unit at a time, the button moves the cursor to the right by one unit at a time.

② The navigation buttons on the front panel can be used to scale the horizontal coordinate.

The button on the navigation keypad of front panel can be used to compress the curves displayed in the “strain distribution” window, the “spectral width distribution” window, and the “loss distribution” window along the horizontal coordinate;

The button on the navigation keypad of front panel can be used to expand the curves displayed in the “strain distribution” window, the “spectral width distribution” window, and the “loss distribution” window along the horizontal coordinate;

③ The knob buttons on the navigation keypad of front panel can be used to move the cursor in the “strain distribution” window, the “spectral width distribution window, and the loss distribution window. Rotate the cursor clockwise to the right and counterclockwise to the left. Click the "fast" button on the front panel, the movement speed of mobile knob will be ten times faster, click the "fast" button again to return to the original speed.

Note!

Moving the position of the cursor in the “strain distribution” window, the “spectral width distribution” window, and the “loss distribution” window will change the selected distance point of the Brillouin spectrum curve displayed in the “Brillouin spectrum” window, so the “Brillouin spectrum” window will be changed to display the Brillouin spectrum curve corresponding to the new selected distance point.

(2) In the "multiwindow" state, after setting the [Cursor] function button in multiwindow sub-menu to "distance/frequency", the cursor can be moved or the curve can be scaled in the "Brillouin spectrum" window.

① In the “multiwindow” state, the curve displayed in the “Brillouin spectrum” window can be operated through clicking the buttons in the waveform operation area through the left mouse button or touch screen. indicate fast movement, and the button moves the cursor to the left by ten units at a time, the button moves the cursor to the right by ten units at a time. indicate normal movement, and the button moves the cursor to the left by one unit at a time, the button moves the cursor to the right by one unit at a time.

②The knob buttons on the navigation keypad of front panel can be used to move the cursor in the “Brillouin spectrum” window. Rotate the cursor clockwise to the right and counterclockwise to the left. Click the [Quick] button on the front panel, the movement speed of mobile knob will be ten times faster, click the [Quick] button again to return to the original speed.

Note!

Moving the position of cursor in the Brillouin Spectrum window will change the sweep frequency point displayed in the loss distribution curve in the “loss distribution” window, so the “loss distribution” window will be changed to display the corresponding loss distribution curve of new sweep frequency point.

1.2 Strain distribution window

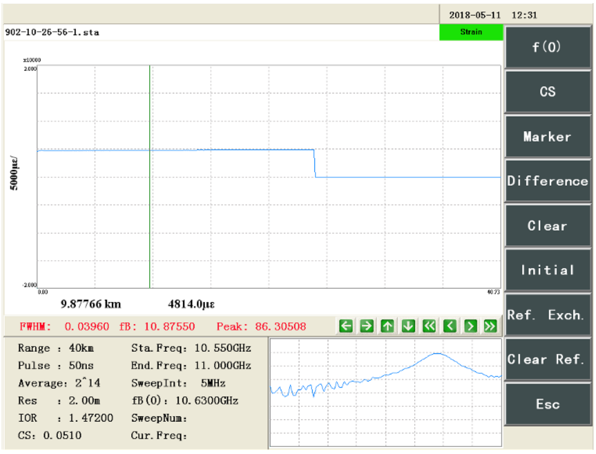


Figure 4 -3 Display window of “strain distribution” state window

1.2.1 Overview

Click [Multiwindow] → [Strain Dis.], or click the [Strain] button on the function keypad of front panel to enter the display interface of strain distribution. The upper right corner of the window display area displays the state as “strain distribution”, and the function menu area displays the sub-menu of strain distribution, and the window display area is as shown in Figure 4-3. The "strain distribution" state is used to display the strain-distribution curve of the fiber under test.

The sub-waveform window in Figure 4-3 displays the Brillouin spectrum line, because the [Sub.Wave] in the main function menu is selected as the "global **Brillouin spectrum**" state. If the [Sub.Wave] is selected as "**global** Brillouin spectrum", then the sub-waveform displays the global curve of the strain distribution.

The “strain distribution” window displays the strain-distance curve, which is used to represent the strain values at different distances on the fiber under test. The strain size at different distances of the fiber under test can be observed visually by observing this window.

The vertical line in the window of Figure 4-3 is the cursor, the “0.37423km” below the horizontal axis is the distance value of the position where the cursor is located, and “2,656.8με” is the strain value of the position where the cursor is located (με is the strain unit, the size is equivalent to the 10^{-6} of the total length, that is, one in a million).

1.2.2 Description of sub-menu

Click the [Strain Dis.] function button in the multiwindow sub-menu, and the function distribution area will display the strain distribution sub-menu. The structure of strain distribution sub-menu is shown in the function menu area in Figure 4-3. The functions are as follows:

[fB (0)]: Used to set the parameters required for the instrument to calculate the strain distribution—the initial frequency shift fB (0), fB (0) is the frequency shift of Brillouin spectrum of the fiber without strain, namely, the initial frequency shift of Brillouin spectrum.

[C.S.]: Used to set the parameters required for the instrument to calculate the strain distribution - strain coefficient, Cs. Cs is the strain coefficient of the frequency shift of Brillouin spectrum of fiber, which is a constant related to the fiber material and the wavelength of the probe light. For the conventional G.652 single mode fiber, the strain coefficient Cs is generally approximate to 493MHz/% or 0.0493MHz/με at the detection wavelength of 1,550nm.

[Marker]: The function menu area will display the sub-menu of Marker for setting the marker points in the “strain distribution” window, and the test condition area will be changed to display the marker point information.

[Difference]: Display the difference between the current data and the reference data in the window.

[Clear Ref.]: Clear all the maker points in the “strain distribution” window.

[Global Display]: Restore the zoom state of the strain distribution window to the initial state.

[Exchange Reference]: Exchange the current display curve with the reference curve, switch the current display curve to the reference curve, and switch the reference curve to the current display curve.

[Clear reference]: Clear the reference curve displayed in the software.

[Back]: Return to the multiwindow sub-menu, the function menu area will display the multiwindow sub-menu.

Note!

After changing fB (0) or Cs., the instrument will recalculate the currently displayed test curve according to the new parameter value and refresh the test curve after calculation.

1.2.3 Description of operation

(1) Cursor movement and coordinate scaling

① In "strain distribution" state, the curve displayed in the window can be zoomed out by clicking the button in the waveform operation area through the left mouse button or the touch screen; the curve will shrink along the horizontal direction by pressing the button, the curve will enlarge along the horizontal direction by pressing the button, the curve will enlarge along the vertical direction by pressing the button, the button curve will shrink along the vertical direction by pressing the button; the movement of the cursor can be moved by clicking the button, indicate fast movement, and the button moves the cursor to the left by ten units at a time, the button moves the cursor to the right by ten units at a time. indicate normal movement, and the button moves the cursor to the left by one unit at a time, the button moves the cursor to the right by one unit at a time.

② In the "strain distribution" state, the arrow direction in the navigation keypad of front panel can be used to scale the curve displayed in the window.

③ The knob buttons on the navigation keypad of front panel can be used to move the cursor in the “strain distribution” window. Rotate the cursor clockwise to the right and counterclockwise to the left. Click the [Quick] button on the front panel, the movement speed of mobile knob will be ten times faster, click the [Quick] button again to return to the original speed.

(2) Operation of maker points of Marker

The maker point of Marker can be set and cleared in the "strain distribution" state. Reasonable setting of makers points and viewing of Marker information can help users reduce the amount of data recording and the amount of data calculation.

① Placement of Marker points

In the "strain distribution" state, the Marker sub-menu can be entered by clicking the [Marker] function button under the strain distribution sub-menu through the mouse, touch screen or menu buttons of front panel. At this time, the test condition area displays the Marker information, as shown in Figure 4- 4.

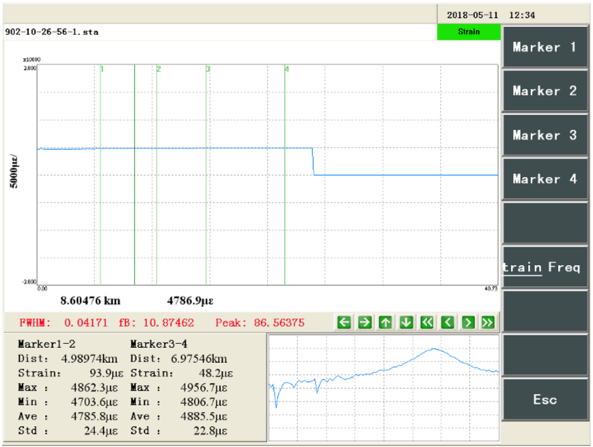


Figure 4-4 Marker interface in the "strain distribution" state

Note! **The maker points of Marker should be placed in the order of Marker 1 to Marker 4. The inversion of sequential order will coincide with the Marker points. In this case, the position of Marker points can be adjusted in order to make them display normally.**

② Description of Marker information

[Strain Frequency]: It is used to switch the Marker information type displayed in the test information area. If this button is [**Strain** Frequency], then the test condition area will display the strain information of the marker area of Marker; if this button is [Strain **Frequency**], then the test condition area will display the Brillouin center frequency information of the marker area of Marker.

In the “strain distribution” state, there are two groups of marker information of Marker, namely “Marker1-2” group and “Marker3-4” group.

1) When [Strain Frequency] is set to **"strain"**.

All information below the "Marker1-2" position belongs to the "Marker1-2" group, and the meaning of the data information is as follows.

Distance: It indicates the difference in distance between marker point 1 and marker point 2, the unit is km, mi. or kft.

Strain: It indicates the difference between the strain at the maker point 1 and the strain at the maker point 2, the unit is % or με.

Max: It indicates the maximum strain value of the fiber segment between the marker point 1 and the marker point 2, the unit is % or με.

Min: It indicates the minimum strain value of the fiber segment between the marker point 1 and the marker point 2, the unit is % or με.

Ave: It indicates the average strain value of the fiber segment between the marker point 1 and the marker point 2, the unit is % or με.

Std: It indicates the standard deviation of the strain of the fiber segment between the marker point 1 and the marker point 2, the unit is % or με.

All information below the "Marker3-4" position belongs to the "Marker3-4" group, and its data information corresponds to the distance (distance), the strain difference (strain), the maximum strain value (Max), the minimum strain value (Min), the average strain value (Ave) and the strain standard deviation (Std) between the marker point 3 and the marker point 4.

2) When [Strain Frequency] is set to **"Frequency"**.

All information below the "Marker1-2" position belongs to the "Marker1-2" group, and the meaning of the data information is as follows.

Distance: It indicates the difference in distance between marker point 1 and marker point 2, the unit is km, mi. or kft.

Frequency: It indicates the difference between the strain at the marker point 1 and the Brillouin center frequency at marker point 2, the unit is GHz.

Max: It indicates the maximum Brillouin center frequency of the fiber segment between marker point 1 and marker point 2, the unit is GHz.

Min: It indicates the minimum Brillouin center frequency of the fiber segment between marker point 1 and marker point 2, the unit is GHz.

Ave: It indicates the average Brillouin center frequency of the fiber segment between marker point 1 and marker point 2, the unit is GHz.

Std: Indicates the difference standard deviation of the Brillouin center frequency of the fiber segment between the marker point 1 and the marker point 2, the unit is GHz.

All information below the "Marker3-4" position belongs to the "Marker3-4" group, and its data information corresponds to the distance (distance), the Brillouin center frequency difference (frequency), the maximum Brillouin center frequency (Max), the minimum Brillouin center frequency (Min), the average Brillouin center frequency (Ave) and the difference standard deviation of Brillouin center frequency(Std).

③ Clearance of Marker points

In the sub-menu of strain distribution, use the left mouse button, touch screen or menu button of front panel to click the [Clear marker] function button under the sub-menu of strain distribution to clear all the maker points set in the "strain distribution" state.

Note!

The position of set Maker points is temporarily saved in the "strain distribution" state, but if the user switches from the "strain distribution" state to the "spectral width distribution" state, the "loss distribution" state, the "comprehensive loss" state" and the "Brillouin spectrum" state, the position of set Maker points that has been temporarily saved in the "strain distribution" state will be cleared, so if the maker point is used in the next test, please save it in time.

(3) Operation of difference analysis

When the system runs the test data and loads the reference data, as shown in Figure 4-5, select the [Difference] button in the sub-menu of strain distribution, and the strain distribution state is displayed for the difference function.

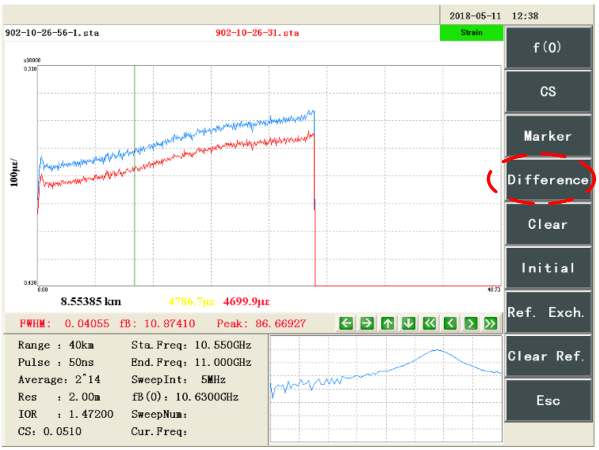


Figure 4-5 Difference interface in the "strain distribution" state

① Changes of strain distribution window

As shown in Figure 4-6, after selecting the difference function, the strain distribution window is divided into upper and lower parts. The upper part shows the strain curve of test data and the reference data. The horizontal coordinate shows the distance of the current cursor position, 4.28858km, and the strain value of the two sets of data of corresponding distance point. The strain value of measured data at the cursor is 3,902.6με, and the strain value of the reference data is 3,842.0με; the lower part shows the difference curve between the test data and the reference data, and the horizontal coordinate shows the distance of the current cursor position, 4.28858km and the difference between the two strains is 60.6με.

Figure 4-6 Difference state interface of strain sub-menu

Note! **The reference data is loaded using [Open Ref.] in the [File] sub-menu of the main function menu.**

② Changes of strain distribution menu

After selecting the difference function, the [Difference] in the original strain distribution sub-menu changes to [Cancel Difference], which is used to exit the strain distribution difference state, as shown in Figure 4-6.

In addition, the [Switch window] function item is added to the [Marker] sub-menu in the strain distribution sub-menu to switch the marker point between the strain distribution curve and the strain distribution difference curve, Figure 4-7 (a) and Figure 4-7 (b) is the result before and after using the [Switch Wilow] function.

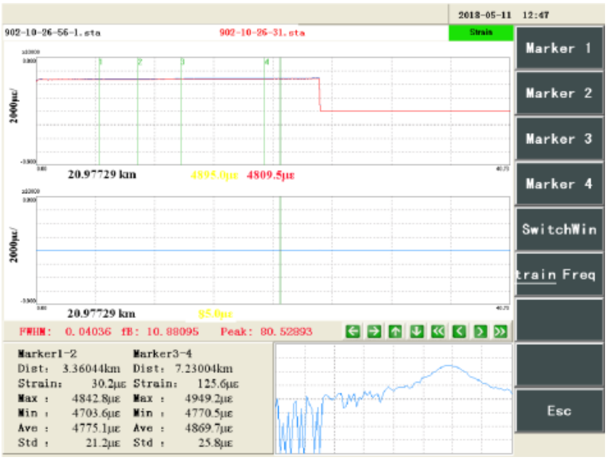


Figure 4-7 (a) Marking the strain curve in the difference state of strain distribution

The marker point information in the test condition area in Figure 4-7 (b) is correspondingly represented as the change in strain (or frequency) between the marker points on the difference curve.

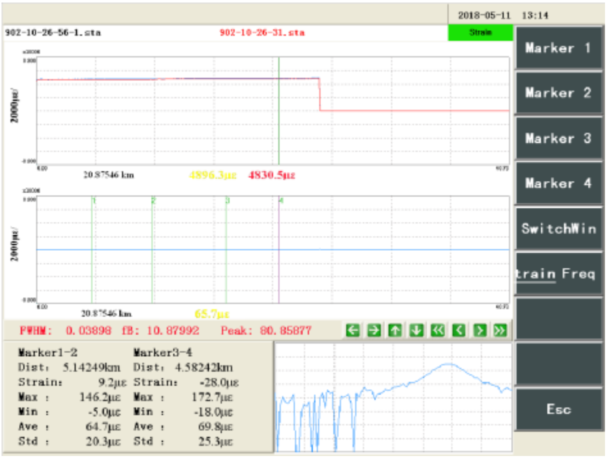


Figure 4-7 (b) Using the menu function [Switch Wilow] to switch the marker points to the position corresponding to the difference curve.

1.3 Spectral width distribution window

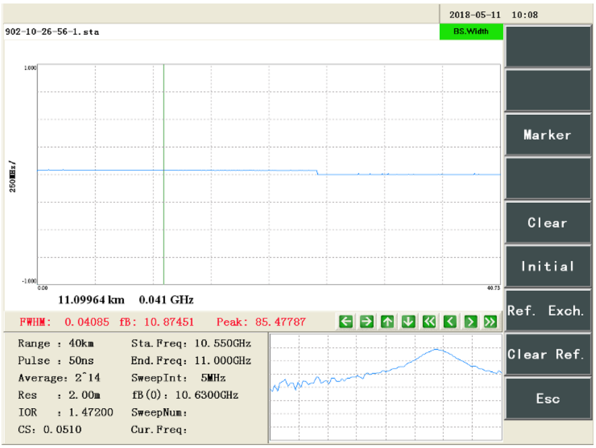


Figure 4-8 Display area of "spectral width distribution" state window

1.3.1 Overview

Click [Multiwindow] → [Spectral width distribution] to enter the display interface of spectral width distribution. The upper right corner of the window display area displays the state as “spectral width distribution”, and the function menu area displays the sub-menu of spectral width distribution, and the window display area is as shown in Figure 4-8.

The “spectral width distribution” window displays the spectral width-distance curve, which is used to display the Brillouin spectrum distribution of the fiber under test. The size of Brillouin spectrum at different distances of the fiber under test can be observed visually by observing this window.

The vertical line in the window of Figure 4-7 is the cursor, the “0.22530km” below the horizontal axis is the distance value of the position where the cursor is located, and “0.063GHz” is the spectral width value of the position where the cursor is located

1.3.2 Description of sub-menu

The functions of button on sub-menu of spectral width distribution are described as follows:

[Marker]: The function menu area will display the sub-menu of Marker for setting the marker points in the “spectral width distribution” window.

[Clear]: Clear all the maker points in the “spectral width distribution” window.

[Global Display]: Restore the zoom state of the spectral width distribution window to the initial state.

[Exchange Reference]: Exchange the current display curve with the reference curve, switch the current display curve to the reference curve, and switch the reference curve to the current display curve.

[Clear reference]: Clear the reference curve displayed in the software.

[Back]: Return to the multiwindow sub-menu, the function menu area will display the multiwindow sub-menu.

1.3.3 Description of operation

(1) Cursor movement and coordinate scaling

① In "spectral width distribution" state, the curve displayed in the window can be zoomed out by clicking the button in the waveform operation area through the left mouse button or the touch screen; the curve will shrink along the horizontal direction by pressing the button, the curve will enlarge along the horizontal direction by pressing the button, the curve will enlarge along the vertical direction by pressing the button, the button curve will shrink along the vertical direction by pressing the button; the movement of the cursor can be moved by clicking the button, indicate fast movement, and the button moves the cursor to the left by ten units at a time, the button moves the cursor to the right by ten units at a time. indicate normal movement, and the button moves the cursor to the left by one unit at a time, the button moves the cursor to the right by one unit at a time.

② In the "spectral width distribution" state, the arrow direction in the navigation keypad of front panel can be used to scale the curve displayed in the window.

③ The knob buttons on the navigation keypad of front panel can be used to move the cursor in the “spectral width distribution” window. Rotate the cursor clockwise to the right and counterclockwise to the left. Click the [Quick] button on the front panel, the movement speed of mobile knob will be ten times faster, click the [Quick] button again to return to the original speed.

(2) Operation of maker points of Marker

① Setting of maker points of Marker

In the “spectral width distribution" state, the Marker sub-menu can be entered by clicking the [Marker] function button under the spectral width distribution sub-menu through the left mouse button, touch screen or menu buttons of front panel. At this time, the test condition area displays the Marker information, as shown in Figure 4- 9.

Note! **The order of the four Marker points is Marker1, Marker2, Marker3, and Marker4.**

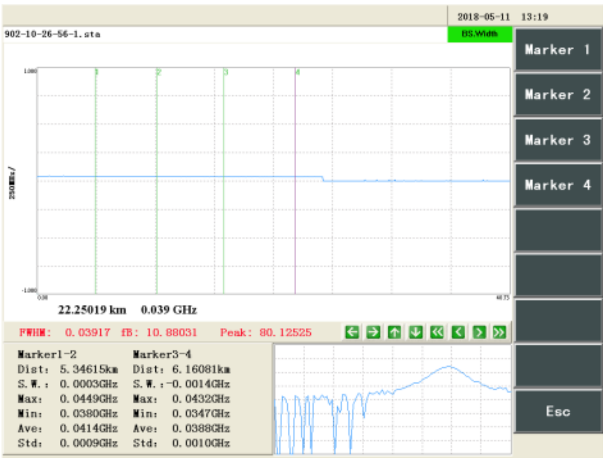


Figure 4-9 Marker interface in the "spectral width distribution" state

② Description of Marker information

In the “spectral width distribution” state, the Marker information displayed in the test condition area is shown in Figure 4-9, there are two groups of marker information of Marker, namely “Marker1-2” group and “Marker3-4” group.

All information below the "Marker1-2" position belongs to the "Marker1-2" group, and the meaning of the data information is as follows.

Distance: It indicates the difference in distance between marker point 1 and marker point 2, the unit is km, mi. or kft.

Spectral width: It indicates the difference of Brillouin spectral width between marker point 1 and marker point 2, the unit is GHz.

Max: It indicates the maximum spectral width of the fiber segment between marker point 1 and marker point 2, the unit is GHz.

Min: It indicates the minimum spectral width of the fiber segment between marker point 1 and marker point 2, the unit is GHz.

Ave: It indicates the average spectral width of the fiber segment between marker point 1 and marker point 2, the unit is GHz.

Std: It indicates the spectral width standard deviation of the fiber segment between marker point 1 and marker point 2, the unit is GHz.

All information below the "Marker3-4" position belongs to the "Marker3-4" group, and its data information corresponds to the distance difference, the spectral width difference, the maximum spectral width, the minimum spectral width, and the average spectral width, and spectral width standard deviation between marker point 3 and marker point 4.

③ Clearance of Marker points

In the sub-menu of spectral width distribution, use the mouse, touch screen or menu button of front panel to click the[Clear marker]function button under the sub-menu of spectral width distribution to hide all the maker points displayed in the [Spectral width distribution] state, as shown in Figure 4-10.

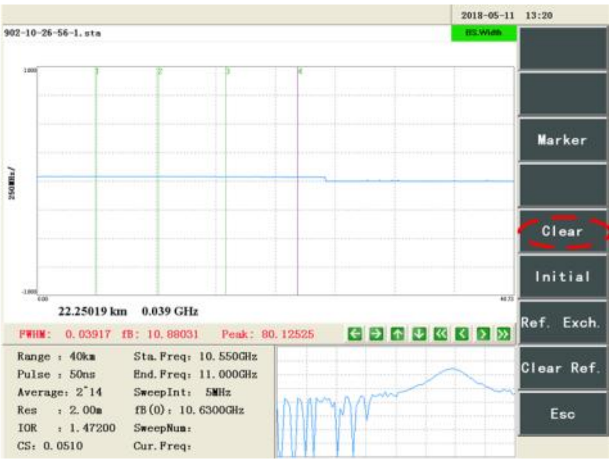


Figure 4-10 Clearing maker points in the "spectral width distribution" state

Note! **The position of set Maker points is temporarily saved in the "spectral width distribution" state, but if the user switches from the "spectral width distribution" state to the "strain distribution" state, the "loss distribution" state, the "comprehensive loss" state" and the "Brillouin spectrum" state, the position of set Maker points that has been temporarily saved in the "strain distribution" state will be cleared, so if the maker point is used in the next test, please save it in time.**

1.4 Brillouin Spectrum Display dialog box

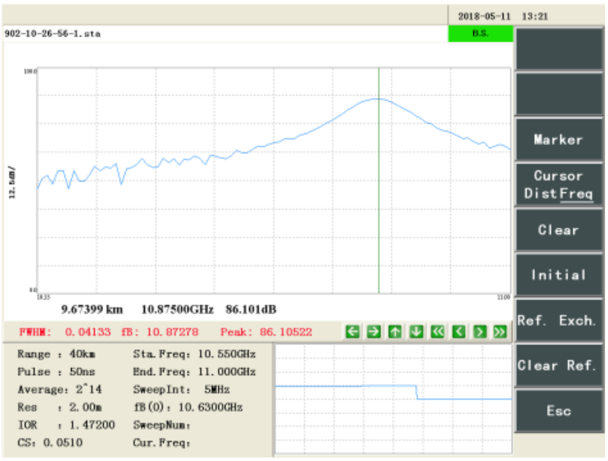


Figure 4-11 Window display area of “Brillouin spectrum" state

1.4.1 Overview

Click [Multiwindow] → [Brillouin spectrum] to enter the display interface of Brillouin spectrum. The upper right corner of the window display area displays the state as “Brillouin spectrum”, and the function menu area displays the sub-menu of Brillouin spectrum, and the window display area is as shown in Figure 4-11, the sub-menu in “Brillouin spectrum” state is displayed as global curve of strain.

The “Brillouin spectrum” window displays the relative power-sweep frequency curve, which is used to represent the Brillouin spectrum curve at the selected distance point of the fiber under test. The relative power value corresponding to the sweep frequency at the selected distance point of the fiber under test can be visually observed by observing this window.

The vertical line in the window in Figure 4-11 is the cursor, the “10.53000GHz” below the horizontal axis is the sweep frequency value of the selected distance point, “68.549dB” is the relative power value of the position where the cursor is located, “0.37423km” is the distance information for the selected distance point at which the Brillouin spectrum curve is shown currently.

1.4.2 Description of sub-menu

The functions of the sub-menu of Brillouin spectrum are described as follows:

[Marker]: The function menu area will display the sub-menu of Marker for setting the marker points in the “Brillouin spectrum” window.

[Cursor]: It is used to select distance mode or the frequency mode of cursor movement in the "Brillouin spectrum" state.

[Clear]: Clear all the maker points in the “Brillouin spectrum” window.

[Global Display]: Restore the zoom state of the Brillouin Spectrum Display dialog box to the initial state.

[Exchange Reference]: Exchange the current display curve with the reference curve, switch the current display curve to the reference curve, and switch the reference curve to the current display curve.

[Clear reference]: Clear the reference curve displayed in the software.

[Back]: Return to the multiwindow sub-menu, the function menu area will display the multiwindow sub-menu.

1.4.3 Description of operation

(1) After setting the [Cursor] function button in the Brillouin spectrum sub-menu to "**distance/frequency**", the "Brillouin spectrum" window is in the distance mode, and the operation of the selected distance point can be performed.

① In "Brillouin spectroscopy" state, the curve displayed in the window can be zoomed out by clicking the button in the waveform operation area through the left mouse button or the touch screen; the curve will shrink along the horizontal direction by pressing the button, the curve will enlarge along the horizontal direction by pressing the button, the curve will enlarge along the vertical direction by pressing the button, the curve will shrink along the vertical direction by pressing the button, the curve will shrink along the vertical direction by pressing the button; the curve of Brillouin spectroscopy in the window can change with the change of distance point accordingly by clicking the button, and the button moves the cursor to the left by ten units at a time, the button moves the cursor to the right by ten units at a time; the button moves the cursor to the left by one unit at a time; the button moves the cursor to the right by one unit at a time;

② In "Brillouin spectrum" state, the curve can be enlarged by using the front panel button ▲, or can be shrunk by using the front panel button ▼.

③ Use the knobs on the knob keypad of front panel to control that the Brillouin spectrum curve in the window changes with the distance point accordingly. Rotate the cursor clockwise to the right by one unit, and rotate the cursor counterclockwise to move the cursor to the left by one unit. Click the [Quick] button on the front panel, the movement speed of mobile knob will be ten times faster, click the [Quick] button again to return to the original speed.

Note!

The "Brillouin spectrum" window displays the Brillouin spectrum curve corresponding to the selected distance point. Therefore, the selected distance point is changed directly by clicking the corresponding position on the global curve of strain with the left mouse button or the touch screen in the sub-window. The Brillouin spectrum curve displayed in the "Brillouin spectrum" window also changes accordingly.

(2) After setting the [Cursor] function button to "distance/frequency", the "Brillouin spectrum" window is in the frequency mode, and the cursor can be moved and the Brillouin spectrum curve can be scaled.

① In "Brillouin spectroscopy" state, the curve displayed in the window can be scaled by clicking the button in the waveform operation area through the left mouse button or the touch screen; the curve will shrink along the horizontal direction by pressing the button, the curve will enlarge along the horizontal direction by pressing the button, the curve will enlarge along the vertical direction by pressing the button, the curve will shrink along the vertical direction by pressing the button, the curve will shrink along the vertical direction by pressing the button; the curve of Brillouin spectroscopy in the window can change with the change of distance point accordingly by clicking the button, and the button moves the cursor to the left by 0.05GHz, the button moves the cursor to the right by 0.05GHz; the button moves the cursor to the left by 0.005GHz; the button moves the cursor to the right by 0.005GHz;

② In "Brillouin spectrum" state, the curve can be enlarged by using the front panel button, or can be shrunk by using the front panel button.

③ The knob buttons on the navigation keypad of front panel can be used to move the cursor in the "Brillouin spectrum" window. Rotate the cursor clockwise to the right and counterclockwise to the left by 0.005GHz separately. Click the [Quick] button on the front panel, the movement speed of mobile knob will be ten times faster, namely, 0.05GHz by one time; click the [Quick] button again to return to the original speed.

(3) Operation of Marker points

① Setting of maker points of Marker

In the "Brillouin spectrum" state, the Marker sub-menu can be entered by clicking the [Marker] function button under the Brillouin spectrum sub-menu through the left mouse button, touch screen or menu buttons of front panel. The test condition area displays the Marker information, as shown in Figure 4-12.

Note!

The order of the four Marker points is Marker1, Marker2, Marker3, and Marker4.

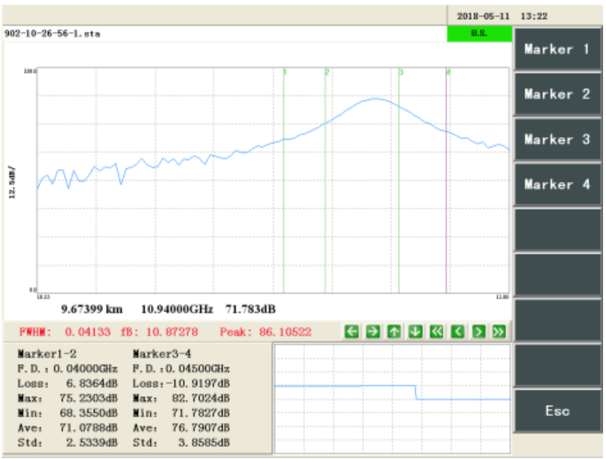


Figure 4-12 Marker interface in the "Brillouin spectrum" state

② The Marker information of "Brillouin spectrum" is as follows:

All information below the "Marker1-2" position belongs to the "Marker1-2" group, and the meaning of the data information is as follows.

Frequency difference: It indicates the frequency difference between marker point 1 and marker point 2, the unit is GHz.

Loss: It indicates the difference of relative power between marker point 1 and marker point 2, the unit is dB.

Max: It indicates the maximum relative power between marker point 1 and marker point 2, the unit is dB.

Min: It indicates the minimum relative power between marker point 1 and marker point 2, the unit is dB.

Std: It indicates the standard deviation of relative power between marker point 1 and marker point 2, the unit is dB.

All information below the "Marker3-4" position belongs to the "Marker3-4" group, and its data information corresponds to the frequency difference (frequency difference) the loss difference (loss), the maximum relative power (Max), the minimum relative power (Min), the average relative power (Ave), and relative power standard deviation (Std) between marker points 3 and maker point 4.

③ Clearance of Marker points

In the “Brillouin spectrum” state, use the mouse, touch screen or menu button of front panel to click the [Clear marker] function button under the sub-menu of Brillouin spectrum to hide all the maker points displayed in the "Brillouin spectrum" state.

Note!

The position of set Maker points is temporarily saved in the "Brillouin spectrum" state, but if the user switches from the "Brillouin spectrum" state to the "strain" state, the "loss distribution" state, the "comprehensive loss" state" and the “spectral width” state, the position of set Maker points that has been temporarily saved in the "strain distribution" state will be cleared. Therefore, if the Brillouin spectrum of the marker point is used in subsequent operation tests, it needs to be saved in time.

1.5 Loss distribution window

1.5.1 Overview

Click [Multiwindow] → [Loss Dis.] to enter the interface of loss distribution. The upper right corner of the window display area displays the state as “loss distribution”, and the function menu area displays the sub-menu of loss distribution, and the window display area is as shown in Figure 4-13.

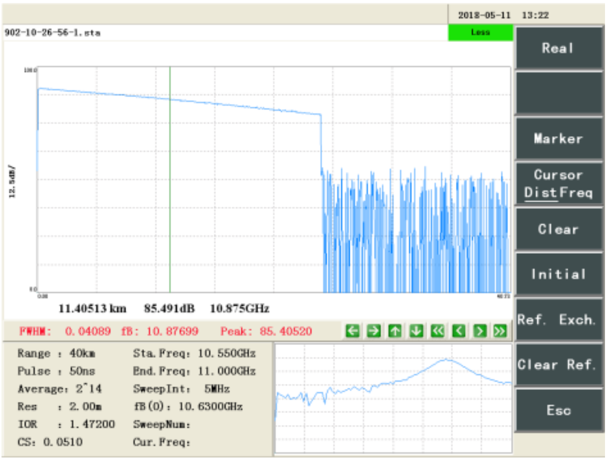


Figure 4-13 Interface of "loss distribution" state

The “loss distribution” window is used to display the relative power distribution curve at the selected frequency point. If the sub-window is Brillouin spectrum, the selected frequency point is changed in the sub-window, and the loss distribution curve displayed in the “loss distribution” window will also have corresponding changes.

The vertical line in the window of Figure 4-12 is the cursor, the “0.36277km” below the horizontal axis is the distance value of the position where the cursor is located, and “84.496dB” is the relative power value of the position where the cursor is located

1.5.2 Description of sub-menu

Click the [loss Dis.] function button in the multiwindow sub-menu, and the function distribution area will display the loss distribution sub-menu. The structure is shown in the function menu area in Figure 4-3.

[Real-time Test]: Same as the [Real-time Test] function button in the main function menu, the instrument will perform real-time loss test on the selected sweep frequency.

[Marker]: The function menu area will display the sub-menu of Marker for setting the marker points in the “loss distribution” window.

[Cursor]: It is used to select distance mode or the frequency mode of cursor movement in the "loss distribution" state.

[Clear]: Clear all the maker points in the “loss distribution” window.

[Exchange Reference]: Exchange the current display curve with the reference curve, switch the current display curve to the reference curve, and switch the reference curve to the current display curve.

[Clear reference]: Clear the reference curve displayed in the software.

[Global Display]: Restore the zoom state of the loss distribution window to the initial state.

[Back]: Return to the multiwindow sub-menu, the function menu area will display the multiwindow sub-menu.

1.5.3 Description of operation

(1) After setting the [Cursor] function button to "**distance/frequency**", the window is in the distance mode, the cursor can be moved or the curve can be scaled.

① In "loss distribution" state, the curve displayed in the window can be zoomed out by clicking the button in the waveform operation area through the left mouse button or the touch screen; the curve will shrink along the horizontal direction by pressing the button, the curve will enlarge along the horizontal direction by pressing the button, the curve will enlarge along the vertical direction by pressing the button, the button curve will shrink along the vertical direction by pressing the button; the movement of the cursor can be moved by clicking the button, indicate fast movement, and the button moves the cursor to the left by ten units at a time, the button moves the cursor to the right by ten units at a time. indicate normal movement, and the button moves the cursor to the left by one unit at a time, the button moves the cursor to the right by one unit at a time.

② In the "loss distribution" state, the arrow direction in the navigation keypad of front panel can be used to scale the curve displayed in the window.

③ The knob buttons on the navigation keypad of front panel can be used to move the cursor in the “loss distribution” window.

(2) After setting the [Cursor] function button to “distance/frequency”, the “loss distribution” window is in the frequency mode. The button in the waveform operation area or the knob on the front panel of the instrument can be used to change the sweep frequency point. Click the button to control the movement of the frequency point. indicate fast movement, moves the cursor to the left by ten frequency points at a time, moves the cursor to the right by ten frequency points at a time indicate normal movement, and the button moves the cursor to the left by one frequency point at a time, the button moves the cursor to the right by one frequency point at a time.

The button or the navigation keys on the front panel can be used to scale in horizontal and vertical coordinates. The curve will shrink along the horizontal direction by pressing the button, the curve will enlarge along the horizontal direction by pressing the button; the curve will shrink along the vertical direction by pressing the button, the curve will enlarge along the vertical direction by pressing the button.

If the instrument is performing the “real-time test” function at this time, the frequency operation can be performed on the “loss distribution” state, the “real-time test” function can be changed to test the sweep frequency point of loss distribution curve to make the instrument measure the new loss distribution curve and display it in the loss distribution window; if the “real-time test” function is turned off at this time, the frequency operation performed on the “loss distribution” state will have no response.

(3) Operation of Marker points

① Setting of maker points of Marker

In the “loss distribution" state, the Marker sub-menu and Marker information interface can be entered by clicking the [Marker] function button under the loss distribution sub-menu through the left mouse button, touch screen or menu buttons of front panel, which is shown in Figure 4-14. The function menu [TPA LSA] represents two different calculation methods for the loss between points. TPA stands for two-point method and LSA stands for least squares method.

Figure 4-14 Marker interface in the "loss distribution" state

Note! **The order of the four Marker points is Marker1, Marker2, Marker3, and Marker4.**

② Information of Marker points

There are two groups of marker information of Marker, namely “Marker1-2” group and “Marker3-4” group.

All information below the "Marker1-2" position belongs to the "Marker1-2" group, and the meaning of the data information is as follows.

Distance: It indicates the difference in distance between marker point 1 and marker point 2, the unit is km, mi. or kft.

Loss: It indicates the difference of relative power between marker point 1 and marker point 2, the unit is dB.

dB/km: It indicates the average loss of the fiber segment between marker point 1 and marker point 2, the unit is dB/km.

All information below the "Marker3-4" position belongs to the "Marker3-4" group, and its data information indicates the distance difference (distance) and the difference of relative power (loss) between marker point 3 and marker point 4, and average loss (dB/km) of fiber segment between marker points.

SP: It indicates the splice loss between two segments of fiber, the unit is dB/km.

If the inter-point loss algorithm in the Marker menu is selected as [TPA **LSA**], the Marker point information becomes the result of the corresponding LSA method.

③ Clearance of Marker points

In the “loss distribution” state, use the mouse, touch screen or menu button of front panel to click the[Clear marker]function button under the sub-menu of spectral width distribution to hide all the maker points displayed in the "loss distribution" state.

Note! **The position of set Maker points is temporarily saved in the "loss distribution" state, but if the user switches from the "loss distribution" state to other states, the position of Maker points that has been temporarily saved will be cleared. Therefore, if the Brillouin spectrum of the marker point is used in subsequent operation tests, it needs to be saved in time.**

1.6 Comprehensive loss window

1.6.1 Overview

Click [Multiwindow] → [Comprehensive Loss], or click the (Loss) button on the front panel to enter the comprehensive loss interface. The upper right corner of the window display area displays the state as "comprehensive loss", and the window display area is as shown in Figure 4-15.

Figure 4-15 Window display area of "comprehensive loss" state

The "comprehensive loss" state is used to display the comprehensive loss distribution curve of the fiber under test, that is, the distribution curve of the relative power along the distance. The loss distribution of maximum value (ie, the center sweep point) and the loss distribution of the mean value of the entire Brillouin scattering spectrum can be switched by clicking the [Max Avg] button on the menu.

The curve in the "comprehensive loss" window is the curve of comprehensive relative power tested by the instrument. The vertical line in the window of Figure 4-15 is the cursor. The "0.17922km" below the horizontal axis is the distance value of the position where the cursor is located. "93.689dB" is the comprehensive relative power value of the position where the cursor is located.

1.6.2 Description of sub-menu

Click the [comprehensive loss] function button in the multiwindow sub-menu, and the function menu area will display the sub-menu of comprehensive loss.

[Max Avg]: Used to select the calculation method of comprehensive loss. The button [**Max** Avg] indicates to calculate the comprehensive loss with the maximum loss; the button [Max **Avg**] indicates to calculate the comprehensive loss with the average loss.

[Marker]: The function menu area will display the sub-menu of Marker for setting the marker points in the "loss distribution" window.

[Clear]: Clear all the maker points in the "comprehensive loss" window.

[Global Display]: Restore the zoom state of the loss distribution window to the initial state.

[Exchange Reference]: Exchange the current display curve with the reference curve, switch the current display curve to the reference curve, and switch the reference curve to the current display curve.

[Clear reference]: Clear the reference curve displayed in the software.

[Back]: Return to the multiwindow sub-menu, the function menu area will display the multiwindow sub-menu.

1.6.3 Description of operation

(1) Cursor movement and coordinate scaling

① The curve displayed in the window can be scaled by clicking the button in the waveform operation area through the left mouse button or the touch screen; the curve will shrink along the horizontal direction by pressing the button, the curve will enlarge along the horizontal direction by pressing the button, the curve will enlarge along the vertical direction by pressing the button, the button curve will shrink along the vertical direction by pressing the button; the movement of the cursor can be moved by clicking the button, indicate fast movement, and the button moves the cursor to the left by ten units at a time, the button moves the cursor to the right by units at a time. indicate normal movement, and the button moves the cursor to the left by one unit at a time, the button moves the cursor to the right by one unit at a time.

② The arrow direction in the navigation keypad of front panel can be used to scale the curve displayed in the window.

③ Use the knobs on the knob keypad of front panel to move the cursor in the “comprehensive loss” window: Rotate the cursor clockwise to move the cursor to the right, and rotate the cursor counterclockwise to move the cursor to the left. Click the [Quick] button on the front panel, the movement speed of mobile knob will be ten times faster, click the [Quick] button again to return to the original speed.

(2) Operation of maker points of Marker

① Setting of maker points of Marker

In the “comprehensive loss" state, the Marker sub-menu can be entered by clicking the [Marker] function button under the comprehensive loss sub-menu through the left mouse button, touch screen or menu buttons of front panel. The test condition area displays the Marker information, as shown in Figure 4-16.

The function menu displayed in the function menu area is the Marker sub-menu, where the [Max Avg] menu item is used to set the calculation of comprehensive loss distribution with the maximum relative power value (Max) or the average relative power value (Avg); [TPA LSA] menu item is used to set the calculation of fiber loss between points by two point method (TPA) or least squares method (LSA).

Note! **The order of the four Marker points is Marker1, Marker2, Marker3, and Marker4.**

Figure 4-16 Marker interface in the "comprehensive loss" state

② Description of Marker information

There are two groups of marker information of Marker, namely “Marker1-2” group and “Marker3-4” group.

All information below the "Marker1-2" position belongs to the "Marker1-2" group, and the meaning of the data information is as follows.

Distance: It indicates the difference in distance between marker point 1 and marker point 2, the unit is km, mi. or kft.

Loss: It indicates the difference of relative power between marker point 1 and marker point 2, the unit is dB.

dB/km: It indicates the loss per km of the fiber segment between marker point 1 and marker point 2, the unit is dB/km.

All information below the "Marker3-4" position belongs to the "Marker3-4" group, and its data information indicates the distance difference (distance) and the difference of relative power (loss) between marker point 3 and marker point 4, and loss per km (dB/km) of fiber segment between marker points.

SP: It indicates the splice loss between two segments of fiber, the unit is dB/km.

If the inter-point loss algorithm in the Marker menu is selected as [TPA LSA] and [Max Avg], the Marker point information changes to the result obtained by the least squares method on the comprehensive relative intensity curve calculated by the average loss. The rest can be done in the same manner.

③ Clearance of Marker points

In the “comprehensive loss” state, use the left mouse button, touch screen or menu button of front panel to click the [Clear marker] function button under the sub-menu of comprehensive loss to hide all the maker points displayed in the "comprehensive loss" state.

Note! **The position of set Maker points is temporarily saved in the "comprehensive loss" state, but if the user switches from the "comprehensive loss" state to other states, the position of Maker points that has been temporarily saved will be cleared. Therefore, if the Brillouin spectrum of the marker point is used in subsequent operation tests, it needs to be saved in time.**

2 Description of sub-waveform window

The sub-waveform window is located at the bottom right of the screen, as shown in Figure 4-17. The sub-waveform window is used to help the user to more conveniently observe the global curve or the Brillouin spectrum curve under the "strain distribution" state, "spectral width distribution" state, "loss distribution" state, and "comprehensive loss" state; the sub-waveform window under Brillouin spectrum state is displayed as a global curve of strain distribution. The type of curve displayed in the sub-waveform window is selected by the [Sub.Wave] function button in the main function menu.

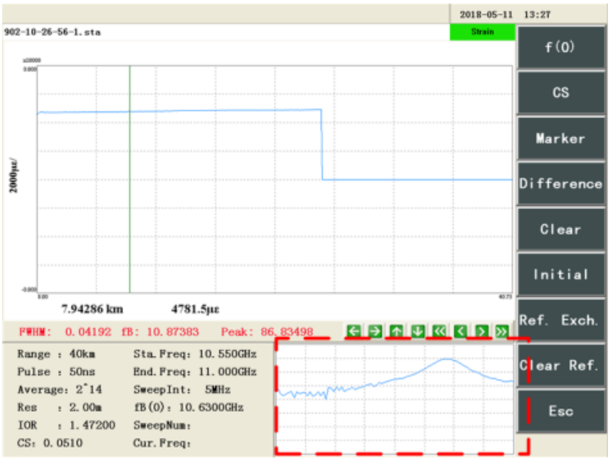


Figure 4-17 Sub-waveform window

(1) [Sub.Wave] The function button is set to [Global **Brillouin spectrum**].

When the window display area is in the "strain distribution" state, the "spectral width distribution" state, the "loss distribution" state, and the "comprehensive loss" state, the sub-waveform window will display the global curve of Brillouin spectrum of the selected distance point, and its curve is same as the Brillouin spectrum curve displayed in the “Brillouin spectrum” window. In the "loss distribution" state, the sweep frequency point can be changed by the Brillouin spectrum of the sub-window, and the loss distribution curve in the "loss distribution" window is updated with the difference of the sweep points.

(2) [Sub.Wave] The function button is set to [**Global** Brillouin spectrum].

① If the window display area is in the “strain distribution” state, the sub-waveform window will display the global curve of the strain distribution curve.

② If the window display area is in the “spectral width distribution” state, the sub-waveform window will display the global curve of the Brillouin spectrum curve.

③ If the window display area is in the “loss distribution” state, the sub-waveform window will display the global curve of the loss distribution curve.

④ If the window display area is in the “strain distribution” state, the sub-waveform window will display the global curve of the strain distribution curve.

When the horizontal or vertical coordinate is scaled by the buttons or the navigation keys in the waveform operation area, the rectangle marking window on the global curve of the sub-window is used to display the range of the distribution curve in the global curve.

(3) In the “Brillouin spectrum” state, the [Sub.Wave] function button is set to [Global **Brillouin spectrum**] or [**Global** Brillouin spectrum], and the sub-waveform window displays the global curve of the strain distribution. After changing the selected distance point in the sub-window, the Brillouin spectrum curve in the “Brillouin spectrum” will change accordingly.

Chapter V Description of 3D Display Functions

1 Overview of state

Click the [3D display] button in the main function menu to use the 3D display function of the instrument. At this time, the window display area displays the “3D” state, and the function menu area displays the 3D display sub-menu.

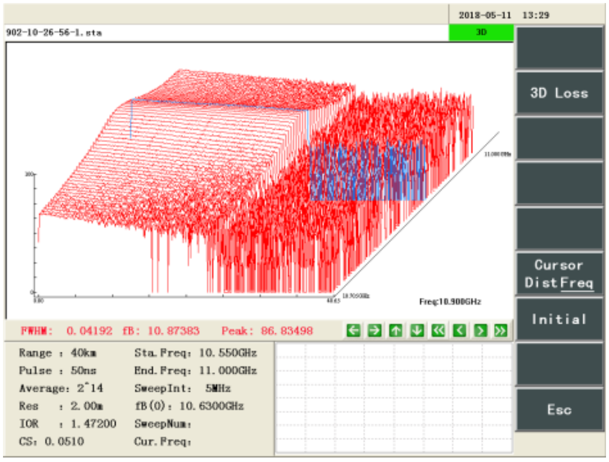


Figure 5-1 “3D” state and 3D display sub-menu

In the "3D" state, the three-dimensional curve of the test data is displayed in the window, wherein the horizontal axis is the distance, the vertical axis is the relative intensity, and the oblique axis is the sweep frequency.

The “3D” state is the most intuitive observation interface. The curve at each sweep frequency point represents the loss curve corresponding to the sweep frequency point, and the curve at each distance point represents the Brillouin spectrum curve corresponding to the distance point. Therefore, the distribution of the Brillouin spectrum on the fiber under test can be visually observed in the "3D" state.

2 Description of display sub-menu

The 3D display sub-menu is shown in the function menu in Figure 5-1. The functions of the button are described below.

[3D Loss]: The window display area displays the “loss distribution” state, showing the loss distribution curve at the selected frequency point in the “3D” state, and the function menu area displays the loss distribution sub-menu.

[Cursor]: The cursor mode in the “3D” state can be selected as the distance mode or the frequency mode. After selecting the “distance” mode, the distribution of the Brillouin scattering spectrum at different distance points can be observed by moving the cursor; after selecting the “frequency” mode, the loss distribution along the fiber distance under different sweep points can be observed.

[Global Display]: Restore the zoom state of the 3D curve to the initial state.

[Back]: Return to the main function menu, the function menu area will display the main function menu.

3 Description of display operation

(1) In the 3D” state, set the [Cursor] function button to “**distance/frequency**”, the cursor operation mode will be in the distance mode, the cursor shape is dark curve as shown in Figure 5-2, and the curve shown by the cursor is the Brillouin spectrum curve corresponding to the selected distance point, at this time, the lower right corner of the "3D" window displays the distance information of the current cursor. At this time, the cursor movement operation or the curve scaling operation can be performed on the horizontal axis.

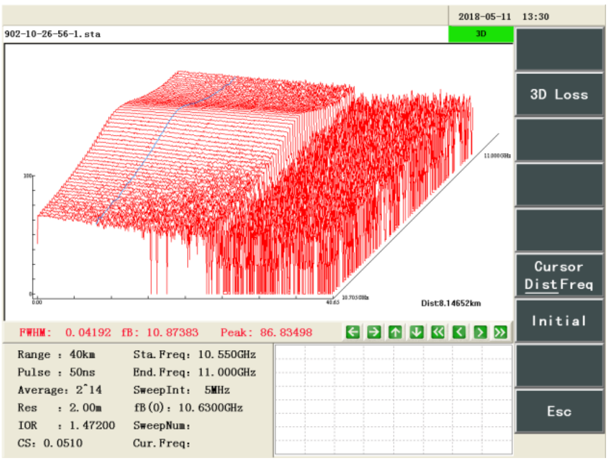


Figure 5-2 “3D” state and 3D display sub-menu

① The 3D curve displayed in the window can be scaled by clicking the button in the waveform operation area with the left mouse button or the touch screen. The curve will shrink along the horizontal direction by pressing the button, the curve will enlarge along the horizontal direction by pressing the button. The movement of the cursor can be controlled by pressing the button, the indicate fast movement, and the button moves the cursor to the left by ten units at a time, the button moves the cursor to the right by ten units at a time. indicate normal movement, and the button moves the cursor to the left by one unit at a time, the button moves the cursor to the right by one unit at a time.

② The buttons and on the front panel can be used to scale the horizontal coordinate.

③ Use the knobs on the knob keypad of front panel to move the cursor in the window: Rotate the cursor clockwise to move the cursor to the right, and rotate the cursor counterclockwise to move the cursor to the left. Click the [Quick] button on the front panel, the movement speed of mobile knob will be ten times faster, click the [Quick] button again to return to the original speed.

(2) In the 3D” state, set the [Cursor] function button to “distance/frequency”, the cursor operation mode will be in the frequency mode, the cursor shape is dark curve as shown in Figure 5-1, and the curve shown by the cursor is the loss distribution curve corresponding to the selected distance point and frequency point, the lower right corner of the "3D" window displays the frequency information of the current cursor. At this time, the cursor movement operation or the curve scaling operation can be performed on the horizontal axis.

① In the “3D” state, the curve displayed in the window can be operated through clicking the buttons in the waveform operation area through the left mouse button or touch screen. indicate fast movement, and the button moves the cursor to the left by ten units at a time, the button moves the cursor to the right by ten units at a time. indicate normal movement, and the button moves the cursor to the left by one unit at a time, the button moves the cursor to the right by one unit at a time.

② Use the knobs on the knob keypad of front panel to move the cursor in the window: Rotate the cursor clockwise to move the cursor to the right, and rotate the cursor counterclockwise to move the cursor to the left. Click the [Quick] button on the front panel, the movement speed of mobile knob will be ten times faster, click the [Quick] button again to return to the original speed.

Chapter VI Description of File Functions

Click the [File] button in the main function menu to enter the file sub-menu, as shown in the function menu in Figure 6-1. The functions of the button are described below.

[Open]: Enter the file opening interface and read the historical test data of 6419 from the index path to display it in the window display area.

[Save]: Enter the file saving interface and save the data in current window display area to the selected path.

[Delete]: Enter the file deletion interface to delete the selected files in the path.

[Transfer]: Enter the file transfer interface and copy the data file selected in the source path to the target path.

[Open Ref.]: Enter the file opening interface and read the historical test data of 6419 from the index path as reference data to display it in the window display area (provided that data already exists in the window display area).

[Back]: Return to the main function menu, the function menu area will display the main function menu.

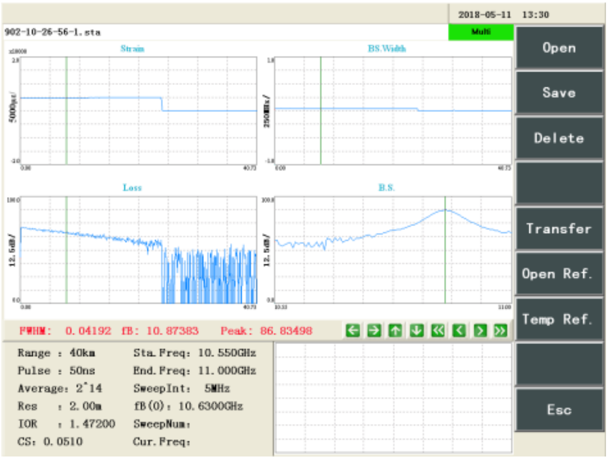


Figure 6-1 Schematic diagram of file sub-menu

1 File opening

Click the [Open] function button in the file sub-menu, and the function menu area displays the sub-menu of file opening, including three function buttons of [New Folder], [OK] and [Back]; the state of the upper right corner of the window is displayed as "Open File". The file path in the left side of the window is the index bar, including the drop-down menu of drive letter selection and the folder (or file) list under the drive letter, showing the remaining storage space of the selected drive letter; the right side of the window is the “file path” text box, the file list in the index folder, the “file, folder name” text box, and the “file type” drop-down menu from top to bottom, as shown in Figure 6-2.

When opening a file, first select the file type. The "file type" drop-down menu contains two file types: "*.sta" and "*.eis". The system defaults to "*.sta"; then select the corresponding file folder in the index path, if the folder contains the selected file type, the file list on the right side of the window lists all the files of the type, if not, it is empty; finally use the mouse or touch screen to click the required data, click the [OK] function key to open the selected file to display it in the window display area. The "*.sta" type file contains all measurement data of 6419, including strain, loss, and Brillouin spectrum data; the "*.eis" type file contains only the strain data measured by 6419.

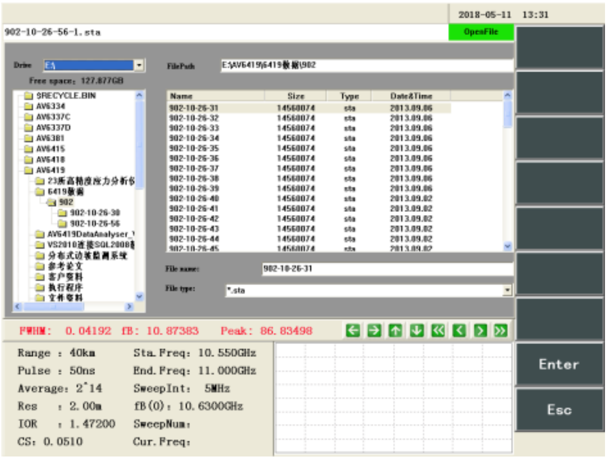


Figure 6-2 File opening interface

2 File saving

Click the [Save] function button in the file sub-menu, the function menu area displays the file saving sub-menu, including three buttons: [New Folder], [Enter], [Back]; the state of the upper right corner of the window is displayed as "save file", the content distribution in the window is same as the file opening window. If only save the strain data measured by the instrument, select the “*.eis” type in the file Type drop-down menu, otherwise, keep the default “*.sta” file type (since the “*.sta” type file stores more comprehensive information, so opening this type of file takes a little longer than compared with opening the "*.eis" type file. Select the target path to be stored in the file path index field, then enter the file name in the "file, folder name" text box and click the [OK] function key to save the file to the selected path.

If create a new folder in the file path index bar to store data, enter the folder name in the "file, folder name" text box and click the [New Folder] function key, the folder will be newly created in the current file path. Then repeat the process of saving the file described in the previous paragraph to save the data file in the newly created folder.

Soft keyboard input is added to facilitate the input of files or folder names using the mouse or touch screen when opening or saving data. When double-click the "file name, folder name" input box with the mouse or touch screen, the soft keyboard pops up, as shown in Figure 6-3.

Figure 6-3 File saving interface

In addition to characters such as numbers in the soft keyboard, "<--", "-->" controls the cursor to move forward or backward character by character, and the "Clear" key is used to clear characters from back to front. After inputting, use the “OK” button on the soft keyboard to confirm the input file name and exit the soft keyboard, or use the “Cancel” button to exit the file name input status.

3 Open reference

If the data already exists in the graphics window area, you can open the reference file to compare with it. The method for opening the reference file is to use the [Open Ref.] function button in the file sub-menu, and open it according to the method described in the second section of this chapter, as shown in Figure 6-4. However, if there is no data in the current window display area, the system will pop up a message box to prompt for this operation.

Figure 6-4 Interface of opening the reference

4 Description of file type

The 6419 distributed optical fiber strain tester saves files in two file types, one in sta format and one in eis format.

4.1 sta file format

The sta format is a customized detailed storage format of the 6419 distributed optical fiber strain tester. Under this storage format, the 6419 distributed optical fiber strain tester stores all Brillouin gain spectrum data obtained in one test for a long time, thus occupying a large capacity. However, the data file stored in this format can further analyze the Brillouin spectrum data after reading, including loss distribution, strain distribution, Brillouin spectrum center frequency shift distribution, Brillouin spectrum width distribution and other subsequent calculations.

The format can carry out further analysis and data export through the analysis software provided with the 6419 distributed optical fiber strain tester. The txt format files of loss distribution data, the strain distribution data, the Brillouin spectrum center frequency shift distribution data, and the Brillouin spectral width distribution data can be exported.

4.2 eis file format

The eis format is a customized fast strain data storage format of the 6419 distributed optical fiber strain tester. Under this storage format, the 6419 distributed optical fiber strain tester stores the strain distribution data analyzed in one test for a short time, thus occupying small capacity, which is more suitable for rapid transmission and transfer of a large number of test data. However, the data file stored in this format can only obtain the strain distribution data after reading, and the Brillouin spectrum data, the loss distribution data, and the Brillouin spectral width distribution data cannot be obtained.

The data in this format can be exported by the analysis software provided with the 6419 distributed optical fiber strain tester, and the txt format file of the strain distribution data can be exported.

EIS file format:

＝＝＝＝＝＝＝＝＝＝＝＝＝＝＝＝ File header (accounting for 470 bytes)

String type: "AV6419”

String type: "DATD”

Short type: Number of addition

Short type: Range, in km.

int type: Pulse width

1 represents 10ns

2 represents 20ns

3 represents 30ns

......

......

19 represents 190ns

20 represents 200ns

Short type: Sampling resolution

0 represents 0.05m

1 represents 0.10m

2 represents 0.20m

3 represents 0.50m

4 represents 1.00m

5 represents 2.00m

6 represents 4.00m

Double type: Start frequency, in MHz.

Double type: Ending frequency, in MHz.

Double type: fB0, in GHz

Double type: CS, in MHz/με

Double type: Refractive index

int type: Frequency interval

0 represents 1MHz

1 represents 2MHz

2 represents 5MHz

10 represents 20MHz

50 represents 50MHz

UINT type: Number of data points DATANUM

int type: Number of frequency points SPECTRUMNUM

Double type: Starting point of test BEGINDISTANCE

UINT type: UINT type reserved data

Double type X33: 33 double type reserved data

int type X30: 30 int type reserved data

================ Data

Double type: The stress distribution value of each point in turn, the number of data points is DATANUM, and the strain unit is %.

Chapter VII Description of System Menu

1 Description of system sub-menu

Click the [System] button in the main function menu to enter the system sub-menu. In the system sub-menu, the enabling and setting of VFL (visible red light failure system), system settings, system upgrade, and view of system information can be performed.

Figure 7 -1 Interface of system sub-menu

The system sub-menu is shown in the function menu in Figure 7-1, and the functions of buttons are described below.

[VFL]: The VFL control window pops out, the VFL function is turned off and the VFL type is selected.

[System Self-test]: The system self-check window pops out and the system self-check is performed.

[System Set]: Enter the sub-menu and setting interface of system settings

[Touch Cal.]: The touch screen calibration interface pops out to perform touch screen calibration. After calibration, it will automatically return to the system interface.

[Update]: Insert the USB flash drive with the upgrade software into the USB interface of the instrument. Click this button to automatically search for the upgrade file in the USB flash drive and perform the system software upgrade function.

[Shut Down]: Execute the instrument shutdown function, pop out inquiry dialog box of confirming the shutdown.

[Help]: Pop out help sub-menu, the window display area can query the help instructions of the software.

[Back]: Return to the main function menu, the function menu area will display the main function menu.

2 Description of VFL functions

The 6419 has a built-in visible red light fault location (VFL) function that can help determine where the fiber breaks and where the light energy leaks. The VFL control window is shown in Figure 7-2.

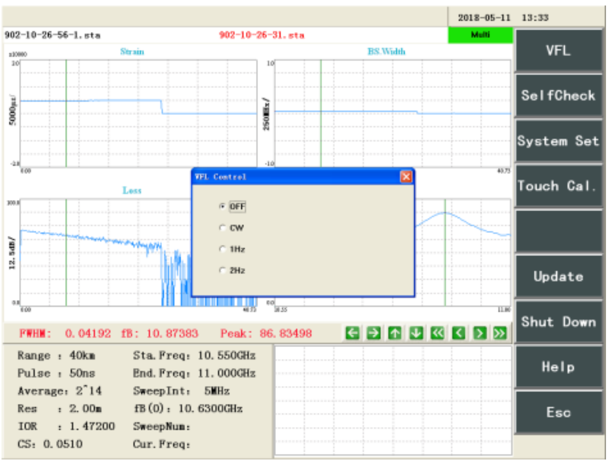


Figure 7-2 Control window of VFL

Select the [VFL] function button in the system sub-menu, and the software will pop out the VFL control window. It includes four options: "OFF", "CW", "1Hz", and "2Hz". The working status of the VFL can be adjusted via the navigation key or on the front panel.

(1) Select the "OFF" option, then the VFL function is off;

(2) Select the "CW" option, the instrument will output continuous visible red light in the VFL optical interface;

(3) Select the "1Hz" option, the instrument will output visible red light with a frequency of 1Hz in the VFL optical interface;

(4) Select the "2Hz" option and the instrument will output visible red light with a frequency of 2Hz in the VFL optical interface.

3 Description of system self-check functions

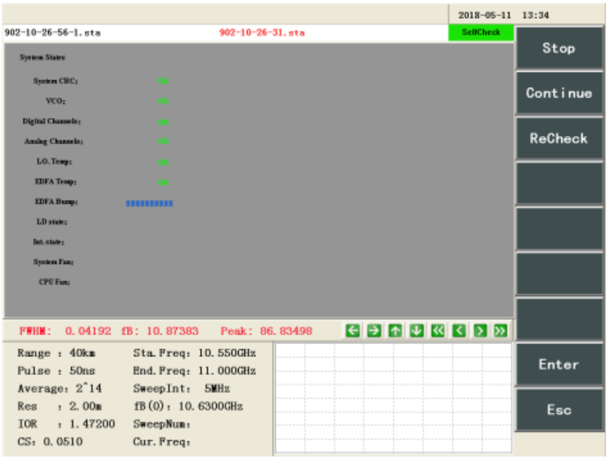


Figure 7-3 Interface of system self-check

In the system sub-menu, select the [System Self-test] function button, the software pops out the system self-check interface shown in Figure 7-3, and performs a system self-check on the instrument. If an error is found in the self-check, a dialog box will pop out.

4 Description of system settings sub-menu

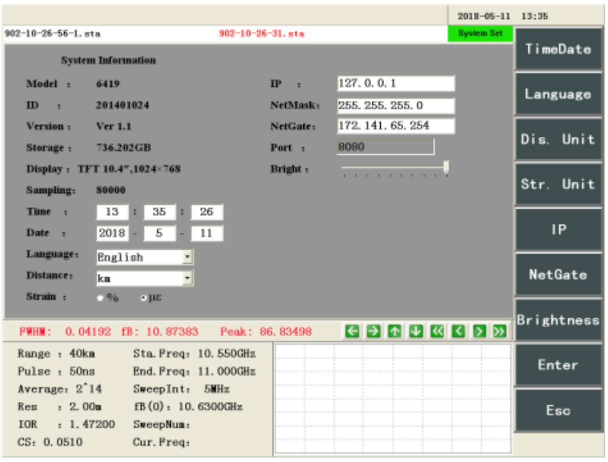


Figure 7-4 Interface of system settings

Click the [System Set] button in the system sub-menu to enter the system settings interface, as shown in Figure 7-4. The system setting interface displays information such as the model number, serial number, software version, storage capacity, display parameters, and sampling points.

[DateTime]: Set the system time or date. Press or click this button, the cursor is positioned in the "hour" setting input box in the time format. The buttons in the numeric key area on the front panel of the instrument can be used to modify the number in the box, or double-click the input box to input the number in the software disk, and then click "OK".

Click the [Cursor] button in the front panel navigation area to toggle the cursor between "Hour", "Minute" or

"Second" in the time format and "Year", "Month" or "Day" in the date format.

[Language]: Set the software language. Press or click this menu button to expand the language drop-down menu in the system setting interface. The front panel navigation keys can be used to select between Chinese and English.

[Dis.Unit]: Set the distance unit of the instrument system. Press or click this menu button to expand the distance unit drop-down menu in the system setting interface. The buttons on the navigation keypad can be used to select between km, mi. and kft. (1mi = 1.609344km, 1kft = 0.3048m), press other menu buttons to save the settings.

[Strain Unit]: Set the display unit of the instrument system strain data to % or με (1με is equivalent to 10^-6, which is one millionth). Press or click this menu button to position the cursor in the με radio box. The buttons on the front panel navigation keypad can be used to select the unit as % or keep the current unit as με.

[IP]: Set the network IP address of the instrument. Press or click this menu button to position the cursor in the IP address box on the system setting interface and use the number keys on the instrument front panel, or enter the IP on the soft keyboard that appears after double-clicking the input box. Then, click OK.

[Gateway]: Set the instrument network gateway. Press or click this menu button to position the cursor in the gateway address box on the system setting interface. The gateway address can be modified by using the keys in the numeric area on the instrument front panel.

[Brighness adjustment]: Set the brightness of the instrument screen. Press or click this menu button to position the cursor on the LCD brightness adjustment bar in the system setting interface. Use the front panel navigation keys to adjust the brightness. The cursor moves to the left, the screen becomes brighter, and the cursor moves to the right, the screen is dimmed.

In the system settings, the cursor key in the navigation keys can control the cursor to switch in the system setting parameter box. The arrow keys can select the previous or next menu option of the currently displayed menu item in the drop-down menu options.

The above menu functions can be realized by touch screen or mouse. Characters should be input in setting the time and date, IP, subnet mask and gateway in the interface. Double-click on the mouse or touch screen where you need to input, the screen will pop out the numeric keypad, and then click on the keyboard to input. Other settings such as the drop-down menu can be realized by clicking directly with the mouse or touch screen.

Note! **The remote connection of the instrument needs to be realized through four network parameters: IP address, subnet mask, gateway and network port in the system setting interface. Only the instrument network parameters and the remote control host are set in the same network segment and share the same network port, so as to achieve remote connection. For details, see "Chapter VIII, Section 6 Remote Control".**

5 Help

Click the [Help] button in the system sub-menu to pop out the help file as shown in Figure 7-5. The file includes three parts: Precautions for using the instrument, maintenance and care of the instrument, and methods of using the instrument.

Precautions for using the instrument: List the basic items to be aware of when using the instrument to avoid misuse during operation. Do not look directly at the optical output connector to avoid damage to the body, pay attention to port matching, and maintain the purity of the test light, and avoid organic solvents that can damage the display.

Maintenance and care of the instrument: List the temperature and humidity range for the usage and storage of instrument, and use regular cleaning tools and proper maintenance methods.

Methods of using the instrument: Briefly list the basic usage of the instrument to help the user familiar with the instrument operation steps and data testing.

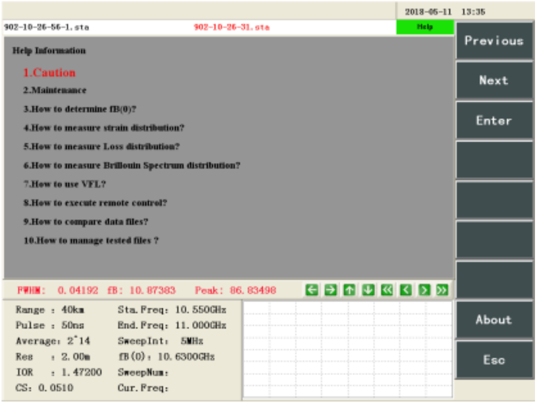


Figure 7-5 Help interface

Chapter VIII Application Methods

1 Basic operation

1.1 Turn on the instrument

Step 1: After ensuring that the power supply voltage is $220V_{AC}$, use the power cord supplied with the instrument to connect to the external AC power supply (as shown in Figure 8-1).

Step 2: Turn on the power switch on the back panel of the instrument. At this time, the front panel power indicator should be orange, indicating that the instrument is in standby mode.

Figure 8-1 Slot and switch of back panel power cord

Step 3: Press the switch on the front panel. At this time, the power indicator changes from orange to green. After the instrument starts normally, the initialization test interface is displayed, as shown in Figure 8-2.

Figure 8-2 On-off key of the front panel

1.2 Fiber access

Step 1: Gently unscrew the protective sleeve of the BOTDR interface on the front panel of the 6419 distributed optical fiber strain tester. The position of the BOTDR interface is shown in Figure 8-3.

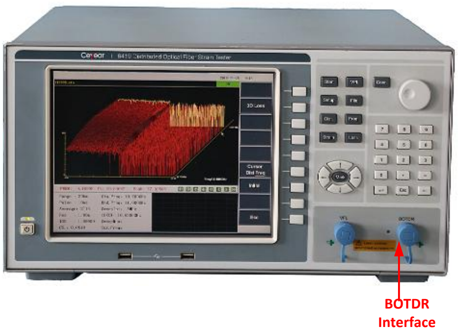


Figure 8-3 BOTDR interface

Step 2: Connect the optical connector of the fiber under test to the BOTDR interface. As shown in Figure 8-4, there is a groove at the BOTDR optical interface, and a protrusion at the FC/APC fiber connector, align with the groove at the BOTDR interface with the protrusion at FC/APC fiber connector.

Step 3: After aligning the protrusion at the FC/APC fiber connector with the groove at the BOTDR interface, slowly push the FC/APC fiber connector into the BOTDR optical interface, and gradually tighten the thread on the FC/APC fiber connector.

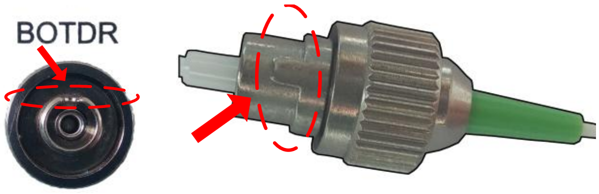


Figure 8-4 Groove of BOTDR interface and protrusion of FC/APC fiber interface

Note: The BOTDR interface is an FC/APC fiber connector. It does not support access of FC/UPC or other types of fiber connectors. If the fiber access connector is not an FC/APC connector, please use the optical fiber patch cord (see Appendix D for details). Please check the fiber end face before inserting. If the end face is contaminated, it should be cleaned in time (see Appendix F for details).

1.3 Setting parameters

Step 1: Click the [Settings] button on the front panel, and the [Settings] key position is as shown in Figure 8-5. Enter the test condition interface (you can also enter it by clicking the [Test Condition] button in the main function menu), the test condition interface is as shown in Figure 8-6.

Figure 8-5 Setting buttons on the front panel

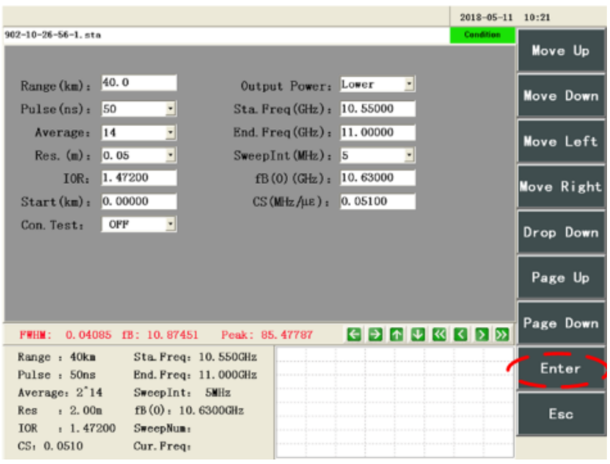


Figure 8-6 Interface of test condition

Step 2: Use the touch screen or mouse to set each parameter. The description of each parameter can be seen in **Chapter II, Section 2**.

Step 3: After the parameters are modified, click [OK], as shown in Figure 8-6, save the test parameters and exit the test parameter setting interface.

1.4 Turn off the instrument

Step 1: Click the [System] button in the function menu button, as shown in Figure 8-7.

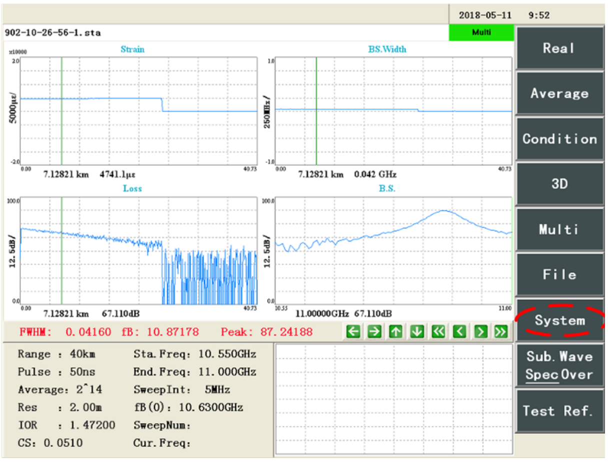


Figure 8-7 Position of [System] button

Step 2: Click the [Shutdown] button in the system sub-menu, as shown in Figure 8-8.

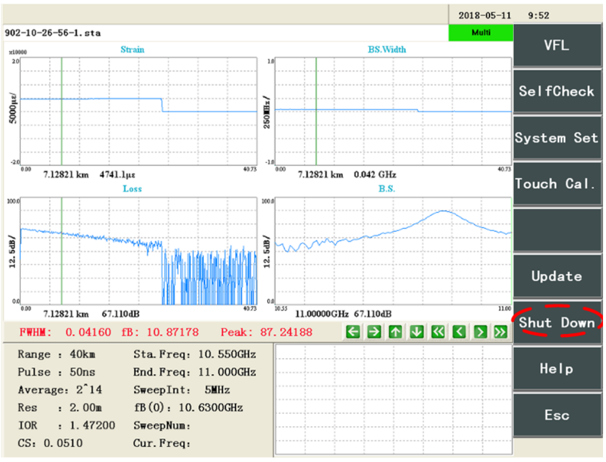


Figure 8-8 Position of [Shutdown] button

Step 3: After the display is turned off, turn the switch on the back panel of the instrument to the off state, then turn off the power and unplug the power cord. If the fiber is no longer used to test, remove the fiber and cover the optical connector.

2 Test operation

2.1 Strain distribution test of fiber

Step 1: Connect the fiber under test to the BOTDR optical interface of front panel. For detailed steps, see **Chapter VIII, Section 1.2**.

Step 2: Set the test parameters according to the parameter values in Table 8-1 below. For detailed steps, see **Chapter VIII, Section 1.3**.

Table 8-1 Table of initial frequency shift of Brillouin spectrum parameter setting

Parameter name	Parameter value
Range	Set value greater than the fiber length
Pulse width	Set according to requirements of fiber length
Average times	14
Resolution	1m/2m/4m
Refractive index	Given by fiber / cable manufacturers
Starting point	0km
Continuous test	Close
Output optical power	Lower

Start frequency	For details, see Chapter III, Section 2
Ending frequency	For details, see Chapter III, Section 2
Frequency interval	5MHz/10MHz
fB(0)	For details, see Chapter III, Section 2
CS.	Given by fiber / cable manufacturers

Step 3: Click the button [Test] on the front panel or the menu button [Average] to start the strain test. The background color of the [Average] button in the main function menu changes to **light blue**. After the test is completed, the [Average] button restores the primary color, the curve of [strain distribution] and [spectral width distribution] is displayed in Figure 8-9.

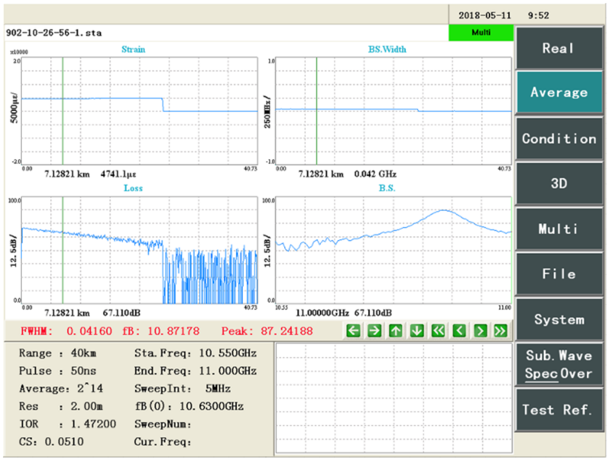


Figure 8-9 [Average] button changes to light blue

Step 4: Click [Multiwindow] → [Strain Dis.] to enter the strain distribution window as shown in Figure 8-10. The specific operation of the strain distribution window is described in **Chapter IV, Section 1.2**.

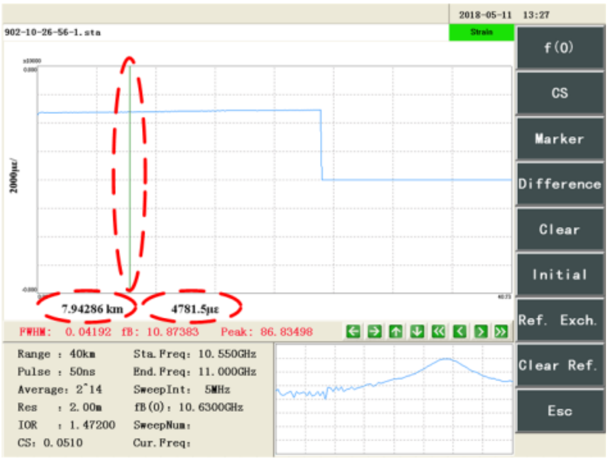


Figure 8-10 Interface of optical fiber strain distribution curve

Note! The vertical line in the window of Figure 8-10 is the cursor, the **"7.94286km"** below the horizontal axis is the distance value of the position where the cursor is located, and **"4781.5με"** is the spectral width value of the position where the cursor is located.

2.2 Loss distribution test of fiber

Step 1: Follow steps 1-3 in **Section 2.1 of this chapter**;

Step 2: Click [Multiwindow] → [Comprehensive Loss] on the main interface to enter the comprehensive loss window as shown in Figure 8-11. For detailed operation of the comprehensive loss window, see **Chapter IV, Section 1.6**.

Figure 8-11 Comprehensive loss curve of fiber

Note! The curve in the "comprehensive loss" window is the curve of comprehensive relative power tested by the instrument. The vertical line in the window of Figure 8-11 is the cursor. The **"7.94286km"** below the horizontal axis is the distance value of the position where the cursor is located. **"86.870dB"** is the comprehensive relative power value of the position where the cursor is located.

2.3 Brillouin spectrum test of fiber

Step 1: Follow steps 1-3 in **Section 2.1 of this chapter**;

Step 2: Click [Multiwindow] → [Brillouin spectrum] on the main interface to enter the Brillouin Spectrum Display dialog box as shown in Figure 8-12, change the selected distance point, and observe the measured Brillouin spectrum curve of fiber under test corresponding to each distance point. For detailed operation of the Brillouin Spectrum Display dialog box, see **Chapter IV, Section 1.4**.

Figure 8 -12 Brillouin Spectrum Display dialog box

Note! The vertical line in the window in Figure 8-12 is the cursor, and the **"7.94286km"** below the horizontal axis is the distance information of the selected distance point where the current Brillouin spectrum curve is located. **"10.87000GHz"** is the sweep frequency value corresponding to the cursor, and **"86.767dB"** is the relative power value of the position where the cursor is located.

2.4 Brillouin spectral width test

Step 1: Follow steps 1-3 in Section 2.1 of this chapter;

Step 4: Click [Multiwindow] → [Spectral width distribution] to enter the spectral width distribution window as shown in Figure 8-13. The specific operation of the spectral width distribution window is described in **Chapter IV, Section 1.3**.

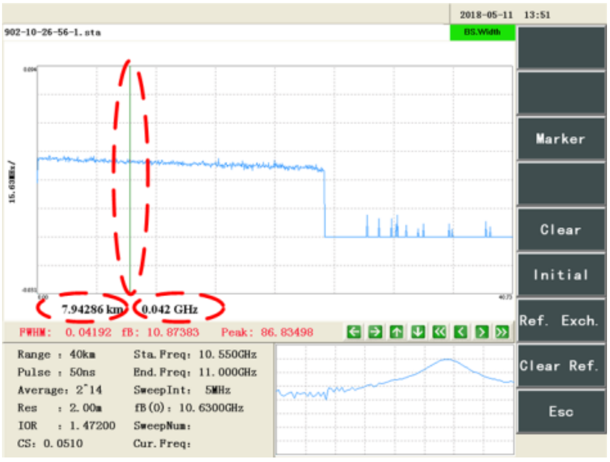


Figure 8-13 Spectral width distribution curve

Note! The curve in the "spectral width distribution" window is the distribution curve of Brillouin spectral width along the fiber tested by the instrument. The vertical line in the window of Figure 8-13 is the cursor. The **"7.94286km"** below the horizontal axis is the distance value of the position where the cursor is located. **"0.042GHz"** is the spectral width value of the position where the cursor is located.

2.5 Fiber length test

Method 1: Connect the fiber to the fiber interface, and measure the comprehensive loss curve of the fiber according to the range, pulse, resolution, and refractive index set in **Section 2.3**. It can be seen from the figure that the loss curve has fallen in a certain area. Position the cursor in this area as shown in Figure 8-14. Click ▶ on the front panel to enlarge the area, then slowly rotate the front panel knob clockwise. It is seen that the Brillouin spectrum of the sub-window gradually becomes clear. After crossing a certain point, the Brillouin spectrum suddenly disappears, as shown in Figure 8-15, the point can be considered as the end of the fiber, and the position is 24.63712km.

6

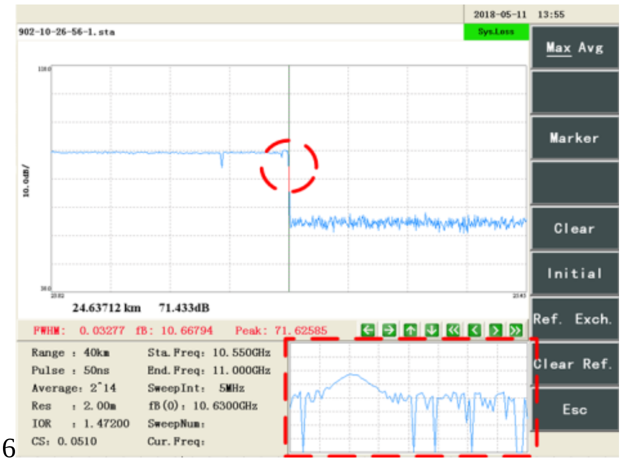


Figure 8-14 Comprehensive loss curve of the fiber under test

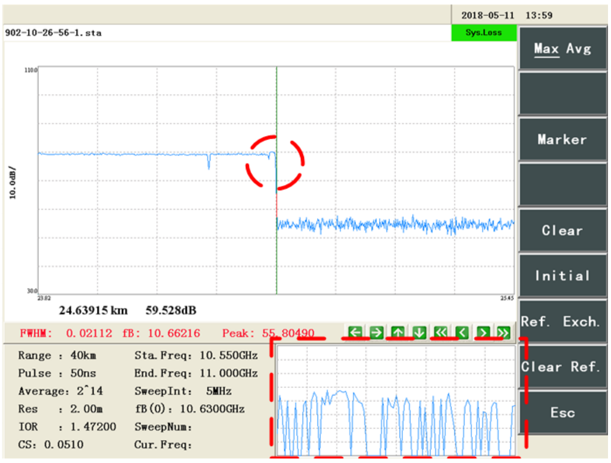


Figure 8-15 Brillouin spectrum disappears after crossing a certain point

Method 2: Connect the fiber to the fiber interface, and measure the spectral width distribution curve of the fiber as shown in Figure 8-16 according to the range, pulse, resolution, and refractive index set in **Section 2.5**.

6

Figure 8-16 Spectral width distribution curve of fiber under test

It is seen that the spectral width value falls at a certain point, the point can be considered as the end of the fiber, and the length of the fiber can be obtained from the reading on the lower left corner is 24.63915km.

2.6 Continuous test of fiber strain

Step 1: Click the [Settings] button on the front panel or the [Test Condition] on the main interface menu to enter the test condition interface;

Step 2: Select “ON” through the continuous test drop-down menu to start the continuous test. At the same time, the continuous test option will appear on the test condition setting interface: **Time, Autosave** options, if select autosave, **File No., File type, and SavePath** can be set, as shown in Figure 8-17. After setting the parameters, click OK and click the [Test] button on the front panel to start the test.

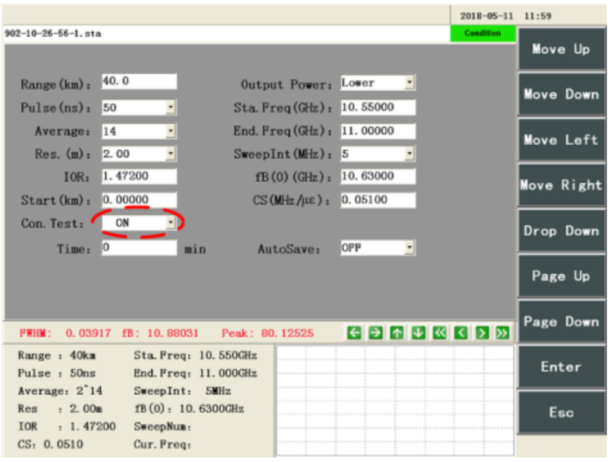


Figure 8-17 Continuous test parameter setting

After the continuous test option is turned on, the user starts the average processing test and enters the continuous test state. The instrument will time and measure according to the time interval setting value until the user stops the average processing test.

3 Visible red light fault location (VFL) function

The 6419 has a built-in visible red light fault location (VFL) function that can help determine where the fiber breaks and where the light energy leaks.

Step 1: Connect the fiber under test to the VFL optical interface of front panel. VFL optical interface is shown in Figure 8-18, for detailed steps, see **Chapter VIII, Section 1.2**.

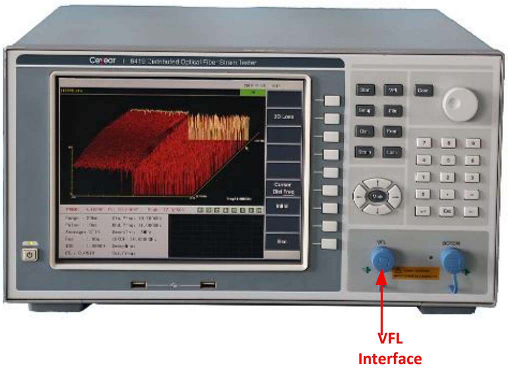


Figure 8-18 VFL interface with protective cover

Step 2: Select the [VFL] function button in the system sub-menu (or click the VFL) button on the front panel) and the software will pop out the VFL control window. As shown in Figure 8-19, there are four options: [OFF], [CW], [1Hz], and [2Hz]. The mouse or touch screen adjusts the working state of the VFL.

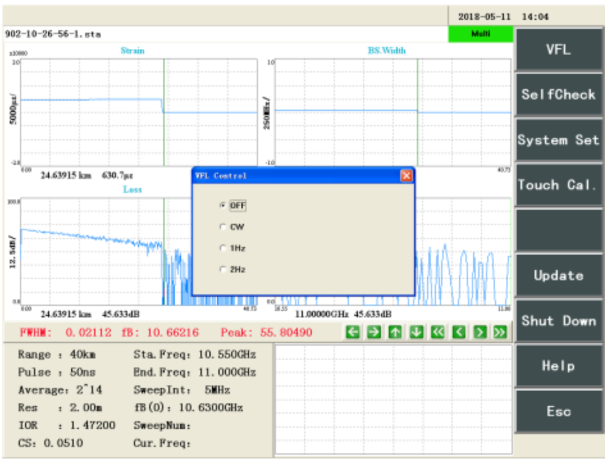


Figure 8-19 Control window of VFL

Step 3: Set the VFL function in the VFL window according to the needs. Select the [CW] option, the instrument will output continuous visible red light in the VFL optical interface; select [1Hz] option, the instrument will output the visible red light with a frequency of 1Hz in the VFL optical interface; select [2Hz] option, the instrument will output the visible red light with a frequency of 2Hz in the VFL optical interface.

Step 4: Check the fiber line and the end of the fiber. If there is no red light at the end of the fiber and a large amount of red light is emitted at a certain position in the fiber line, check whether the fiber at the red light emission position is broken or a small radius bend occurs.

Step 5: After the VFL function is used, set the VFL option to [OFF] in the VFL window to disable the VFL function.

Step 6: Remove the fiber under test from the VFL optical interface and cover the VFL optical interface protection cover.

4 File management

6419 BOTDR internally contains a file management system, which can quickly and accurately process test data, including operations such as opening, saving, deleting, transferring, and opening reference files. Press the [File] key on the front panel or the [File] button on the main interface menu to enter the file management interface, the details are as below.

4.1 Open the data file

Step 1: Click [File] → [Open] on the main interface to enter the interface as shown in Figure 8-20.

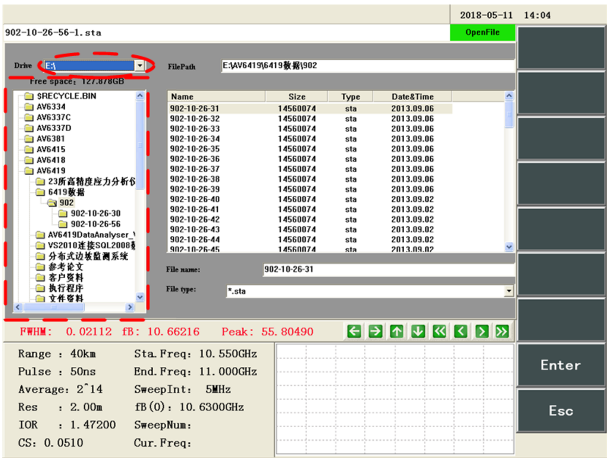


Figure 8-20 File opening interface

Step 2: Select the index disk in the file opening interface of Figure 8-20, list the information tree under the index disk, select the file folder and file type, all the files in the folder will be listed, select the files to be opened from the list, and click [OK] to open the file.

4.2 Save the data files

Step 1: Choose **File** > **Save** on the main interface, and the interface displayed in Figure 8-21 will be displayed.

Figure 8-21 File saving interface

Step 2: Select the index disk in the file save interface as shown in Figure 8-21 to list the information tree under the index disk, select the target folder and file type (if necessary, click [New Folder] to create a new target path folder), double-click the file name input box to pop out the numeric keys on the soft keyboard or front panel to enter the saved target file name, and click [OK] to save the file.

Note! 6419 BOTDR save files in two types, one is .sta format, which will store all the Brillouin spectrum distribution data obtained by the test. The storage time is long and the occupying capacity is large, but the Brillouin spectrum data can be read after further analysis; the other is .eis format, which only saves the strain distribution data. The storage time is short and the occupying capacity is small, which is more suitable for data transmission and transfer. A detailed description of the file type can be found in Chapter VI, Section 4.

4.3 Delete the data files

Step 1: Click [File] → [Delete] on the main interface to enter the interface as shown in Figure 8-22.

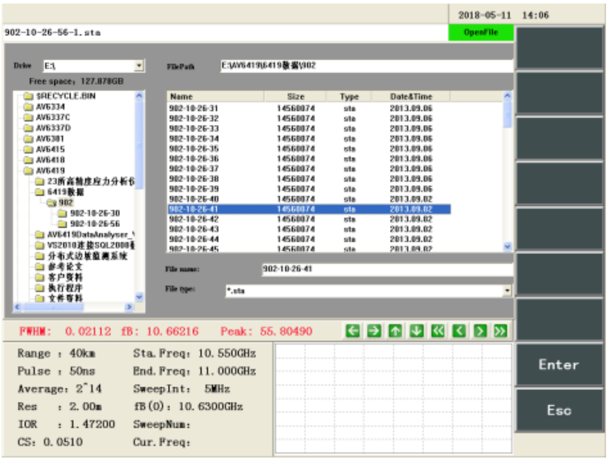


Figure 8-22 File deleting interface

Step 2: Select the index disk in the file deleting interface of Figure 8-22, list the information tree under the index disk, select the file folder and file type, all the files in the folder will be listed, select the files to be deleted from the list, and click [OK] to delete the file.

4.4 Open the reference files

Step 1: Click [File] → [Open Ref.] on the main interface to enter the interface as shown in Figure 8-23.

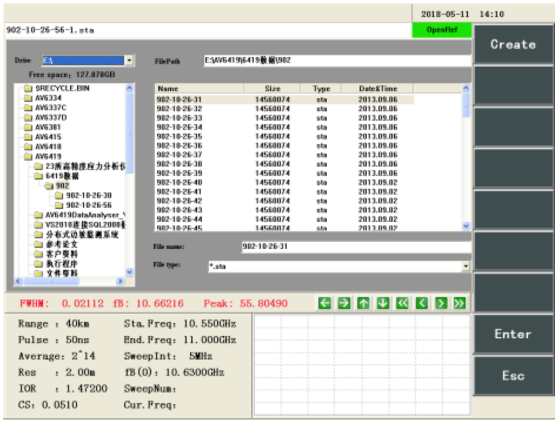


Figure 8-23 Interface of opening the reference

Step 2: Select the index disk in opening the reference interface of Figure 8-23, list the information tree under the index disk, select the file folder and file type, all the files in the folder will be listed, select the reference files to be opened from the list, and click [OK] to open the reference file.

Step 3: As shown in Figure 8-24, the reference curve interface is displayed. The test data and the reference data are drawn in different colors. The blue curve is the test data, and the red curve is the reference file data.

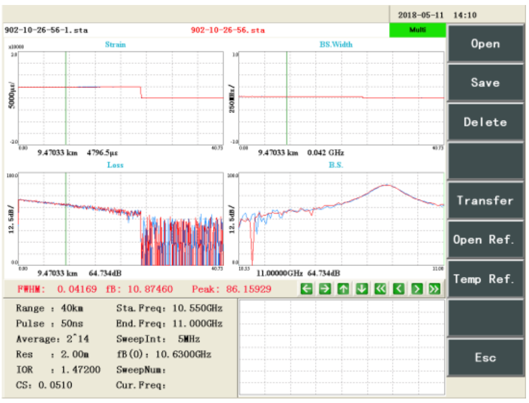


Figure 8-24 Image of reference files

Note: The range of the reference file data should be consistent with the range of the original file data, otherwise, it will not be used as a reference!

4.5 Transfer the data files

Step 1: Click [File] → [Transfer] on the main interface to enter the interface as shown in Figure 8-25.

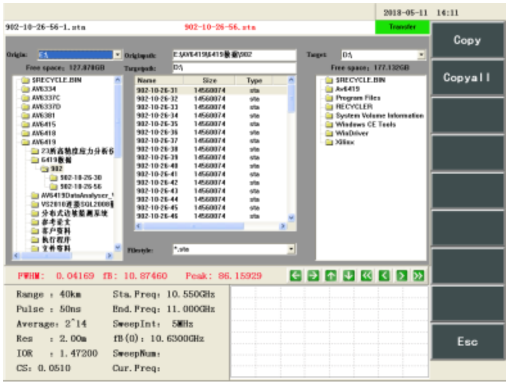


Figure 8-25 File transfer interface

Step 2: In the file transfer interface of Figure 8-25, select the source index disk, select the folder and file type, and select the file to be transferred.

Step 3: Select the target drive letter, select the target folder, and press the [Copy] or [Copy All] button to transfer the data file in the source folder to the target location.

5 Waveform comparison function

Step 1: Open the reference file through the method in **Section 4.3 of this chapter** and enter the multiwindow reference file interface, as shown in Figure 8-26.

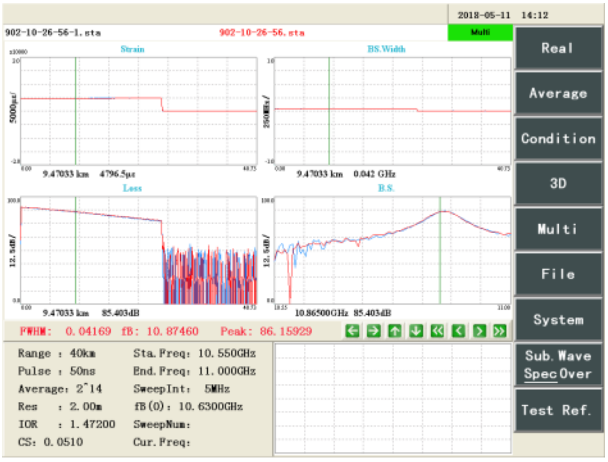


Figure 8-26 Main interface of multiwindow file reference

Step 2: Click [Multiwindow] → [Strain Dis.] in the main interface to enter the strain distribution reference interface, and perform the curve operation by zooming in and out on the interface and moving the buttons left and right, as shown in Figure 8-27.

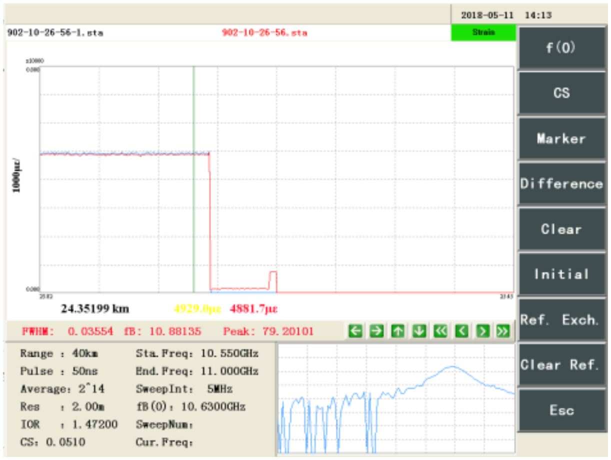


Figure 8-27 Reference interface of strain distribution

Step 3: Same as **step 2,** click [Multiwindow] → [Spectral Width Distribution], [Brillouin spectrum], [Loss Distribution] and [Comprehensive Loss] in the main interface respectively to enter the corresponding curve interface.

Note: The reference file will not open when the range of the current data does not match the range of opening the reference file.

6 Remote control function

Step 1: Connect the network cable (crossover type) to the Ethernet interface of the tester and computer respectively;

Step 2: Configure the IP address of the instrument. On the main interface, click [System] → [System Set] to enter the system configuration interface. Enter the IP address and gateway through the soft keyboard or the numeric keys on the front panel to ensure that the instrument and the computer are in the same network segment. Click the [OK] button to save the IP address, as shown in Figure 8-28.

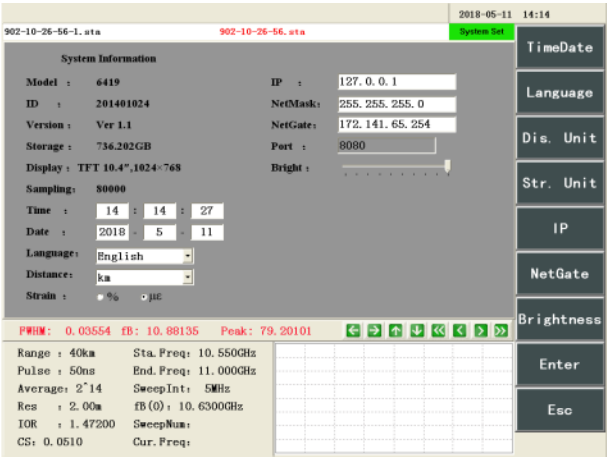


Figure 8-28 Interface of system settings

Step 3: After setting the IP address as shown in 8-28, the instrument will save the current address. The instrument control port number is 8080, which cannot be modified. **After the setting is completed, the instrument will be restarted**, and the remote control of the instrument can be performed through the client.

Step 4: Use the host computer in the same IP segment to control the instrument test according to the list of related remote control commands in **Appendix B** through the network. For details, see Section 7 in **Appendix A**.

Chapter IX General Faults and Processing Methods

1 Quick check of general fault

Table 9-1 shows the possible faults and solutions for the instrument:

Table 9-1 Faults and solutions

Fault	Possible reasons	Solutions
The instrument can't be started.	The switch of back panel is in the "OFF" position.	Turn the switch on the back panel to the "ON" position.
	The AC power cord is not plugged in.	Insert the AC power cord correctly.
The button does not respond.	Check whether there's a button is pressed down all the time	Make sure that no button is pressed down.
	The soft keyboard is in the pop-out state.	Close the soft keyboard.
The measured fiber length is inaccurate.	The fiber refractive index setting is inaccurate.	Set the fiber refractive index to the refractive index calibrated by the fiber manufacturer. For details, see Chapter II, Section 2.
	The calibration data of length is lost	Contact the manufacturer
The loss distribution curve can't be seen	When the frequency setting range deviates from the initial frequency shift to a large extent, the image is shown in Figure 9-2 in Section 2 of this chapter.	Set correct range of scanning frequency
	Poor connection of fiber connector	(1) Please check whether the fiber connector is contaminated, if necessary, check it with fiber end face microscope and make it clean; (2) Check whether the fiber connector is not properly inserted and tightened (see Chapter VIII, Section 1 for details).
	The flange ceramic core of BOTDR interface is contaminated or worn.	Please return to factory for repair.
	The type of fiber port is not matched	Please check whether the fiber connector is FC/APC type (see Appendix D for details)
	There is a large loss point at the near end of the fiber.	Connect the fiber to the VFL test end and start the VFL function check (see Chapter VIII, Section 6 for details).
	The test starting point is set incorrectly and exceeds the length of the fiber under test. (See Chapter IX, Section 3 for details.)	Re-adjust the position of test starting point.
The loss distribution curve is abnormal, and the attenuation is large at a long distance.	The test range is smaller than the fiber length.	Reset the appropriate test range and the test range is required to be longer than the length of the fiber under test (see Chapter VIII, Section 1 for details).
	The power of the probe light is too large.	Adjust the output optical power in the "test condition" (see Chapter XI, Section 4 for details).
The Brillouin scattering spectrum is not visible.	The frequency setting range deviates from the initial frequency shift to a large extent.	Set correct range of scanning frequency(see Chapter VIII, Section 1 for details).
	The frequency setting range is too small.	Set correct range of scanning frequency(see Chapter VIII, Section 1 for details).
	The interval of frequency scanning is too large	Appropriately reduce the frequency scanning interval (see Chapter VIII, Section 6 for details).
The display brightness of LCD is	The LCD brightness setting is incorrect.	Click [System] → [System Set.] → [Brighness adjustment] to adjust the LCD display brightness appropriately (see

too dark.		Chapter VI, Section 6 for details).
The touch screen cannot be clicked to the correct position.	The touch screen is not calibrated.	Click [System] → [Touch Screen Calibration] to calibrate the touch screen. For details, see Chapter XI, Section 7.

2 Setting of refractive index

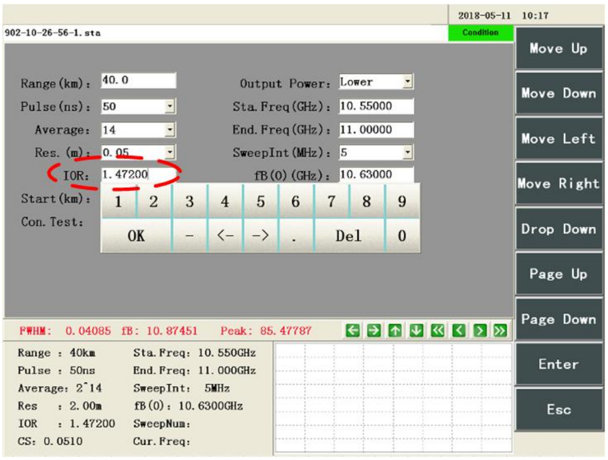


Figure 9-1 Setting interface of refractive index

Click the [Settings] button on the front panel to enter the test condition interface shown in Figure 9-1.Enter the refractive index in the refractive index input box or double-click the input box to input with the soft keyboard. **The refractive index is given by the fiber/cable manufacturer** (refer to **Chapter III, Section 2.5**) and the starting point is set to zero.

3 Solutions when the frequency setting range deviates from the initial frequency shift to a large extent

Figure 9-2 shows the image when the frequency setting range deviates from the initial frequency shift to a large extent. There are several reasons for this situation, which will be analyzed one by one as follows.

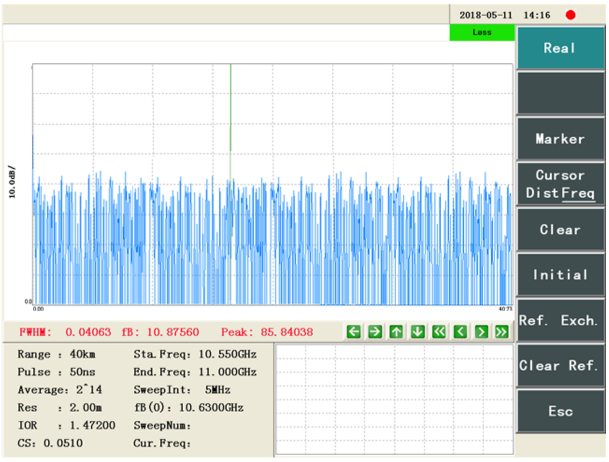


Figure 9-2 Image when the frequency setting range deviates from the initial frequency shift to a large extent

1. The starting and ending frequencies are too deviated and too narrow to include the initial frequency shift of Brillouin spectrum.

Solution: Set the Start frequency to 9.9GHz and the ending frequency to 12GHz. The frequency interval is set to 20MHz. The Brillouin spectrum can be swept out, as shown in Figure 9-3. From this, the initial frequency shift of Brillouin spectrum can be roughly determined. In this figure, the initial frequency shift of Brillouin spectrum is 10.85000GHz, and the subsequent operation method is as described in **Chapter VIII, Section 2**.

Figure 9-3 Brillouin spectrum

2. When the initial and ending frequencies are deviated to the left, the Brillouin spectrum shown in Figure 9-4 will appear.

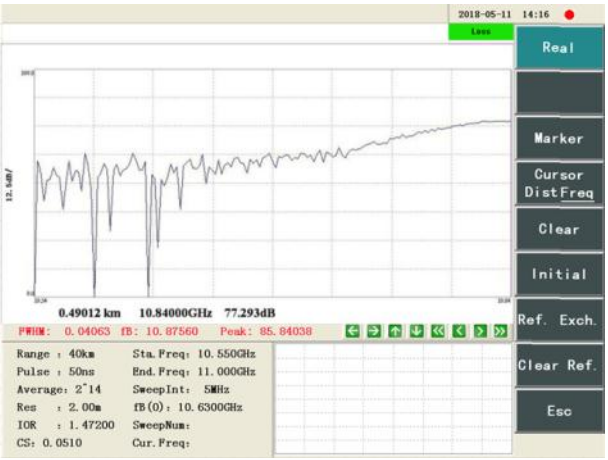


Figure 9-4 Starting and ending frequency deviated to the left

Solution: Move the starting and ending frequencies to the right, or use the current ending frequency as the approximate value of the initial frequency shift of Brillouin spectrum, and set the starting and ending frequencies to fB (0)-fy, fB (0)+fy. Table 9-2 shows the correspondence relation between common pulse width and spectral width. If the ending frequency is appropriately increased when measuring the tensile deformation, the ending frequency should be appropriately reduced when measuring the compression deformation.

Table 9-2 Correspondence relation between common pulse width and spectral width

Pulse width (ns)	Fy (GHz)
10	0.2
20	0.1
50	0.05
100	0.05
200	0.05

3. When the starting and ending frequencies are deviated to the right, the Brillouin spectrum shown in Figure 9-5 will appear.

Figure 9-5 Frequency spectrum of starting and ending frequency deviated to the right

Solution: Move the starting and ending frequencies to the left, or use the current Start frequency as the approximate value of the initial frequency shift of Brillouin spectrum, and set the starting and ending frequencies to fB (0)-fy, fB (0)+fy. Table 9-3 shows the correspondence relation between common pulse width and spectral width. If the Start frequency is appropriately increased when measuring the tensile deformation, the ending frequency should be appropriately reduced when measuring the compression deformation.

Table 9-3 Correspondence relation between common pulse width and spectral width

Pulse width (ns)	Fy (GHz)
10	0.2
20	0.1
50	0.05
100	0.05
200	0.05

4. The starting point of test is set incorrectly and exceeds the length of the fiber under test, the loss distribution curve shown in Figure 9-6 will appear (in this figure, the measurement starting point is 1.02109km, and the actual length of the fiber is 1km).

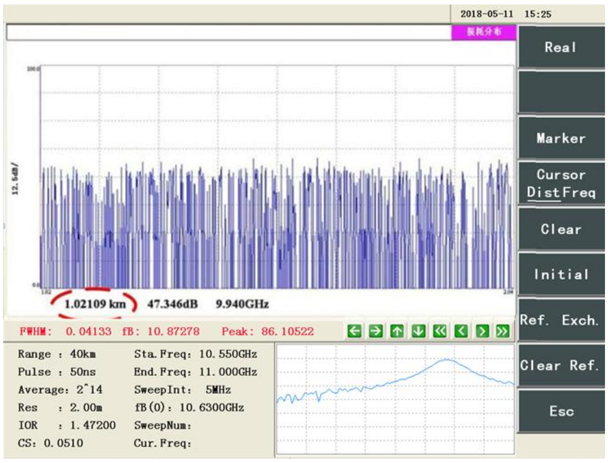


Figure 9-6 Loss distribution curve when the starting point is set incorrectly

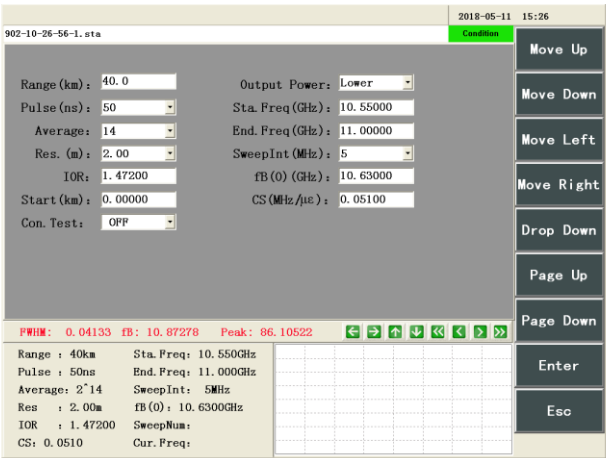


Figure 9-7 Setting interface of starting point

Solutions: As shown in Figure 9-7, the starting point distance should be re-adjusted (since the 6419 can collect the data of up to 80,000 distance points. When the sampling point is less than 80,000, the starting point setting is invalid, when the distance sampling point is greater than 80000, the starting point setting value will take effect, and the starting distance of the test data of 6419 will be the setting value of starting point). Table 9-4 is a table of the relationship between resolution and range when the starting point takes effect.

Table 9-4 Relationship between resolution and range when the starting point takes effect.

Resolution (m)	Range (km)
0.05	≥4
0.1	≥8
0.2	≥16
0.5	≥40
1	≥80
2	≥128

4 Adjustment of optical power

As shown in Figure 9-8, after clicking the drop-down menu of output optical power, users can choose from four options: Relatively low, low, medium and high, providing optical power of different intensities.

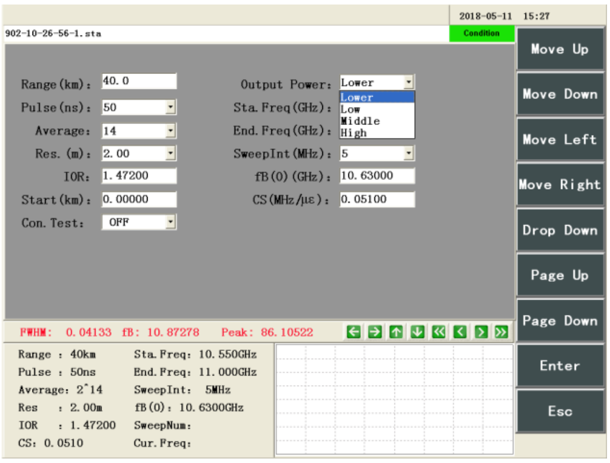


Figure 9-8 Adjustment interface of optical power

5 Relationship among common pulse width, resolution and length measurement

Table 9-5 shows the relationship among common pulse width, resolution and length measurement for users' reference.

Table 9-5 Relationship among common pulse width, resolution and length measurement

Pulse width (ns)	Spatial resolution (m)	Length measurement (km)
10	1	10
20	2	15
50	5	30
100	10	40
200	20	80

6 Brightness adjustment

Click [System] → [System Set] to enter the system setting interface shown in Figure 9-9, click the LCD brightness through the touch screen, move the screen to the left to make it darken, and move the screen to the right to make it brighten, or the brightness can be controlled by the arrow direction on the front panel, move the left or upper arrow to make the screen darken, and move the right or lower arrow to make the screen brighten.

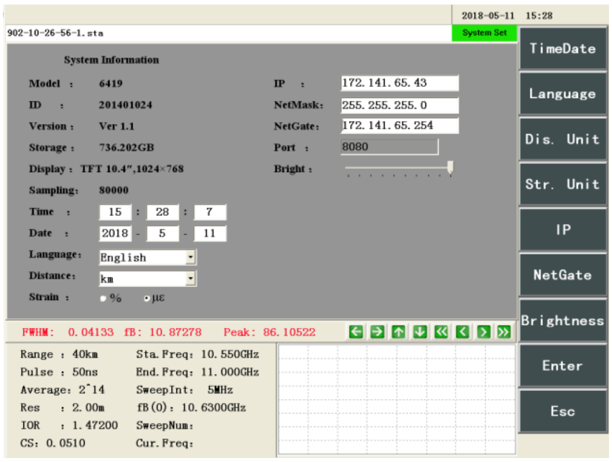


Figure 9-9 Interface of system settings

7 Calibration of touch screen

Click [System] → [Touch Cal.] to enter the interface as shown in Figure 9-10.

Figure 9-10 Calibration interface of touch screen

Then calibrate the touch screen by clicking on the red circle in the figure.

Chapter X Working Principles

1 Fiber optic sensing technology

Compared with traditional sensing technology, optical fiber sensing technology has shown great advantages. Compared with traditional electrical and mechanical sensor technologies, optical fiber sensing technology has unparalleled advantages in many applications due to its own characteristics. It's featured by resistance to electromagnetic interference, corrosion resistance, small size, variable shape, high sensitivity and many sensing objects. It provides a very effective means for measuring in certain special industrial environments (such as flammable, explosive, high voltage, high current, high current field interference, etc.).

2 Distributed optical fiber sensing technology

The distributed optical fiber sensor not only has the advantages of general fiber-optic sensors, but also realizes continuous real-time monitoring of large-scale information fields through optical fibers, such as tens to hundreds of kilometers of measurement range, which makes the acquisition cost of unit information greatly reduced, greatly improving the cost performance. The distributed fiber optic sensing is used in a wide range of applications to monitor physical changes in buildings, dams, bridges, tunnels and oil pipelines, and submarine cables.

3 Spontaneous Brillouin scattering

Under normal temperature conditions, atoms, molecules or ions in the fiber undergo continuous elastic mechanical vibration due to self-heating motion, forming a spontaneous acoustic wave field in the light. Acoustic vibrations along the direction of the fiber cause the density of the fiber to periodically change with time and space such that the index of refraction index on the fiber is periodically modulated. This spontaneous acoustic wave can be thought of as a density grating moving along the fiber at a certain speed (and with a certain frequency). Therefore, Brillouin can be seen as the scattering of incident light on a moving grating. The Doppler effect causes a frequency shift of the scattered light relative to the incident light, called the frequency shift of Brillouin spectrum. The spontaneous Brillouin scattering can occur in the forward and backward directions. The frequency shift of Brillouin spectrum v_B in the fiber can be expressed as:

$$v_B = \pm \frac{2nv_a}{\lambda_p} \tag{10.1}$$

Where, v_a is the speed of sound, n is the refractive index of the fiber material, and λp is the wavelength of the incident light in free space. For a typical quartz fiber, n = 1.45, v_a = 5.96km/s, and the incident light wavelength is 1,550nm, the frequency shift of Brillouin spectrum is about 11.2GHz.

If the acoustic wave in the fiber is assumed to be exponentially attenuated, the Brillouin scattering spectrum is a Lorentz curve shape with the following formula:

$$g_B(v) = \frac{\left(\Delta v_B/2\right)^2}{\left(v - v_B\right)^2 + \left(\Delta v_B/2\right)^2} g_P \tag{10.2}$$

Where, ΔvB is the full width at half maximum (FWHM) of the Brillouin gain spectrum, and its relationship with Γb is ΔvB = Γb/2π, and the phonon lifetime Γb = Tb-1, usually less than 10ns. For a common fiber with ΔvB as dozens of MHz, g_P is the value of the Brillouin gain spectrum at the frequency shift of Brillouin spectrum, i.e.:

$$g_P = g_B(v_B) = \frac{2\pi^2 n^7 p_{12}^2}{c\lambda_p^2 \rho_0 V_a \Gamma_B} \tag{10.3}$$

Where, p_{12} is the longitudinal elastic coefficient and ρ_0 is the density of the medium. For the incident light of 1.55um wavelength, the Brillouin gain coefficient g_p is approximately equal to $5*10^{-11}$m/W by taking the typical parameter value of the quartz fiber into the above equation.

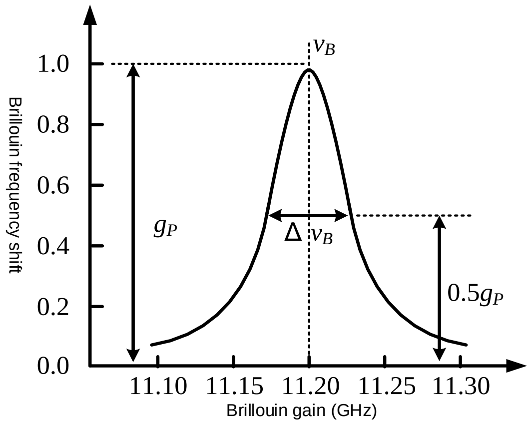


Figure 10-1 Brillouin scattering gain spectrum

4 BOTDR technology

BOTDR is a distributed optical fiber sensing technology that uses spontaneous Brillouin scattering, its basic principle is to sensor the temperature/strain using the spontaneous backward Brillouin scattering effect of the fiber, and combines OTDR technology to achieve the positioning of the sensing parameters. BOTDR is a single-ended measurement method, which is more convenient to use in practical engineering applications. BOTDR technology uses optical pulses to locate the sensing parameters. In addition to the limitation of the spatial resolution of the system to the pulse width, since Brillouin scattering is the collision of photons and phonons, if the pulse width is smaller than the phonon lifetime, it will lead to the sharp decrease of the measurement accuracy of the sensing parameter, and the lifetime of the phonon is about 10 ns, so the spatial resolution achievable by the BOTDR technique is on the order of m (meter).

Its basic structure is shown in Figure 10-4. The optical pulse is injected into one end of the sensing fiber, and the spontaneous Brillouin scattering in the backward scattered light replaces Rayleigh scattering as a function of time, with temperature and stress distribution information along the fiber, and the temperature and strain distribution in the fiber can be obtained after measuring the frequency shift of Brillouin scattering.

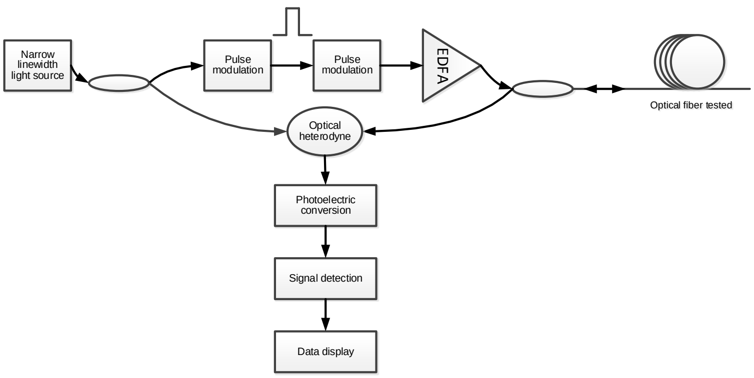


Figure 10-2 Schematic diagram of the basic structure of the spontaneous Brillouin scattering

Due to the interaction between the pump light injected into the fiber and the dielectric crystal structure in the fiber, the incident pump light is scattered, resulting in a Stokes frequency shift, in addition to generating the Rayleigh scattered light and the Fresnel reflected light of the same frequency as the pumping light in the opposite direction to the incident light, there is another kind of scattered light with Stokes frequency shift, that is, Brillouin scattering light, which is called frequency shift of Brillouin spectrum relative to the Stoke frequency shift of pump light frequency. As shown in Figure 10-3, the frequency shift of Brillouin spectrum is related to the material of the fiber and the wavelength of the pump light injected into the fiber. For the quartz fiber, when the wavelength of the pump light is 1550nm, the frequency shift is around 11GHz.

The theory shows that the frequency shift of Brillouin spectrum fB (0) of the fiber has linear relationship with strain and is expressed as follows:

$$f_B(\varepsilon)=f_B(0)(1+C_S \cdot \varepsilon) \tag{10.4}$$

Where, ε is the strain of the fiber, fB (0) is the frequency shift of Brillouin spectrum of the fiber without strain, i.e.

the initial frequency shift of Brillouin spectrum, Cs is the strain coefficient of the fiber frequency shift of Brillouin spectrum, and is a constant related to the fiber material and the wavelength of the probe light. For a conventional G.652 single mode fiber, the strain coefficient Cs is typically approximate to 493MHz/%, or 0.0493MHz/με at a 1,550 nm detection wavelength. The formula is expressed as follows:

$$C_s = \frac{dv_B}{d\varepsilon} \approx 0.0493 MHz / \mu\varepsilon \tag{10.5}$$

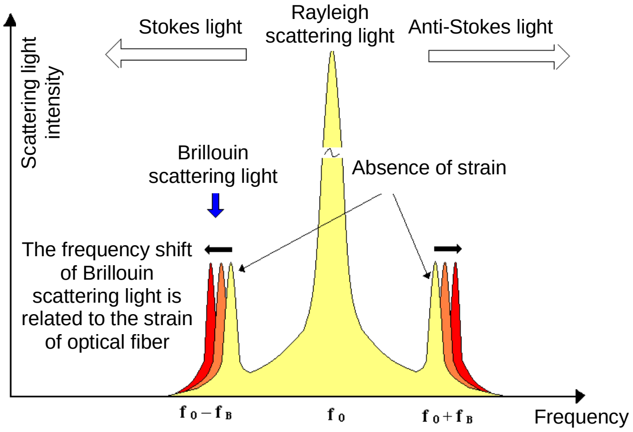


Figure 10-3 Schematic diagram of Brillouin scattering light spectrum

The meaning of 1% strain: If the 1m fiber changes to 1.01m, the strain of the fiber is 1%, 100με corresponds to 0.01%, and 1με corresponds to 0.0001%, and the strain is a relative change amount of zero dimension.

The calculation formula of the fiber length can be obtained according to the following formula:

$$\mathrm{L} = \frac{1}{2} \cdot \frac{c\Delta T}{n} \tag{10.6}$$

Where, c is the velocity of light in vacuum; t is the time interval between the initial transmitted pulse and the returned optical signal; n is the refractive index of the fiber under test. Since light travels back and forth twice in the fiber, the fiber length should be multiplied by a factor of 1/2.

Chapter XI Technical Parameters

1 General characteristics

The general characteristics of the 6419 distributed optical fiber strain tester are shown in Table 11-1.

Table 11-1 General characteristics of 6419 distributed optical fiber strain tester

NAME	CONTENT
DISPLAY	10.4" color LCD
OPTICAL OUTPUT CONNECTOR	FC/APC TYPE (STANDARD TYPE)
EXTERNAL INTERFACE	LAN PORT, RS232 PORT, VGA, USB PORT, HEADPHONE JACK
POWER SUPPLY	$220V_{AC}$ ± 10％, 50HZ ± 5％
ENVIRONMENTAL REQUIREMENTS	OPERATING TEMPERATURE: 0°C ~ 40°C STORAGE TEMPERATURE: 0°C ~ 50°C RELATIVE HUMIDITY: ≤ 85%, NO CONDENSATION
DIMENSIONS	Width × Height × Depth: 435 × 230 × 495 (mm)
WEIGHT	About 19kg
POWER SUPPLY	100 ～ $240V_{AC}$ (1.5A), frequency allowable range: 50/60Hz
MAXIMUM POWER CONSUMPTION	≤ 100W
VFL	650nm ± 30nm, 2mW (typical); working status: CW, 1HZ, 2Hz

2 Main functions

1. System power-on self-test function;
2. Chinese interface and Chinese menu display functions;
3. Strain distribution test function;
4. Brillouin scattering spectrum test function;
5. Fiber distance test function;
6. Fiber loss distribution test function;
7. VFL (visible red light fault location) function;
8. Multiwindow display function;
9. Real-time date and time display function;
10. File management function；
11. Color LCD display and brightness adjustable functions;
12. Touch screen operation function;
13. Remote control function;
14. Timing test and data storage functions;
15. Function of online upgrade of system software.

3 Main technical indicators

1. Operating wavelength: 1,550nm ± 5nm
2. Distance-measuring error: ± (0.2 + 2 × 10^{-5} × distance + 2 × sampling interval) (m)
3. Maximum spatial resolution: 1m
4. Maximum dynamic range: 15dB
5. Strain test accuracy: ≤ ± 50με (10 ~ 20ns pulse width)
   ≤ ± 10με (50~200ns pulse width)

6. Repeatability of strain test: better than ± 100με
7. Strain test range: -15,000 ~ +15,000 (με)
8. Setting range of refractive index: 1.00000~1.99999, minimum step size: 0.00001
9. Distance-measuring range: 0.5, 1, 2, ..., 128km optional, 1km step
10. Test pulse width: 10, 20, 30, ..., 200ns optional, 10ns step
11. Maximum sampling points: 80,000
12. Setting range of average times: 2^{10}~2^{24}
13. Scale type of strain display: %, με
14. Scale type of distance display: km, mi., kft.
15. Horizontal distance readout resolution: 0.05m
16. Vertical strain readout resolution: 1με
17. Scale range of vertical strain display: 10～+20,000 (με)
18. Vertical strain display range: -80,000～+80,000 (με)
19. Scale range of vertical Brillouin spectrum display: 1.0dB~10.0dB
20. Frequency scanning range: 9.9GHz to 12GHz
21. Frequency scanning interval: 1, 2, 5, 10, 20 and 50MHz are optional
22. In-machine storage capacity: ≥ 25GB
23. LCD display: 10.4 inches, display resolution is 1024 × 768
24. External electrical interface: VGA, RS232C, USB, Ethernet, support keyboard and mouse
25. External optical interface: FC/APC

Appendix A Instruction for Use of the Analysis Software

The 6419 analysis software is used to read data files tested and saved by the 6419 optical fiber strain analyzer on the PC, and perform the remote control function. It has a standard version of 6419 Analyser Standard and professional version of 6419 Analyser Professional. The standard version is attached with the purchased analyzer while the professional version is charged extra and needs a specific annotation in an order.

1 Software Installation

1.1Runtime Environment

Table A-1 Recommended 6419 runtime environment

Operating system	Windows XP and later versions of Windows operating system
Memory	More than 2G
Hard disk	More than 60G
CPU	Higher than 3.0GHz
Screen resolution	1,920 x 1,080 pixels

1.2 Installation Procedures

Taking the standard version as an example, perform the following steps to install the software:

Step 1 Run setup.exe in the installation package of the standard analysis software. The Select Installation Language dialog box is displayed, as shown in Figure A-1. Select the required language and click Next.

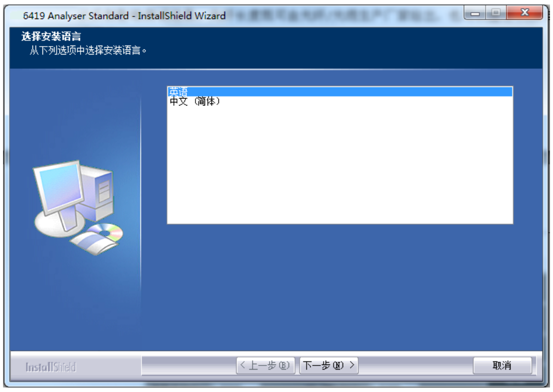


Figure A-1 Select Installation Language dialog box

Step 2 The installation software displays a dialog box indicating the installation preparation progress. After the preparation is complete, the Welcome dialog box is displayed. Click Next. The License Agreement dialog box is displayed, as shown in Figure A-2. Click I accept the terms in the license agreement (A) and Next.

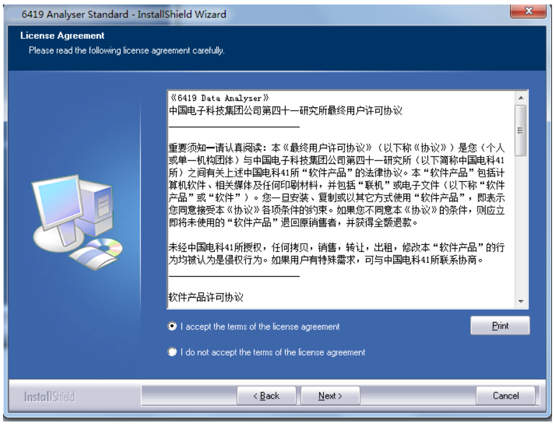


Figure A-2 License Agreement dialog box

Step 3 In the displayed User Information dialog box, specify the user name and company name, as shown in Figure A-3. Then, click Next.

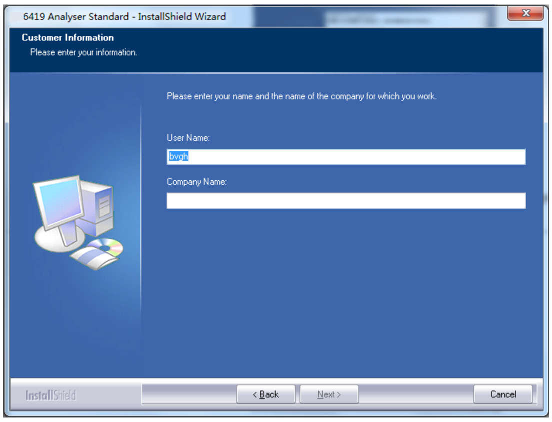


Figure A-3 User Information dialog box

Step 4 The Select Installation Type dialog box is displayed, as shown in Figure A-4. If you click Full Installation and Next, the software installs all application functions in the default system path. If you click Custom Installation, you need to specify the software installation path and functions. Click Next. The Select Installation Path dialog box is displayed. Click Change to specify a new path for saving the software installation files. Then, click Next. The Select Software Function dialog box is displayed. Select the function to be installed and click Next.

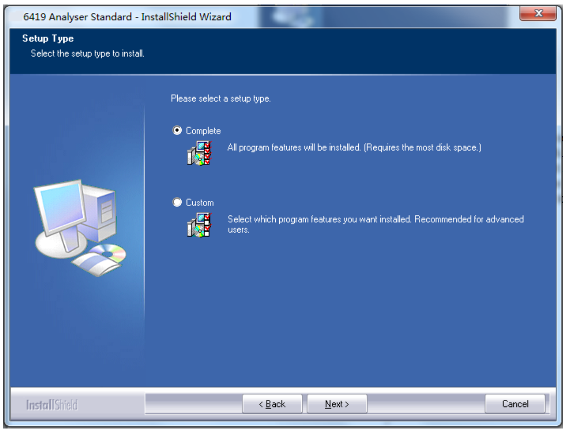


Figure A-4 Select Installation Type dialog box

Step 5 In the Conform Installation dialog box, click Next to enter the Installation Progress dialog box. After the installation is complete, a dialog box will be automatically displayed, indicating successful installation. Click Finish to finish installing the software.

1.3 Software Running

After the 6419 analysis software is installed, taking the standard version for example, you can choose Start > Programs > CETC > 6419 Analyzer Standard > 6419 Analyzer Standard to run the analysis software. Alternatively, you can search the software installation path for the 6419 Analyzer Standard application to run it, as shown in Figure A-5.

1.4 Software Uninstallation

After the 6419 analysis software is installed, taking the standard version for example, you can choose Start > Programs > CETC > 6419 Analyzer Standard > Uninstall Application to uninstall the analysis software. Alternatively, you can uninstall it by using Add/Remove Programs in the Control Panel or the professional uninstallation software.

2 Software Interface

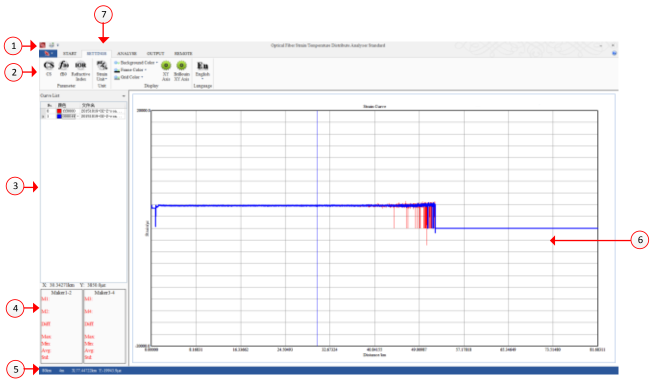


Figure A-5 Software interface

As shown in Figure A-5, the software interface consists of the following:

① File command button: Reads, exports, and prints data files.

② Function area: Includes functions such as data file display and analysis, settings, and remote control.

③ Curve list: Lists curves of files read.

④ Marker information bar: Displays marker information.

⑤ Status bar: Displays parameters is like the data measurement range and sampling resolution, and the coordinate value corresponding to the cursor location.

⑥ Image display area: Displays the curve of data read in the specified display mode.

⑦ Quick launch toolbar: Sets the tools frequently used, which is on the top of the interface by default.

3 Data Reading

Click the file operation button. A drop-down list is displayed, as shown in Figure A-6.

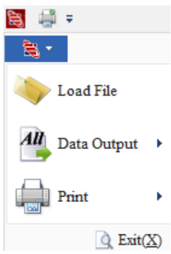


Figure A-6 File operation button menu

Choose Read File from the drop-down list. A dialog box is displayed, as shown in Figure A-7. The dialog box is divided into three areas from left to right: The left area displays a navigation tree to find a specified file; the middle area contains the file list and the Read Mode drop-down list; the right area lists files read.

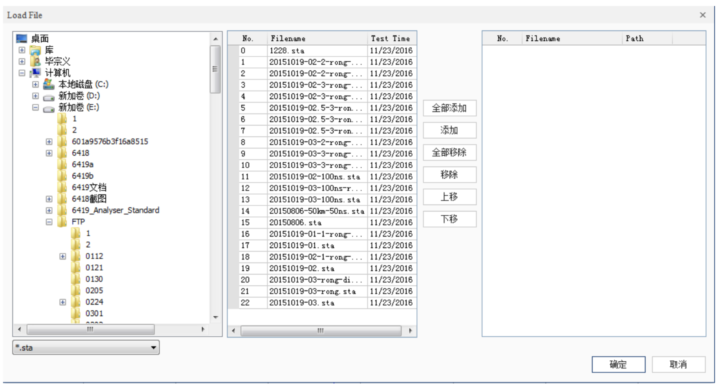


Figure A-7 Read File dialog box

Perform the following steps to read a file:

(1) Select the format of a file to be read from the left navigation tree. Two file formats are required: *.sta and *.eis. An .sta file contains data information including the strain distribution, maximum loss, and Brillouin spectrum; while an .eis file contains only strain information.

(2) Select a folder from the left navigation tree. The files in a specified format will be displayed in the middle area.

(3) Click Add All or Add to add files from the left area to the middle area (considering the limit to the largest number of files to be read). Up and Down are used to adjust the file sequence on the read list; Remove or Remove All are used to delete files from the read list.

(4) Select a Read Mode from the middle Read Mode drop-down list.

(5) Click Conform to load files on the read list.

Note! **The Read Mode drop-down list consists of Brief Reading and Detailed Reading. The Brillouin spectrum can be displayed only when you select Detailed Reading.**

Note! **In the standard analysis software (6419 Analyser Standard), two files can be read by using Brief Reading and Detailed Reading every time respectively. In the professional analysis software (6419 Analyser Professional), a maximum of 100 files can be read by using Brief Reading and a maximum of 20 files can be read by using Detailed Reading every time.**

4 Data Display

4.1 Display Mode

As shown in Figure A-8, the Display Mode functional group framed in red includes Display Strain, Center Frequency, and Maximum Loss.

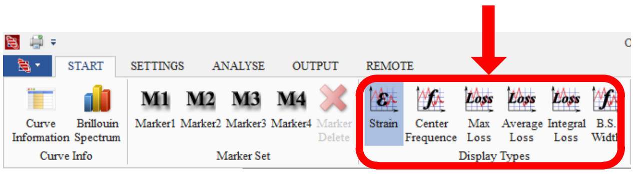


Figure A-8 Display Mode functional group on the Start tab

Display Strain is highlighted by default after a file is read. Therefore, the file read is displayed as a strain curve in the graphic display area. If you need to view data about the center frequency and maximum loss in the file, click Center Frequency and Maximum Loss. The corresponding curves will be displayed in the graphic display area.

4.2 Marker Placement

The marker placement tool is in the Marker Placement functional group on the Start tab, as shown in Figure A-9, which includes M1 (Marker 1), M2 (Marker 2), M3 (Marker 3), and M4 (Marker 4) four marker placement tools and a marker deletion tool. The four markers must be placed in sequence from M1 to M4.

Alternatively, you can right-click on the graphic display area and obtain the preceding functions in the displayed shortcut menu.

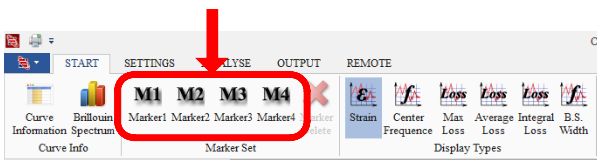


Figure A-9 Marker Placement functional group on the Start tab

You can use the marker placement tool as follows: Select a file to be marked with a marker from the curve list, click and locate the cursor (blue vertical line in the graphic display area) on the curve to the marker location, and click a marker placement tool. The blue cursor line will turn red; the sequence number of the marker will be displayed on the upper right of the blue cursor line; the marker information will be displayed in the marker information bar. Display Strain is used as an example. After a marker is placed, the graphic display area is displayed, as shown in Figure A-10.

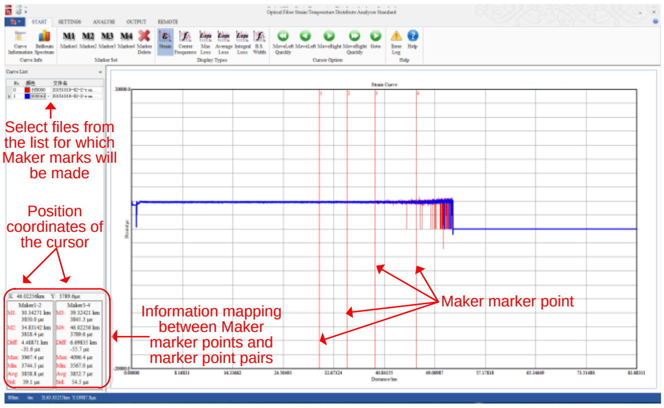


Figure A-10 Results of marker placement in Display Strain mode

The marker point information bar of Marker consists of two columns: Marker1-2 group and Marker3-4 group. In particular, Marker1-2 group displays the coordinate information including the maximum vertical coordinate value (Max), minimum vertical coordinate value (Min), average vertical coordinate value (Avg), standard deviation of the vertical coordinate (Std) of Marker1 and Marker2, and the coordinate difference between Marker1 and Marker2 (Diff), while Marker3-4 group displays the coordinate information including the maximum vertical coordinate value (Max), minimum vertical coordinate value (Min), average vertical coordinate value (Avg), standard deviation of the vertical coordinate (Std) of Marker31 and Marker4, and the coordinate difference between Marker3 and Marker4 (Diff)

4.3 Curve Information

The Curve Information functional group framed in red on the Start tab consists of Detailed Information and Brillouin Spectrum, as shown in Figure A-11.

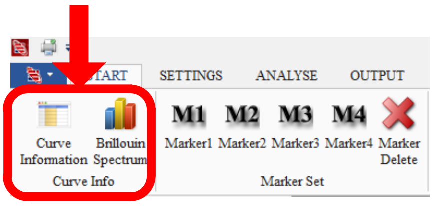
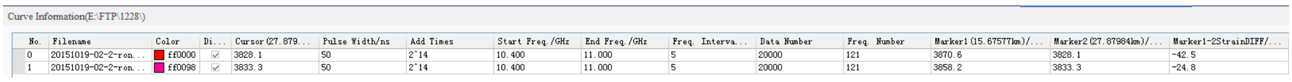


Figure A-11 Curve Information functional group on the Start tab

4.3.1 Detailed Information

Click Detailed Information. The Detailed Information dialog box is displayed, as shown in Figure A-12.


Curve Information(E:\FTP\1228\)

No.	Filename	Color	Di...	Cursor(27.879...	Pulse Width/ns	Add Times	Start Freq./GHz	End Freq./GHz	Freq. Interva...	Data Number	Freq. Number	Marker1(15.67577km)/...	Marker2(27.87984km)/...	Marker1-2StrainDIFF/...
0	20151019-02-2-ron...	ff0000	✓	3828.1	50	2^14	10.400	11.000	5	20000	121	3870.6	3828.1	-42.5
1	20151019-02-2-ron...	ff0098	✓	3833.3	50	2^14	10.400	11.000	5	20000	121	3858.2	3833.3	-24.8

Figure A-12 Detailed Information dialog box

The Detailed Information dialog box displays data information in the reading sequence, including measurement parameters such as File Name, Curve Color, Display, Cursor, and Pulse Width, as well as the marker information. In particular, Curve Color and Display can be configured.

Display: Controls whether the curve is displayed in the graphic display area.

Curve Color: Sets the curve color of a corresponding file. You can click on the curve to enter the Color Settings dialog box.

Display All and Hide All in the lower right corner of the dialog box control whether to display or hide all files on the read list.

The modified settings of Curve Color and Display take effect after you click Conform in the lower right corner.

4.3.2 Brillouin spectrum

This function takes effect when you choose the detailed Read Mode. Click Brillouin Spectrum. The Brillouin Spectrum Display dialog box is displayed, as shown in Figure A-13. It shows the Brillouin spectrum of a data file selected from the curve list at the location of the cursor. Re-click Brillouin Spectrum. The Brillouin Spectrum

Display dialog box is closed.

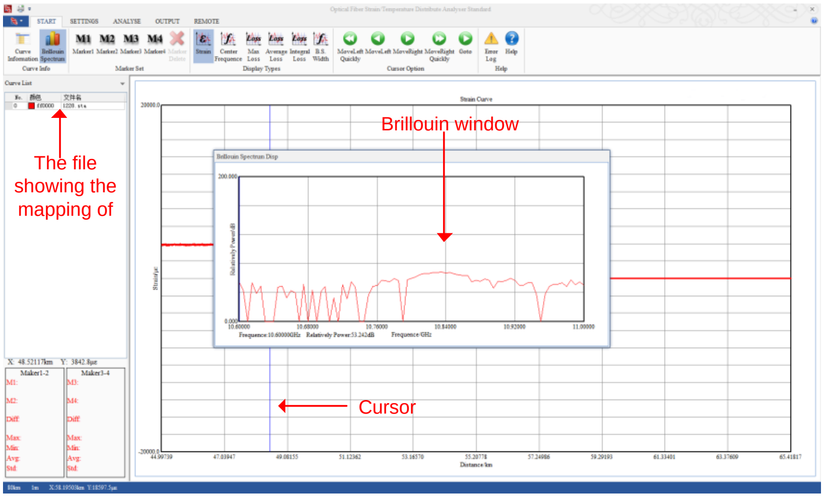


Figure A-13 Brillouin Spectrum Display dialog box

In the Brillouin Spectrum Display dialog box, you can right-click and choose Copy Image from the displayed shortcut menu to copy the displayed Brillouin spectrum to the clipboard as required.

4.4 Curve Zooming

To view the detailed information of a part of the curve, zoom in the part. To be specific, click on the graphic display area and hold the cursor to the lower right. After the cursor is released, the selected area is zoomed in. After the curve is zoomed in, click on the curve and hold the cursor to the upper left. Then, the curve is zoomed out after you release the cursor.

4.5 Cursor Operation

In the graphic display area such as the Brillouin Spectrum Display dialog box, click to locate the cursor. The located cursor is displayed as a blue vertical line. Alternatively, you can move the cursor by using the Cursor Operation functional group framed in red on the Start tab, as shown in A-14.

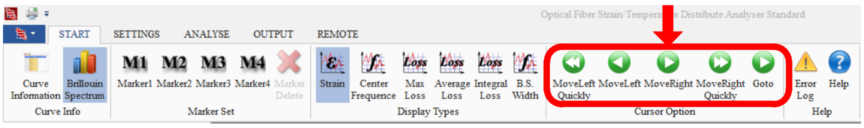


Figure A-14 Cursor Operation functional group

: Moves the cursor left one data point horizontally.

(First from left): Moves the cursor right one data point horizontally.

: Moves the cursor left 10 data points horizontally.

: Moves the cursor right 10 data points horizontally.

(Second from left): Displays the Go To dialog box after being clicked, as shown in Figure A-15. Enter the location the cursor goes to and click OK. The cursor goes to the specified location.

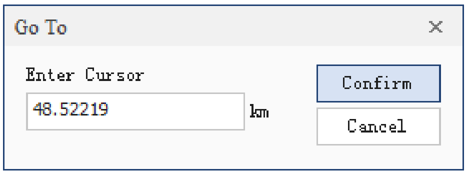


Figure A-15 Go To dialog box

The Cursor Operation button is of great help for precise movement, making up for the shortcoming of the cursor that is difficult to locate the movement precisely.

4.6 Settings

The Settings tab consists of four functional groups: Parameter, Unit, Display, and Language. It is used to set the color, unit, parameters, and display language for the data curves displayed. The following details the settings of the parameters and strain unit.

Parameter: Is used to modify data parameters. The data curve will be refreshed based on new parameters. Figure A-16 shows the Parameter functional group.

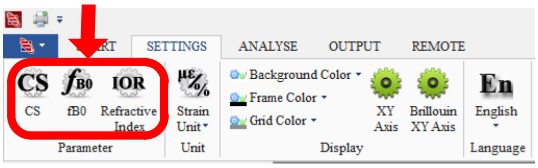


Figure A-16 Parameter functional group on the Settings tab

The Parameter functional group consists of three buttons: CS (coefficient of strain), fB0, and Refractive Index. Click a button to enter the related setting dialog box, as shown in Figures A-17(a) to (c). Enter related parameters in the input box and click Confirm to confirm settings. After the preceding three parameters are modified, the curve in the graphic display area will be refreshed based on new parameters.

Figure A-17 (a) CS Settings dialog box

Figure A-17 (b) fB0 Settings dialog box

Figure A-17 (c) Refractive Index Settings dialog box

Strain Unit: Is used to set the strain unit, highlighted as shown in Figure A-18. Click Strain Unit. In the displayed shortcut menu, με and % are available. Once a unit is chosen, the shortcut menu is hidden. If the strain curve is displayed in the graphic display area, the unit of the longitudinal axis will change accordingly. In addition, all other information related to the strain unit will change accordingly.

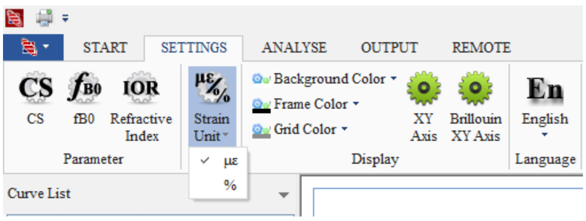


Figure A-18 Strain Unit functional group on the Settings tab

5 Data Analysis

The Analysis tab is configured with functions including Splicing, Difference, and Multi-peak, among which Splicing and Multi-peak are unavailable temporarily.

As shown in Figure A-19, when the cursor hovers on Difference, this button is highlighted. Click Difference. A shortcut menu containing Single-curve Difference and Multi-curve Difference is displayed. Choose an option to enter the related dialog box.

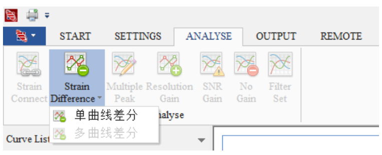


Figure A-19 Difference function

Note!

The multi-curve difference function is available only in the professional software (6419

Analyser Professional).

As shown in Figure A-20, the left part of the Single-curve Difference dialog box lists files. The upper part lists the principal strain files while the lower part lists the reference strain files. The right part of the dialog box consists of three graphic display boxes. The upper one displays the principal strain curve; the middle one displays the reference strain curve; the lower one displays the difference strain curve.

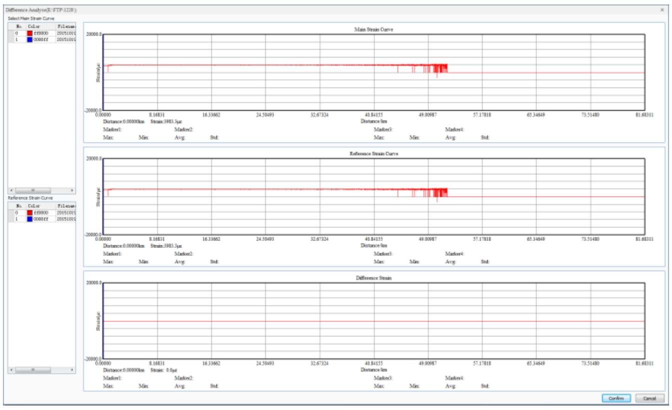


Figure A-20 Single-curve Difference dialog box

All files read are listed on the two read lists. Click files of a reference strain curve and principal strain curve in the left pane. The corresponding reference strain curve, principal strain curve, and difference curve between the two are displayed in the graphic display area in the right pane. The strain difference curve has the same color as the principal strain curve. Click a color box in the Select Principal Strain Curve area. The Color Settings dialog box is displayed, used to set the display color for the related curve. The function of curve zooming in section 4.4 “Curve Zooming” also works here.

Right-click on any graphic display box. A shortcut menu including functions such as marker placement and data export is displayed, as shown in Figure A-21.

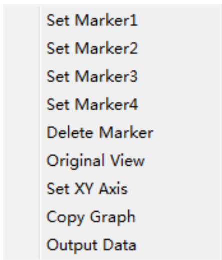


Figure A-21 Data analysis shortcut menu

Based on the marker placement methods provided in section 4.2 “Marker Placement”, place markers in the current graphic display box by using the marker placement tool on the shortcut menu. The difference strain curve is displayed as shown in Figure A-22. The lower left corner of the box displays the corresponding distance and strain value of each marker, and the maximum value (Max), minimum value (Min), average value (Avg), and standard deviation (Std) of each pair of markers. If you set markers on a curve in a graphic display box in the Difference Analysis dialog box, the curves in the other two graphic display boxes will be set synchronously.

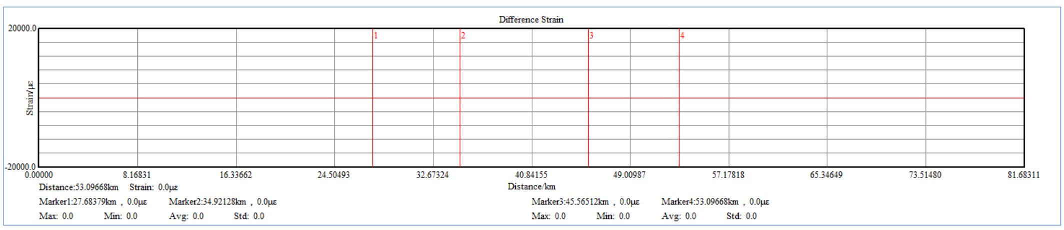


Figure A-22 Marker placement and information

Data Export is used to export the curve data in the current three graphic display boxes to the folder specified by the user in .txt format. The file includes the test parameters of the principal and reference strain curves, as well as raw data and strain difference data of the two, as shown in Figure A-23.

```
/****Reference Strain Curve Parameter****/
Span:80km
Resolution:4m
CS:0.0500MHz/με
fB0:10.640GHz
Refractive Index:1.4680
Add Times:2^14
Pulse Width:50ns
Start Freq.:10.400GHz
End Freq.:11.000GHz
Freq. Interval:5MHz
Data Number:20000
Freq. Number:121
/****Reference Strain Curve Parameter****/
Span:80km
Resolution:4m
CS:0.0500MHz/με
fB0:10.640GHz
Refractive Index:1.4680
Add Times:2^14
Pulse Width:50ns
Start Freq.:10.400GHz
End Freq.:11.000GHz
Freq. Interval:5MHz
```

Figure A-23 Data exported from single-curve difference analysis

Note!

(1) If you right-click a selected reference strain curve on the read list and choose Data Export from the displayed shortcut menu, all files in the principal strain curve list, and the strain information and difference strain information of the selected reference strain file are exported.

(2) If you right-click on the reference strain curve list and choose Data Export from the displayed shortcut menu, all files in the principal strain curve list, and the strain information and difference strain information of the first reference strain file are exported.

6 Data Export and Print

6.1 Data Export

The function allows exporting information in .sta files read, including the strain, center frequency, and maximum loss to .txt files respectively. For details about the operation, see section 5.1.

Note!

Only strain information can be exported from .eis files.

6.1.1 Using the Export Tab

As shown in Figure A-24, the Export tab framed in red consists of Strain, Center Frequency, Maximum Loss, and All Types. The former three are used to export the related data information in the file read to a specified directory in .txt format with the original file name. Clicking All Types means to export the three types of data simultaneously.

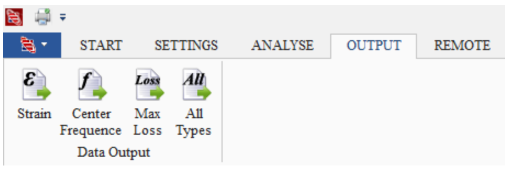


Figure A-24 Data Export functional group on the Export tab

6.1.2 Using the File Operation Button

As shown in Figure A-25, in the menu bar, you can export data by choosing the file operation button > Export Data > Export to TXT File/Export Strain/Export Center Frequency/Export Maximum Loss. The four items on the Export Data submenu have the same functions of the four on the Export tab. In particular, Export to TXT File equals to All Types.

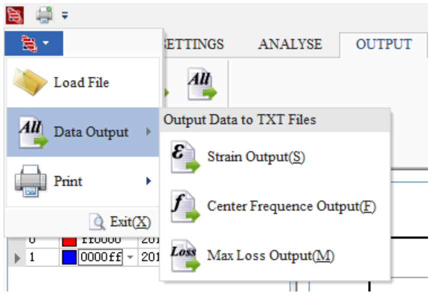


Figure A-25 File operation button menu and Export Data submenu

A case study of exporting strain data shows that the exported .txt file contains test parameters and the strain value at the corresponding location, as shown in Figure A-26.

```
Span:80km
Resolution:4m
CS:0.0500MHz/μ ε
fB0:10.640GHz
Refractive Index:1.4680
Add Times:2^14
Pulse Width:50ns
Start Freq.:10.400GHz
End Freq.:11.000GHz
Freq. Interval:5MHz
Data Number:20000
Freq. Number:121
Distance/km     Strain/μ ε
0.00000  3901
0.00408  3450
0.00817  3411
0.01225  3417
0.01634  3421
0.02042  3414
0.02451  3414
0.02859  3412
0.03267  3409
0.03676  3414
0.04084  3417
```

Figure A-26 Data in the exported strain file

6.1.3 Shortcut Menu

In the graphic display area, right-click on the curve. A shortcut menu is displayed, as shown in Figure A-27. The menu contains five marker placement tools, as described in section 3.2 “Marker Placement.”

Copy Image is used to copy the image in the current graphic display area to the clipboard.

Copy Spectrum Data is used to copy the Brillouin spectrum data of a selected file at the location of the cursor in the graphic display area to the clipboard.

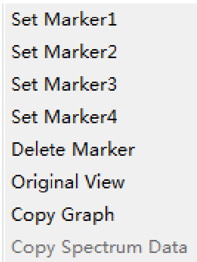


Figure A-27 Shortcut menu in the graphic display area

Note! **Copy Spectrum Data is available only in the professional software (6419 Analyser Professional).**

6.2 Print

The file print function is available by choosing the file operation button > Print. Alternatively, you can add Print to the quick access toolbar via Custom Settings on the quick access toolbar. As shown in Figure A-28, you can perform the quick print function by choosing the file operation button > Print > Quick Print.

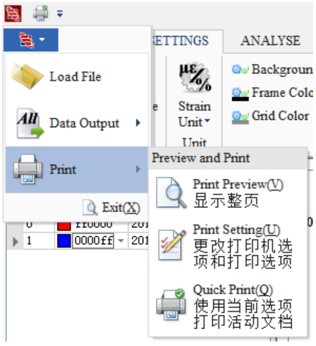


Figure A-28 Print submenu

The Print submenu consists of Print Preview, Print Settings, and Quick Print. You are recommended to configure print settings first and preview the print by choosing Print Preview before printing.

6.2.1 Print Settings

Choose Print > Print Settings. The Print Settings dialog box is displayed, as shown in Figure A-29. The dialog box consists of five areas: Print Curve, Printer, Print Content, Print Parameters, and Print Style.

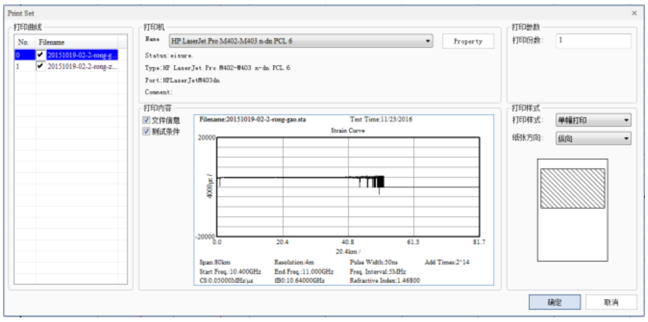


Figure A-29 Print Settings dialog box

The Print Curve area lists data files currently read. Select a file to be printed by selecting the check box in front of the file name.

The Printer area allows selecting a printer to print files and setting the printer properties.

The Print Content area consists of File Information and Test Conditions. The file information includes the file name and test time, and the test conditions mean the file test conditions. After an option is selected, the printed file contains the corresponding content.

The Print Style area is used to set the print style for files in the Print Curve list. You can specify Print Style and Paper Orientation. The Print Style drop-down list contains Single-copy Print, Dual-copy Print, and Quad-copy Print. If Quad-copy Print is chosen and the paper orientation is longitudinal, you can preview print in the lower right corner, as shown in Figure A-29.

6.2.2 Print Preview

Choose Print > Print Preview to enter the Print Preview dialog box. The Print Preview functional group consists of Print, Zoom, and Preview, as shown in Figure A-30. You can preview the print via the Zoom and Preview functions. If the print is unsatisfactory, you need to click Close on the Print Preview tab to reconfigure print settings; otherwise, click Print on the left.

Figure A-30 Print Preview

6.2.3 Quick Print

It allows printing data files in the curve list based on the current default print settings.

7 Remote Control

The analysis software allows you to remotely control the instrument by choosing Remote Control > Connection Parameters/Remote Control/Disconnect, as shown in Figure A-31.

Figure A-31 Remote Control tab

7.1 Connection Parameters

Choose Remote Control to enter the Remote Control dialog box, as shown in Figure A-32.

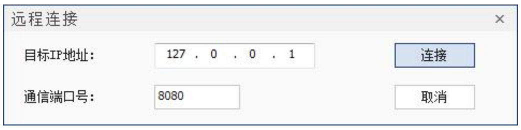


Figure A-32 Remote Control dialog box

In the Remote Control dialog box, enter the IP address of the target instrument to be remotely controlled in the Target IP Address box and 8080 in the Telecommunication Port Number box that is the same as the telecommunication port number of the target instrument. As described in section 8.6 "Remote Control," keep the IP address, subnet mask, and gateway of the host installed with the analysis software and the target instrument in the same network segment. Then, click Connect to perform the remote control on the instrument. If the connection is successful, this dialog box is automatically closed; otherwise, a connection failure message box is displayed.

7.2 Remote Control

After remote connection is successful, choose Remote Control to enter the Remote Control dialog box, as shown in Figure A-33. It is divided into the test condition operation area and graphic display area. The test condition operation area consists of Run Parameters and Command Action. The Run Parameters group box allows specifying test conditions. The right pane shows the strain curve tested by the instrument. The lower section displays Start Test, Stop Test, and Save File.

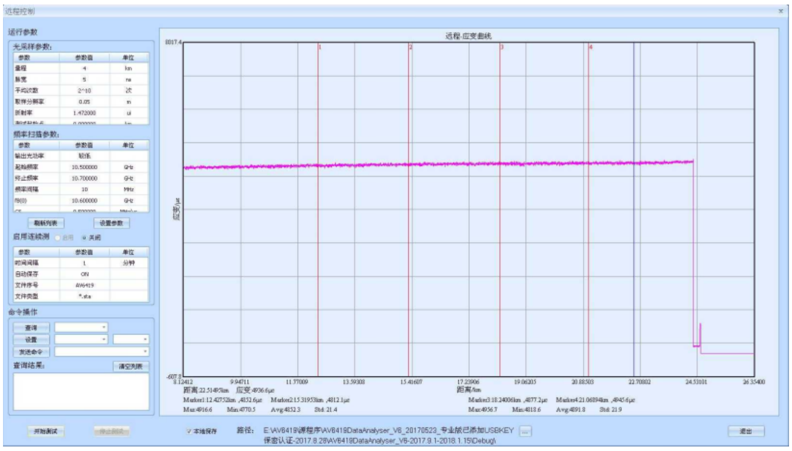


Figure A-33 Remote Control dialog box

The Run Parameters area has the same contents as the test condition operation area. However, it is divided into three areas based on parameter properties: Optical Sampling Parameters, Frequency Scanning Parameters, and Start Continuous Test. You can specify parameters like Range, Pulse Width, Average Times, Sampling Resolution, and Frequency Interval by double-clicking a parameter value, clicking on the right of the parameter value input box, and selecting a value from the displayed drop-down list. You can specify parameters like Refractive Index, Test Start Point, Start Frequency, Stop Frequency, fB (0), and CS by double-clicking a parameter value and entering a value where the cursor appears. You can synchronize the preceding parameter settings to the test conditions of the instrument by clicking Set Parameters in the lower part of Run Parameters. The Refresh List button allows reading the current test conditions of the instrument into the Run Parameters area.

The Command Action area provides functions like parameter query, parameter setting, and sending remote control command, as shown in Figure A-34.

Figure A-34 Command Action in the Remote Control dialog box

The Query drop-down list contains all items of the optical sampling and frequency scanning parameters. Select an item and click Query. The parameter value of this item will be displayed in the lower Query Results text box.

The Setting drop-down list similarly contains all items of the optical sampling and frequency scanning parameters. Select an item, and the input box on the right displays a drop-down list or number input box.

The Send Command drop-down list lists commands in Appendix B "Remote Control Command Set." Select a command and click Send Command to send the command to the target instrument. If a query command is selected, the results returned will be displayed in the Query Results text box.

Clear List is used to clear contents of the Query Results text box.

Start Test and Stop Test enable the instrument to start or stop a test. When the instrument is running a test, the progress bar is displayed in the graphic display area. If the test is complete, the strain curve tested by the instrument is displayed in the graphic display area.

The lower part of the graphic display area shows data results and contains three lines. Line 1 shows the distance and strain value at the cursor location; line 2 shows the location and strain value of each marker; line 3 shows the maximum value (Max), minimum value (Min), average value (Avg), and standard deviation (Std) of markers 1 and 2 and markers 3 and 4.

7.3 Disconnect

After exiting from the Remote Control dialog box, click Disconnect to disconnect the remote connection.

8 Status Bar and Quick Access Toolbar

8.1 Status Bar

In the lower left of the software window, the status bar shows in sequence the range and sampling resolution of data currently read when being tested by default. X and Y values are the coordinate values on the corresponding curve of the current cursor.

Right-click on the status bar. The Status Bar Configuration dialog box is displayed. You can set the contents displayed in the status bar, as framed in red in Figure A-35.

Figure A-35 Status Bar Configuration dialog box

8.2 Quick Access Toolbar

The quick access toolbar is used to set the tools frequently used, which is on the top of the interface by default. Click on the right of the toolbar. A drop-down list is displayed for customizing the quick access toolbar. In particular, you can set the quick access command, change the toolbar display position, and minimize the functional area, as shown in Figure A-36.

Figure A-36 Quick access toolbar

In the drop-down list as shown in Figure A-36, choose More Commands. A dialog box for customizing the quick access toolbar is displayed, as shown in Figure A-37. In this dialog box, you can add the selected quick access tools to the quick access toolbar and set the display position of the quick access toolbar and corresponding shortcut keys.

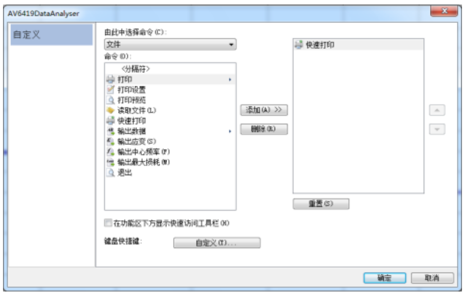


Figure A-37 Quick access toolbar

Appendix B 6419 Remote Control Command Set

Table B-1 6419 remote control command set

Remote Control Command	Description	Value (String)
:SENSe:CONDition:Model?	Queries the equipment model.	Equipment model returned, such as AV6419.
:SENSe:CONDition:ID?	Queries the serial number.	Serial number returned, such as 201706001.
:SENSe:CONDition:Version?	Queries the software version.	Software version returned, such as Ver 2.001.
:SENSe:CONDition:RANGe?	Queries the range.	Current range returned, such as 0.5km.
:SENSe:CONDition:RANGe<value>	Sets the range.	0 or an integer from 1 to 127, separated from the preceding SCPI command with a space. The values are corresponding to 0.5km, 1km to 127km.
:SENSe:CONDition:PULSewidth?	Queries the pulse width.	Current pulse width returned, such as 10ns.
:SENSe:CONDition:PULSewidth<value>	Sets the pulse width.	An integer from 1 to 20, separated from the preceding SCPI command with a space. The values are corresponding to 10～200ns.
:SENSe:CONDition:AVERage?	Queries the average times.	Current average times returned, such as 10, indicating that the average times is 2^{10}.
:SENSe:CONDition:AVERage<value>	Sets the average times.	An integer from 10 to 24, separated from the preceding SCPI command with a space. The value is the index of 2.
:SENSe:CONDition:RESolution?	Queries the sampling resolution.	Current sampling resolution returned, such as 0.05m.
:SENSe:CONDition:RESolution<value>	Sets the sampling resolution.	An integer from 0 to 6, separated from the preceding SCPI command with a space. The values are corresponding to 0.05m, 0.10m, 0.20m, 0.50m, 1.00m, 2.00m and 4.00m.
:SENSe:CONDition:IOR?	Queries the refractive index.	Current refractive index returned, such as 1.472.
:SENSe:CONDition:IOR<value>	Sets the refractive index.	A number greater than 1 and less than 2, such as 1.47200 or 1.46800, separated from the preceding SCPI command with a space.
:SENSe:CONDition:STARtsamplept?	Queries the start point.	Current test start point returned, such as 0.39996.
:SENSe:CONDition:STARtsamplept<value>	Sets the start point.	Configured based on the current range and sampling resolution and separated from the preceding SCPI command with a space.
:SENSe:CONDition:INTErvalfreq?	Queries the frequency interval.	Current frequency interval returned, such as 1MHz.
:SENSe:CONDition:INTErvalfreq<value>	Sets the frequency interval.	An integer from 0 to 7, separated from the preceding SCPI command with a space. The values are corresponding to 1MHz, 2MHz, 5MHz, 10MHz, 20MHz and 50MHz.
:SENSe:CONDition:fB?	Queries fB (0).	Current fB (0) returned, such as 10.60000.
:SENSe:CONDition:fB<value>	Sets fB (0).	A number greater than 9.9 and less than 12.0, such as 10.7 or 10.75, separated from the preceding SCPI command with a space. The unit is GHz.
:SENSe:CONDition:CS?	Queries the coefficient of	Current coefficient of strain returned, with a unit

	strain.	of MHz/με, such as 0.05000.
:SENSe:CONDition:CS<value>	Sets the coefficient of strain.	A number greater than 0 and smaller than 1, such as 0.5 or 0.66, separated from the preceding SCPI command with a space. The unit is MHz/με.
:SENSe:FREQuency:STARt?	Queries the start frequency.	Current start frequency returned, such as 10.70000.
:SENSe:FREQuency:STARt<value>	Sets the start frequency.	A number greater than 9.9 and smaller than 12, such as 10.700 or 10.751, separated from the preceding SCPI command with a space. The unit is GHz. The value is correct to three decimal places and the start frequency must be less than the cut-off frequency.
:SENSe:FREQuency:STOP?	Queries the stop frequency.	Current cut-off frequency returned, such as 10.90000.
:SENSe:FREQuency:STOP<value>	Sets the stop frequency.	A number greater than 9.9 and smaller than 12, such as 10.700 or 10.751, separated from the preceding SCPI command with a space. The unit is GHz. The value is correct to three decimal places and the start frequency must be less than the cut-off frequency.
:SENSe:CONDition:LIGHtpower?	Queries the output optical power.	Current output optical power returned, such as Lower.
:SENSe:CONDition:LIGHtpower<value>	Sets the output optical power.	An integer from 0 to 3, separated from the preceding SCPI command with a space. In particular, 0 corresponds to Lower; 1 corresponds to Low; 2 corresponds to Middle, and 3 corresponds to High.
:SENSe:CONDition:ReadAllPara	Reads the parameter structure.	Parameter structure received after the command is issued. It contains information about test parameters of the current equipment. For details about struct Send, see the next table.
:SENSe:CONDition:WriteAllPara	Sets the parameter structure.	Parameter structure containing parameter information configured by users sent after the command is issued. For details about struct Send, see the next table.
:IMMediate:AVERage:STARt	Starts a test.	Starting average processing.
:IMMediate:AVERage:STOPt	Stops a test.	Stopping average processing.
:SENSe:CONDition:Teststate?	Queries the test status.	Test status returned after a query: -1 indicates test error; 0 indicates test complete; A number greater than 0 indicates the current number of test points.
:SENSe:CONDition:SendTstData	Reads an .eis test file.	Test results returned: 0 indicates no valid data currently. A file size indicates that testing is complete and the file is ready to be returned. Then, the server enters the wait state and the user can send the required package number to request the server for the required folder. The packet number can be calculated based on the file size and 2044, greater than or equal to 0. If a number less than 0 is sent, file transfer is ended. The file read via remote control is in .eis format. For details about the .eis format, see **section 6.4.2 "EIS File**

		Format."

Structure description:

struct Send

{

int D_Range;

int D_PulseWidth;

int D_AVERage;

int D_RESolution;

double D_IOR;

double D_STARtsamplept;

int D_INTErvalfreq;

double D_fB;

double D_CS;

double D_STARfreq;

double D_ENDfreq;

int D_LIGHtpower;

};

Table B-2 Data name description

Data Type	Data Name	Description
int	***D_Range***	Selects the range. Optional. It is an integer ranging from 0 to 127, corresponding to 0.5km, 1km to 127km.
int	***D_PulseWidth***	Sets the pulse width. Optional. It is an integer ranging from 1 to 20, corresponding to 10～200ns.
int	***D_AVERage***	Selects the average times. It is an integer ranging from 0 to 23, corresponding to the index of 2.
int	***D_RESolution***	Selects the sampling resolution. Optional. It is an integer ranging from 0 to 6, corresponding to 0.05m, 0.1m, 0.2m, 0.5m, 1.00m, 2.00m, and 4.00m.
double	***D_IOR***	Sets the refractive index, such as 1.472.
double	***D_STARtsamplept***	Sets the start point of sampling. The value is a number such as 0.
int	***D_INTErvalfreq***	Selects the frequency interval. Optional. It is an integer ranging from 0 to 5, corresponding to 1MHz, 2MHz, 5MHz, 10MHz, 20MHz and 50MHz.
double	***D_fB***	Sets fB (0), such as 10.6.
double	***D_CS***	Sets the coefficient of strain, such as 0.5.
double	***D_STARfreq***	Sets the start frequency, such as 10.3.
double	***D_ENDfreq***	Sets the stop frequency, such as 10.7.
int	***D_LIGHtpower***	Selects the output optical power. Optional. It is an integer ranging from 0 to 3, corresponding to Lower, Low, Middle, and High.

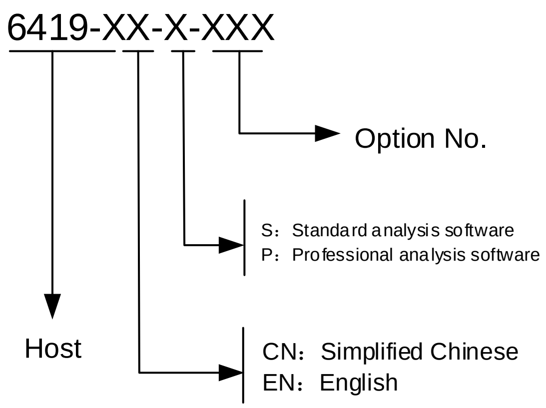
Sample code of remote control:

```
//Read test file:
void FileRead()
{
  char OrderBuf[50];
```

```
  char RecvData[2048];
  int RecvLength;
  strcpy(OrderBuf,":SENSe:CONDition:SendTst");
  send(Socket,OrderBuf,strlen(OrderBuf),0);//Send the file read command
  RecvLength=recv(Socket,RecvData,2048,0);//Receive file size
  DWORD FileSize;
  int num,rem;
  FileSize=atoi(RecvData);
  num=FileSize/2044;//Calculate the total number of packets to be transferred
  rem=FileSize%2044;
  if(rem!=0)
    num++;
  CFile File;
  File.Open("6419.eis", CFile::modeCreate|CFile::modeWrite|CFile::modeRead);
  char NumberBuf[10];
  for(int i=0;i<num;i++)//Request packets from the instrument in sequence from the beginning
  {
    itoa(i,NumberBuf,10);
    send(Socket,NumberBuf,strlen(NumberBuf),0);
    RecvLength=recv(Socket,RecvData,2048,0);
    File.Write(RecvData+4,RecvLength-4);//Write the last 2044 bytes in the received packets
  }
  strcpy(NumberBuf,"-1");
  send(Socket,NumberBuf,strlen(NumberBuf),0);//Send -1 to notify the instrument that file transfer is complete
  File.Close();
}
//Process of a test:
void main()
{
  char OrderBuf[50];
  char TestState[50];
  strcpy(OrderBuf,":IMMediate:AVERage:STARt");
  send(Socket,OrderBuf,strlen(OrderBuf),0);//Send the test start command
  strcpy(OrderBuf,":SENSe:CONDition:Teststate?");
  send(Socket,OrderBuf,strlen(OrderBuf),0);//Query the test status
  recv(Socket,TestState,strlen(TestState),0);
  int State;
  State=atoi(TestState);
  while(State!=0)//Query the test status recursively
```

```
  {
    send(Socket,OrderBuf,strlen(OrderBuf),0);
    recv(Socket,TestState,strlen(TestState),0);
    State=atoi(TestState);
    if(State==-1)
    {
      MessageBox("Test error!") ;
      return;
    }
    MessageBox("No. State point tested currently!") ;
  }
  MessageBox("Test complete!") ;
  FileRead();//Read test file
}
```

Appendix C 6419 Ordering Information



Remarks:For details about the option No., see section section 1.2.2 “Option.”

Appendix D Identification of FC/APC from FC/UPC and Patch Cord Connection

1 FC/APC and FC/UPC Optical Fiber Connector

Usually called bevel connection, the FC/APC connector has an 8-degree oblique angle at the end, as shown in Figure D-1.

Figure D-1 FC/APC

Figure D-2 FC/UPC

The FC/UPC connector is flat without any oblique angle, as shown in Figure D-2. Usually, there is another way to differentiate between the two connectors.

Figure D-3 FC/APC green label

Usually, the protector under the FC/APC connector is green, as shown in Figure D-3.

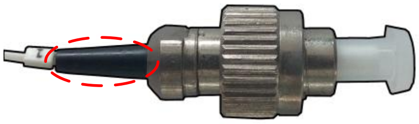


Figure D-4 FC/UPC black label

The protector of the FC/UPC connector is black, as shown in Figure D-4.

2 Usage of FC/APC to FC/UPC Transfer Patch Cord

If the FC/UPC fiber connector is selected, it can be connected to the FC/APC connector via the FC/APC to FC/UPC transfer Patch Cord, as shown in Figure D-5, FC/APC at one end and FC/UPC at the other end.

Figure D-5 FC/APC to FC/UPC jumper

In usage, the FC/APC connector of the fiber patch cord is connected to the BOTDR port of the 6419 distributed optical fiber strain tester while the FC/UPC connector joins the FC/UPC connector of the sensing optical fiber via the flange, as shown in Figure D-6.

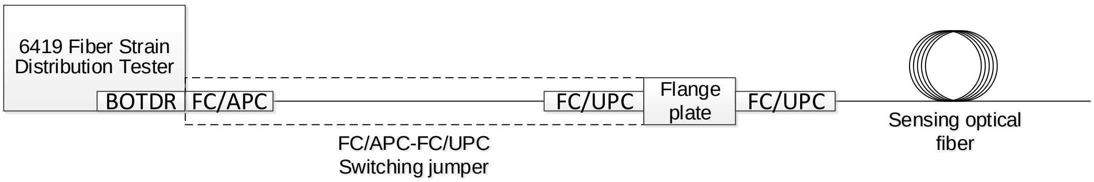


Figure D-6 Jumper connection

Usually, to prevent dust from polluting the flange interior, the two ends of the flange are protected with the protector when it is not in use, as shown in Figure D-7.

Figure D-7 Flange configured with protectors

To connect the flange to the optical fiber, first remove the protectors at both ends of the flange slowly and evenly. Keep hands from the flange interior to prevent pollution to the end face of the connected fiber. The flange without protectors are as shown in Figure D-8.

Figure D-8 Flange without the protector

After the protectors at both ends of the flange are removed, it can be seen that the flange has a nick on each end, as shown in Figure D-9. To connect the FC/UPC connector of the transfer patch cordto one end of the flange, first align the protrusion of the FC/UPC connector and the flange nick, as shown in Figure D-10.

Figure D-9 Flange nick

Figure D-10 Align FC/UPC connector protrusion and flange nick

Then, slowly push the FC/UPC fiber connector into the flange connector. Keep your hands or other body parts from the ceramic core end face of the fiber connector to prevent pollution to the fiber end face. When the protrusion matches with the nick and pushing is unavailable, slowly tighten the connector fillet of screw to fix the FC/UPC connector to the flange, as shown in Figure D-11.

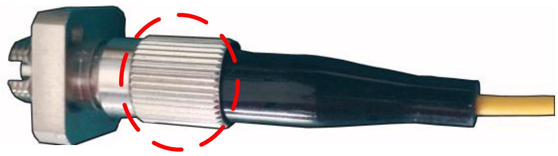


Figure D-11 Fillet of screw of the FC/UPC connector connecting to the flange from one side

As described in the preceding step, connect the FC/UPC connector of the sensing optical fiber to the other connector of the flange. The flange connecting to the FC/UPC connector at both sides is as shown in Figure D-12.

Figure D-12 Flange connecting to the FC/UPC connector at both sides

3 Usage of FC/APC-FC/UPC Extension Patch Cord

In the optical fiber test, if the FC/APC connector fails to be connected to the 6419 optical fiber connector due to insufficient length, the FC/APC-FC/APC extension patch cord is required. The FC/APC-FC/APC extension patch cord is as shown in Figure D-13, with the FC/APC connector at both ends.

Figure D-13 FC/APC-FC/APC extension jumper

In usage, one FC/APC connector of the fiber patch cord is connected to the BOTDR port of the 6419 distributed optical fiber strain tester while the other FC/APC connector joins the FC/APC connector of the sensing optical fiber via the flange, as shown in Figure D-14. For details about how to connect the optical fiber connector to the flange, see chapter 1 "FC/APC and FC/UPC Optical Fiber Connector" in Appendix D "Identification of FC/APC from FC/UPC and Jumper Connection."

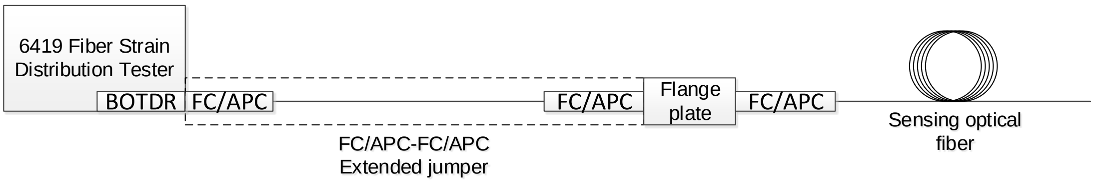


Figure D-14 Extension of the optical fiber jumper

Appendix E Maintenance and Cleaning of the Optical Output Port

1 Maintenance of the Optical Output Port

(1) **Be sure to keep the optical output port clean.** Once it is polluted, plenty of optical signals will lose, affecting the test. If it is polluted by dust for a long time, it will cause wear to the end face and result in permanent damage. Therefore, **the optical output port needs to be cleaned regularly with anhydrous alcohol.**

(2) **Be sure to clean the flange connector of the optical output port.** If the flange connector is polluted, the test results will be affected. It may even pollute the fiber end face of the optical output port, affecting the test results and even causing permanent damage to the fiber end face.

(3) **After BOTDR and VFL optical ports are used, cover them with the dust-proof protective cover that also needs to be cleaned regularly.** Keep them not in air for a long time to prevent the dust in the air from the fiber end face of the optical port; otherwise, the fiber end face may be polluted, causing wear to the end face and even permanent damage. In particular, in a working environment with heavy dust, frequent cleaning is more required.

(4) If the fiber connector needs to be frequently pushed on to and pulled off from the BOTDR port, you are recommended to **use the FC/APC-FC/APC patch cord as the extension cord**. One end of the extension cord is connected to the BOTDR port while the other end is connected to the FC/APC connector of the sensing optical fiber via the flange, as shown in Figure E-1, to avoid damage to the optical port from frequent pushing on and pulling off the optical fiber connector, and even permanent damage. For details about how to use the FC/APC-FC/APC extension patch cord, **see section 3 "Usage of FC/APC-FC/APC Extension patch cord" in Appendix D "Identification of FC/APC from FC/UPC and patch cord Connection."**

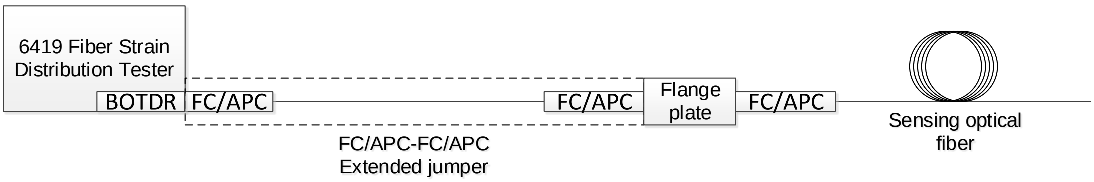


Figure E-1 Protecting 6419 optical port with the fiber extension cord

2 Cleaning of the Optical Output Port

(1) Roles of cleaning the fiber connector and optical output port

1. As the fiber core is very small, the dust and particulate matters attached to the fiber connector and optical output port may cover some part of the fiber core at the output port, deteriorating the instrument performance.
2. The dust and particulate matters may cause damage to the end face of the fiber connector at the output port, thus deteriorating the accuracy and repeatability of the instrument.

(2) Security principles to be followed before cleaning

1. Ensure that the instrument is powered off before cleaning.
2. Non-compliance with the regulated control, adjustment or operation steps may cause dangerous radiation injury.

1. Ensure that the laser source is in the non-working state when any of the optical port is being cleaned.
2. When the instrument is working, please do not look steadily at any optical output port to avoid damage to your eyes.

(3) Tools used to clean the optical output port and connector

3. You can use tools like the fiber cleaner or cleaning swab to clean the optical output port and connector.
4. If the preceding professional tools are unavailable, please prepare the absorbent ball and anhydrous alcohol.

(4) Steps for cleaning the optical output port and connector

5. Power off the instrument.
6. Entirely unscrew the flange nut.
7. Gently pull out the flange, as shown in Figure E-2.

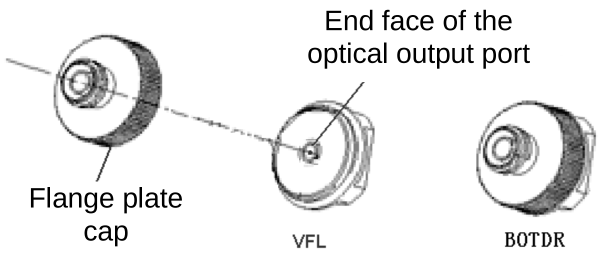


Figure E-2 Pulling out the flange

8. Clean the end face of the optical output port and flange connector with the absorbent ball dipped in anhydrous alcohol.
9. Gently wipe the end face of the optical output port with the professional lens paper.
10. After cleaning, gently connect the flange nut to the optical output port and then screw the flange nut.

Caution!

(1) Pull out and connect the flange slowly and evenly without sudden force, thus avoiding damage to the end face of the optical output port.

(2) Gently wipe the fiber end face to avoid damage to it.

(3) During cleaning, keep the absorbent ball and anhydrous alcohol clean; otherwise, the fiber end face will be polluted, causing test inaccuracy.

Appendix F Maintenance, Check, and Cleaning of the Fiber End Face

1 Introduction to the Structure of the Fiber End Face

An optical fiber is a kind of optical waveguide with a cylindrical cross section, made from silicon dioxide and a small amount of other materials. The guiding of light of the light-guide fiber is designed according to the light total reflection principle. The transmission of the light energy is confined in the fiber transmission interface so that the optical wave can be transmitted only in the fiber axial direction.

Taking the standard fiber SMF-28e for example, it consists of a core surrounded by a cladding layer and coating layer. The fiber core is made from silica (glass) with a 9 um diameter; the cladding layer is made from silica with a 125um diameter; the coating layer is made from ceramics with a 0.9mm diameter. Figure F-1 shows the fiber axial cross section and figure F-2 shows the fiber radial cross section.

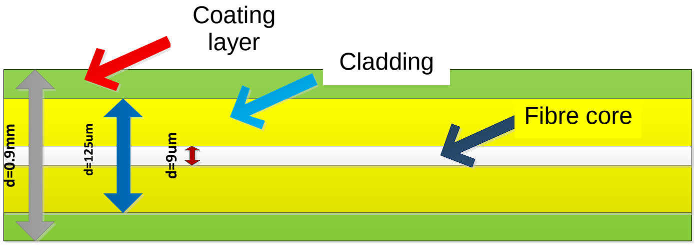


Figure F-1 Fiber axial cross section

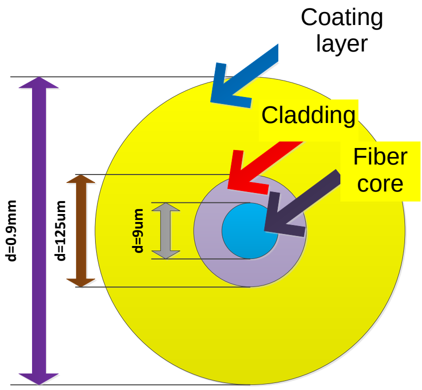


Figure F-2 Fiber radial cross section

2 Maintenance of the Fiber End Face

Handle the fiber connector with care and hold the metal of the fiber connector, as shown in Figure F-3. Check whether the port type matches before inserting the fiber connector into the port. Mismatched port type will cause pollution or permanent damage to the fiber end face. Keep the fiber connector covered with a protector when it is not in use, avoiding pollution to the joint.

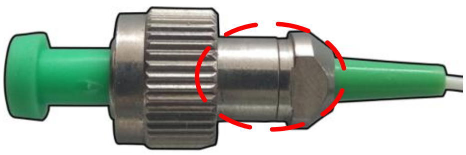


Figure F-3 Metal of the fiber connector

3 Check of the Fiber End Face

In case of non-distinct Brillouin spectrum and non-obvious loss curve, the fiber end face may be polluted and then you need to check it. Figure F-4 shows the fiber end-face inspector required to check the fiber end face. It is an option of the 6419 distributed optical fiber strain tester, with the No. of 001.

Figure F-4 Fiber end-face inspector

Step 1 Connect the fiber connector to the port on the bottom of the inspector, as shown in Figure F-5. This port supports the FC-APC and FC-UPC connectors.

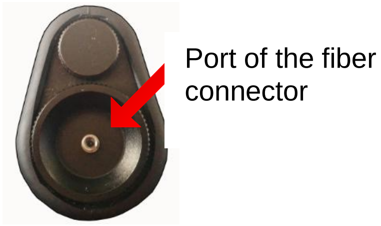


Figure F-5 Port position of the fiber connector

Step 2 Put your eyes in the sight glass in the head of the inspector and keep your eyes close to the glass.

Figure F-6 Position of the sight glass

Step 3 Press and hold the power switch as shown in Figure F-7 and simultaneously rotate the spiral slowly to focus the inspector as shown in Figure F-8 until the clear end face can be seen.

Figure F-7 Position of the power switch

Figure F-8 Position of the spiral

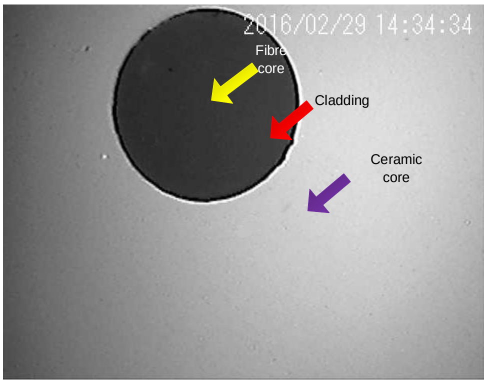


Figure F-9 Image of a clear fiber connector

As shown in Figure F-9, the optical fiber consists of the core, cladding layer, and ceramic core from the inside out. The fiber core ensures total internal reflection of light and transmits energy. Once it is polluted, light transmission is blocked, resulting in non-obvious loss curve and non-distinct Brillouin spectrum. Serious pollution can cause energy concentration and heating at the fiber end face, resulting in fiber connector burnt that is permanent damage.

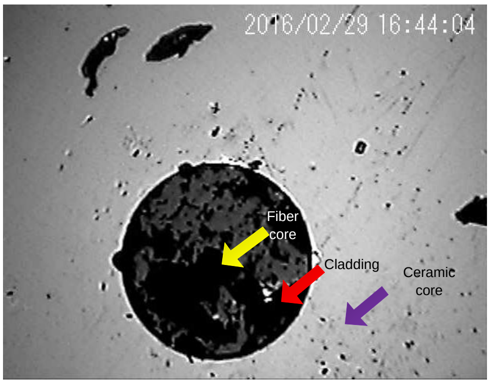


Figure F-10 Image of the fiber connector seriously polluted

As shown in Figure F-10, a lot of gray contaminants gather on the fiber core and cladding layer. The ceramic core is attached with black contaminants. This condition is regarded as serious pollution and cleaning of the fiber end face is required.

4 Cleaning of the Fiber End Face

To clean the fiber end face, prepare the absorbent cotton (as shown in Figure F-11 (a)), alcohol (as shown in Figure F-11 (b)), and lens paper (as shown in Figure F-11 (c)).

(A) Absorbent cotton (b) Alcohol (c) Lens paper

Figure F-11 Tools required to clean the fiber end face

Step 1 Wipe the fiber connector with the absorbent cotton dipped in the alcohol slowly and evenly, as shown in Figure F-12.

Figure F-12 Wipe the fiber connector with alcohol swab

Step 2 Rub the fiber connector at the lens paper horizontally. Do not repeat rubbing the fiber connector at the lens paper used, avoiding secondary contamination to the fiber connector, as shown in Figure F-13.

Figure F-13 Wipe the fiber connector with lens paper

Step 3 Check the fiber end face with the fiber end-face inspector. If there are still foreign matters, continue to rub it. If the foreign matters cannot be removed after repeated rubbing, it is believed that the fiber connector is damaged and needs to be replaced.

Appendix G Check and Handling of Optical Fiber Break

1 Check of Optical Fiber Break

1.1 Check of Optical Fiber Break with BOTDR

We can check whether the optical fiber breaks by measuring the fiber length.

1.1.1 Method 1

Step 1 Connect the fiber to the fiber port and set the appropriate range, pulse width, resolution, and refractive index.

Step 2 Press [Test] on the front panel and click Average to start the test.

Step 3 Choose Multi > Loss, as shown in Figure G-1.

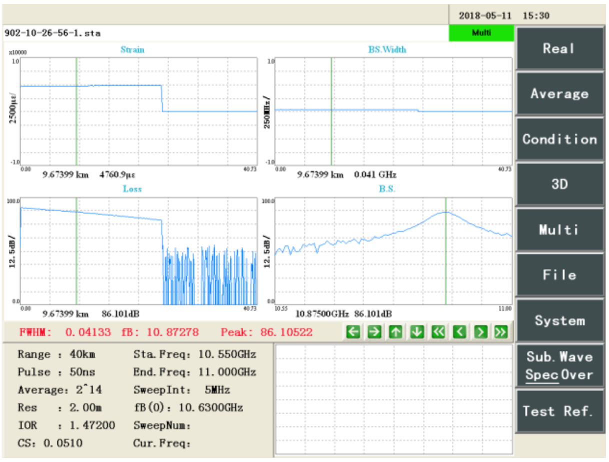


Figure G-1 Multi window

Step 4 In the Loss window, it can be seen that the loss curve drops in a certain area. Move the cursor to this area and press on the front panel to zoom in this area.

Step 5 Slowly rotate the knob on the front panel in a clockwise direction. It can be seen that the Brillouin spectrum gradually becomes non-distinct (as shown in Figure G-2) and disappears suddenly after a certain point as shown in Figure G-3. This point can be regarded as the fiber end, located at the distance of 24.59231 km.

Step 6 Check whether the fiber breaks and the break position by comparing the nominal length and measured length of the fiber. If the nominal length equals the measured length, the fiber does not break; if the measured length is less than the nominal length, the fiber already breaks and the break takes place where the measured length is obtained.

Figure G-2 Comprehensive loss curve of the fiber under test

Figure G-3 Brillouin spectrum disappears after crossing a certain point

1.1.2 Method 2

Step 1 Connect the fiber to the fiber port and set the appropriate range, pulse width, resolution, and refractive index.

Step 2 Press [Test] on the front panel and click Average to start the test.

Step 3 Choose Multi > BS. Width. In the BS. Width window, it can be seen that the loss curve drops in a certain area. Move the cursor to this area and press ▶ on the front panel to zoom in this area.

Step 4 Slowly rotate the knob on the front panel in a clockwise direction. It can be seen that the Brillouin spectrum gradually becomes non-distinct and disappears suddenly after a certain point as shown in Figure G-4. This point can be regarded as the fiber end, located at the distance of 24.64323km.

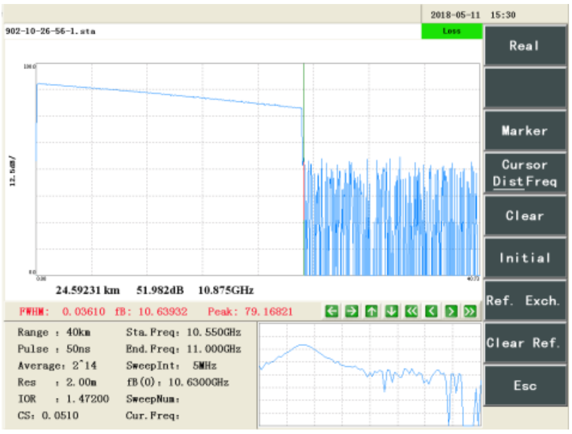


Figure G-4 Loss curve of the fiber to be tested

Figure G-5 Disappearing Brillouin spectrum after a certain point

Step 5 Check whether the fiber breaks and the break position by comparing the nominal length and measured length of the fiber. If the nominal length equals the measured length, the fiber does not break; if the measured length is less than the nominal length, the fiber already breaks and the break takes place where the measured length is obtained.

1.2 Check of Optical Fiber Break and High-loss Point via VFL

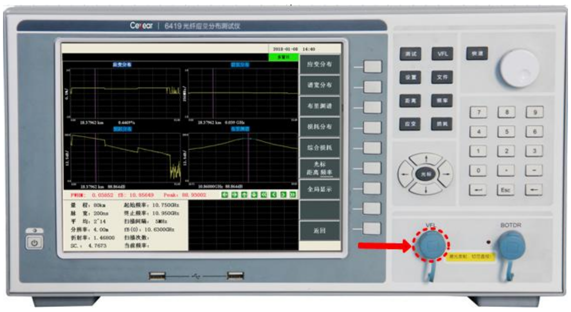


Figure G-6 VFL interface with protector

The 6419 has a built-in visible red light fault location (VFL) function that can help determine where the fiber breaks and where the light energy leaks.

Step 1 Connect the fiber to be tested to the VFL optical port on the front panel as shown in Figure G-6. For details about the connection, see section 8.1.2 “Connecting the Fiber.”

Step 2 Select the [VFL] function button in the system sub-menu (or click the VFL button on the front panel) and the software will pop out the VFL control window. As shown in Figure G-7, it contains four options: OFF, CW, 1Hz, and 2Hz. The mouse or touch screen adjusts the working state of the VFL.

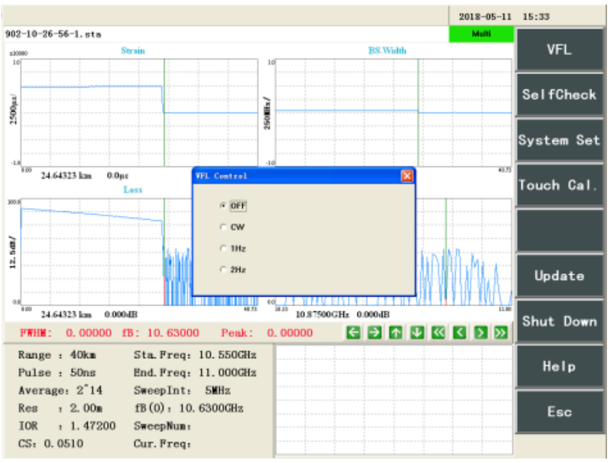


Figure G-7 VFL Control dialog box

Step 3 Set the VFL function in the VFL window according to the needs. Select the [CW] option, the instrument will output continuous visible red light in the VFL optical interface; select [1Hz] option, the instrument will output the visible red light with a frequency of 1Hz in the VFL optical interface; select [2Hz] option, the instrument will output the visible red light with a frequency of 2Hz in the VFL optical interface.

Step 4 Check the optical fiber line and fiber end. If there is no red light at the fiber end but vast red light leaked at a certain point of the fiber line, check whether the fiber breaks at the leaking point, as shown in Figure G-8, or a small-radius bend appears as shown in Figure G-9.

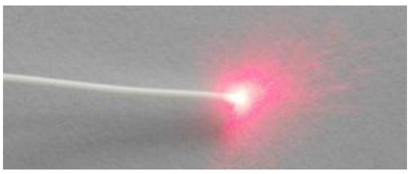


Figure G-8 Fiber with light leakage

Figure G-9 Fiber with a large bending radius

Step 5 After the VFL function is used, set the VFL option to [OFF] in the VFL window to disable the VFL function.

Step 6 Remove the fiber under test from the VFL optical interface and cover the VFL optical interface protection cover.

2 Handling of Optical Fiber Break

The broken fiber needs to be spliced with the optical fiber fusion splicer. **You are recommended to use the 6471A multi-functional optical fiber fusion splicer manufactured by China Electronics Technology Instruments Co., Ltd (CETI). For details about the parameters and introduction, see section 1.2 "6471A Multi-functional Optical Fiber Fusion Splicer" in Appendix H "Recommended Optical Cable Laying, Maintenance, and Testing Tools."** For details about the splicing procedures, see the *User Manual of 6471A Multi-functional Optical Fiber Fusion Splicer*.

After splicing, measure the fiber length by referring to section 1.1 "Check of Optical Fiber Break with BOTDR" in Appendix G "Check and Handling of Optical Fiber Break." If the measured fiber length equals the nominal length, it proves that splicing is good. Alternatively, test the fiber by referring to section 1.2 "Check of Optical Fiber Break and High-loss Point via VFL" in Appendix G "Check and Handling of Optical Fiber Break." If there is no red light leakage at the splicing point, it proves that splicing is good.

Appendix H Recommended Tools for Cable Laying, Maintenance and Testing

1 6416/6418 Optical Time Domain Reflectometer

Figure H-1 6416/6418 high-performance multi-functional optical time domain reflectometer

The 6416/6418 optical time domain reflectometer is mainly used to measure the physical characteristics of optical fiber & cables, including length, transmission loss, and splice loss. It can also accurately locate the event point and fault point along the optical fiber. It is widely used in fiber optic communications, engineering construction, maintenance test, and urgent repairing of the optical fiber sensing system, as well as the R&D, manufacturing, and test of the optical fiber and cables.

Main Features:

1. Single-ended non-destructive testing;
2. Most advanced technology of double color and two materials integrative mold design process, strong and firm;
3. Advanced anti-reflection LCD display providing a quite clear operation interface even in field environment;
4. Multiple testing modes, touch screen and keyboard operation;
5. Automatic detection of the communication light;
6. Two USB interfaces allowing connecting externally to a USB flash drive and printer, and communicating with a PC via the SyncActive software;
7. Supporting Bellcore GR196 and SR-4731 file formats;
8. Battery low-voltage alarm;
9. Built-in the VFL function and optical power meter (only 6418);
10. Exchangeable OTDR optical output connector, more convenient for surface cleaning;
11. On-line upgrading of application software, no need to return back to the manufacturer.

Technical Specifications:

	6416	6418
Dynamic range	28dB to 35dB	35dB to 45dB
Ranging accuracy	± (0.75m + Sampling spacing + 0.0025% × Distance)(excluding refractive index placement error)	
Highest ranging resolution	0.125m	0.05m
Test range	0.5km to 256km (single-mode) 0.5km to 32km (850nm multimode)	0.4km to 512km (single-mode) 0.4km to 32km (850nm multimode)
Test pulse width	10ns to 10,240ns (single-mode) 10ns to 1,280nm (multimode)	5ns to 20,480ns (single-mode) 5ns to 1,280nm (multimode)
Number of sampling points	128k	256k
Linearity	0.05dB/dB	
Refractive index setting range	1.00000 to 2.00000 (step 0.00001)	

VFL	650nm ± 10nm, 2mW (typical), CW/1Hz	
Optical power meter	None	Wavelength range: 1,200nm to 1,650nm Power range: -60dBm to 0dBm Test uncertainty: ± 5% (-25dBm, CW)
Optical output port	FC/UPC (can be changed to ST/UPC or SC/UPC)	
External interface	USB or Min-USB	USB, Min-USB, Ethernet, headset, and SD
Power supply	AC/DC adapter: AC 100V to 240V, 50/60Hz, 1.5A DC: 19V ± 2V (2A) Built-in lithium battery: Working hours: 8 hours (normal temperature)	
Maximum power consumption	5W	10W
Dimension (width x height x depth)	210mm × 100mm × 60mm	186mm × 295mm × 75mm
Weight	About 0.9kg	About 2.2kg
Environmental adaptability	Operating temperature: -5℃ to 50℃ (battery charging: 5℃ to 40℃) Storage temperature: -40℃ to 70℃ (battery: -20℃ to 60℃) Relative humidity: 5% to 95% (noncondensing)	

2 6471A Multi-functional Optical Fiber Fusion Splicer

Figure H-2 6471A multi-functional optical fiber fusion splicer

The 6471A multi-functional optical fiber fusion splicer is a newly designed optical fiber fusion splicer. It is specifically used for fiber splicing under the FTTH environment. With compact structure and exquisite design, it is easy to operate even in confined space. The optical imaging system and full-digital design make the image display clear and exquisite. The embedded real-time operating system provides friendly operation interface and multiple functions. The built-in high capacity lithium battery guarantees long-time field operation. The temperature and air pressure real-time compensation system greatly improves the ability against the hostile external environment, , and thus ensures the consistency of low-loss splicing in different environments.

Main Features:

12. Precise alignment of fiber cores to ensure the low-loss splicing.
13. Small size and light weight with only 2.8kg including the battery.
14. Nine-second splicing and 30-second heat shrink.
15. Simultaneous display of the x-axis and y-axis, 304 times of magnification.
16. Can be set to automatically start splicing once closing the windshield, and automatically start pyrocondensation once closing the heating cover.
17. Real-time discharging correction, no need to adjust the parameters.

18. Long lifetime of electrode, discharging up to 4,000 times.
19. USB and VGA port.
20. Built-in high capability lithium battery, supporting 220 splicings and heatings.
21. Real-time accurate display of remaining battery capability.
22. Automatic software upgrading via the USB flash drive.

Technical Specifications:

Optical fiber type	SM (single-mode), MM (multi-mode), DS (dispersion shifted), and NZDS (dispersion unshifted)	
Splicing loss	0.02dB (SM), 0.01dB (MM), 0.04dB (DS), and 0.04dB (NZDS)	
Return loss	Better than 60dB	
Operation mode	Full-automatic, semi-automatic, and manual	
Fiber alignment	Advanced PAS aligning	
Applicable fibers	Terminal flexible optical cable, SC or FC connector (optional), and 0.25mm or 0.9mm ordinary optical cable	
Cleave length	8mm to 16mm	
Magnification	304/152 times	
Image display	High-performance 5.7-inch LCD providing clear and exquisite image display	
Tension test	Standard 2N (optional)	
Heat shrink tubing	60mm, 40mm, and a series of heat shrink tubing	
Battery capacity	Typical 220 splices, charging about 3.5 hours (available during charging)	
Electrode life	Cycle charging up to 300 to 500 times, can be replaced by the user	
Construction lighting	Built-in high-brightness and wide-range lamp, greatly facilitating night operations	
Power supply	Built-in lithium battery 11.1V; external adapter; input: AC 100 to 240V; output: DC 13.5V/4.5A	
Working environment	Temperature: -10 to +50℃; humidity: 95% RH (40℃, noncondensing); altitude: 0 to 5000m	
Weight	2.3kg (without battery); 2.8kg (with battery)	
Operation interface	Chinese/English	
Dimensions (width x height x depth)	160mm*150mm*140mm	
Maximum power	≤ 20W (without charging); ≤ 55W (with charging)	
DC internal power	Service time (23℃ ± 2℃)	≥4h (continuous operation); ≥10h (standby)
	Charging time	≤ 3.5h (power-off): ≤ 4.5h (power-on)
DC external power (external power adapter)	Input	100V to 240V, 50/60Hz
	Output	13V to 14V, ≥ 4.4A, power plug center as the positive pole
	Leakage current	220V input voltage, leakage current ≤ 3.5mA