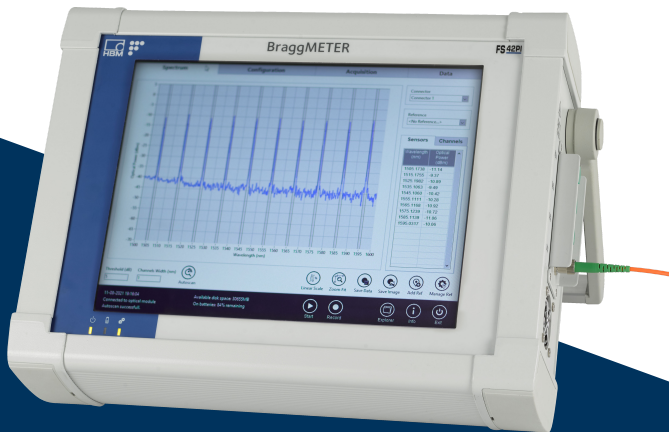


ENGLISH

# Operating Manual



## FS42PI Portable BraggMETER

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Subject to modifications.  
All product descriptions are for general information  
only. They are not to be understood as a guarantee of  
quality or durability.

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# 1 GENERAL DETAILS

## 1.1 General Information

The HBK FiberSensing Portable BraggMETER PI is a continuous swept laser scanning interrogator designed to interrogate Fiber Bragg Grating (FBG) sensors.

The interrogator includes a NIST traceable wavelength reference that provides continuous calibration to ensure system accuracy over long term operation. The high dynamic range and high output power allows high resolution to be attained even for long fiber leads and lossy connections.

The 4 available optical channels make this interrogator particularly suitable for large scale sensing networks, acquiring a large number of sensors, providing an acquisition rate of 1S/s with less than 0.5 pm resolution.

This Manual applies to the following equipment:

1-FS42PI-4FC	FS42PI Portable BraggMETER 4OC FC/APC
1-FS42PI-4SC	FS42PI Portable BraggMETER 4OC SC/APC

## 1.2 System Components

The Portable BraggMETER PI set includes:

Quantity	Description
1	Interrogator, including Windows 10 IoT and BraggMONITOR PI software
4	International power cords (EU, US, UK, Aust/NZ)
1	Power adapter
1	Protection and carrying bag
1	Battery pack (model: RRC2054-2S)
1	Extra fan filter 40x40 mm
1	User manual / Quick guide
1	Calibration certificate

## 1.3 Wear Parts

HBK Optical Interrogators have wear parts (such as ventilation fans, optical connector adapters and batteries) that require minimum running conditions to ensure a correct operation of the equipment.

Wear parts are covered by a limited warranty as they are components that depend on the usage and on the environmental conditions the equipment operates in, such as humidity, temperature, and dust.

#### **1.4 Before using FS42PI - Portable Interrogator PI**

Before using FS42PI Portable Interrogator please read the following warning notes:

- The FS42PI - Portable Interrogator PI is an acquisition device that operates on batteries. Before removing or changing the battery pack, as well as charging the batteries with a third-party cable, carefully read the user manual for instructions.
- A battery level below 10 % will compromise the correct start-up of the interrogator. Ensure that there is the minimum battery level or that the interrogator is plugged in before starting the equipment.
- It is not recommended to charge the batteries at environmental temperature above 35° C [95° F].
- Remove the battery pack fully charged before long periods of inactivity (more than 4 weeks).
- Pointing on the touch screen with sharp objects might cause irreversible damage to the touch screen.
- The optical interrogator operating system is Windows 10 IoT. If the customer intends to use the Windows 10 functions, there is the need to connect regular pc accessories (keyboard and mouse) through the USB interfaces. Alternatively, the Windows On Screen Keyboard will start-up with the interrogator by default.

## 2 REGULATORY AND CERTIFICATION CONSIDERATIONS

### 2.1 Environment Considerations

#### 2.1.1 Disposal of your Old Appliance



When the attached symbol combination - crossed-out wheeled bin and solid bar symbol is attached to a product it means the product is covered by the European Directive 2002/96/EC and is applicable in the European Union and other countries with separate collection systems. All electrical and electronic products should be disposed of separately from the municipal waste stream or household via designated collection facilities appointed by the government or the local authorities. The correct disposal of your old appliance will help prevent potential negative consequences for the environment and human health.

For more detailed information about disposal of your old appliance, please contact your city office, waste disposal service or distributor that purchased the product. HBK FiberSensing is a manufacturer registered in the ANREEE - "Associação Nacional para o Registo de Equipamentos Eléctricos e Electrónicos" under number PT001434. HBK FiberSensing celebrated a "Utente" type contract with Amb3E - "Associação Portuguesa de Gestão de Resíduos de Equipamentos Eléctricos e Electrónicos", which ensures the transfer of Electrical and Electronic appliance waste management, i.e. placing Electronic and Electrical appliances in the Portuguese market, from the manufacturer HBK FiberSensing to Amb3E.

### 2.2 Laser Safety

The FS42PI - Portable BraggMETER PI interrogator contains a laser in its core. A laser is a light source that can be dangerous to people exposed to it. Even low power lasers can be hazardous to a person's eyesight. The coherence and low divergence of laser light means that it can be focused by the eye into an extremely small spot on the retina, resulting in localized burning and permanent damage.

The lasers are classified by wavelength and maximum output power into the several safety classes: Class 1, Class 1M, Class 2, Class 2M, Class 3R and Class 4.

## 2.2.1 Symbols

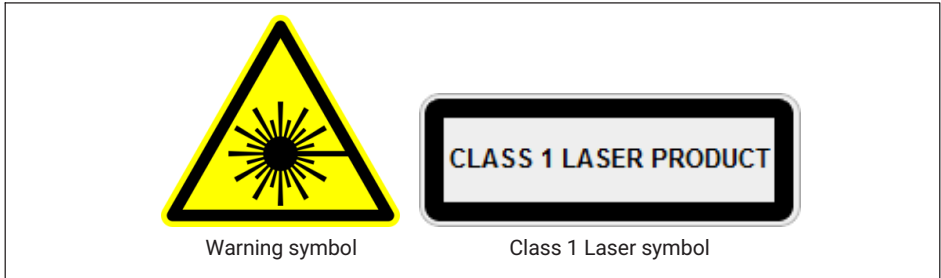


Fig. 2.1 Laser symbols used

## 2.2.2 Class 1 Laser

The FS42PI Portable BraggMETER Interrogator is a Class 1 laser product: «Any laser or laser system containing a laser that cannot emit laser radiation at levels that are known to cause eye or skin injury during normal operation.» It is safe under all conditions of normal use. No safety requirements are needed to use Class 1 laser devices.

Laser Safety	
Laser Type	Fiber Laser
Laser Class (IEC 60825-1)	1
Typical Output Power per channel	≈ 0.3 mW (-5 dBm)
Max Output Power per channel	≈ 0.5 mW (-3 dBm)
Wavelength	1500-1600 nm

## 2.2.3 General Precautions Considerations

Everyone who uses a laser equipment should be aware of the risks. The laser radiation is not visible to the human eye but it can damage user's eyesight. The laser is enabled when the interrogator is turned on.

Users should never put their eyes at the level of the horizontal plane of the optical adapters of the interrogator or uncovered optical connectors. Adequate eye protection should always be required if there is a significant risk for eye injury. When an optical channel is not in use (no optical connector plugged to the interrogator), a proper connector cap must be used. The optical connectors are subjected to maintenance and/or inspection. Please refer to *section 4.3 "Common Measuring Difficulties", page 30* for maintenance procedure.

Do not attempt to open or repair a malfunction interrogator. It must be returned to HBK for repair and calibration.



## 2.3 Certification

This product carries the CE marking and complies with the applicable international requirements for product safety and electromagnetic compatibility, according to the following Directives:

- Low Voltage Directive (LVD) 2014/35/EU - Electrical Safety
- Electromagnetic Compatibility (EMC) Directive 2014/30/EU

It is in compliance with the EN61326/EN55011 Emission Radiated Test Class A, under the Electromagnetic Compatibility Standard.

The corresponding Declaration of Conformity is available upon request.

### 2.3.1 CE Marking



This product carries the CE marking and complies with the applicable international requirements for product safety and electromagnetic compatibility, according to the following Directives: EMC (2014/30/EU) and ROHS (2011/65/EU + (EU) 2015/863). The corresponding Declaration of Conformity is available upon request.






### 2.3.2 UKCA Marking



This product carries the UKCA marking and complies with the applicable international requirements for product safety and electromagnetic compatibility, according to the following Directives: EMC (Electromagnetic Compatibility Regulation 2016, No. 1091) and ROHS (The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulation 2012, No. 3032). The corresponding Declaration of Conformity is available upon request.

## 2.4 Marking Used in this Document

Important instructions for your safety are specifically identified. It is essential to follow these instructions in order to prevent accidents and damage to property.

Symbol	Significance
 <b>CAUTION</b>	This marking warns of a <i>potentially</i> dangerous situation in which failure to comply with safety requirements <i>can</i> result in slight or moderate physical injury.
<b>Notice</b>	This marking draws your attention to a situation in which failure to comply with safety requirements <i>can</i> lead to damage to property.
 <b>Important</b>	This marking draws your attention to <i>important</i> information about the product or about handling the product.
 <b>Tip</b>	This marking indicates application tips or other information that is useful to you.
 <b>Information</b>	This marking draws your attention to information about the product or about handling the product.
<i>Emphasis</i> See ...	Italics are used to emphasize and highlight text and identify references to sections, diagrams, or external documents and files.
	This marking indicates an action in a procedure.

## 3 OPERATION

### 3.1 Connectors

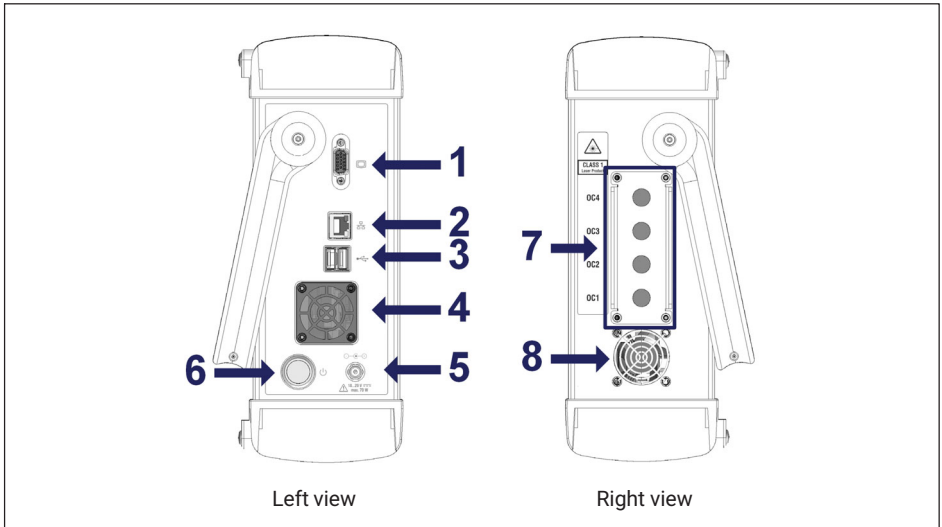


Fig. 3.1 Left and right views from FS42PI

The connectors and buttons in Fig. 3.1 are:

- 1 VGA connector (for connecting an external monitor)
- 2 LAN connector
- 3 USB connector (2 x)
- 4 Air intake fan with filter
- 5 Power connector
- 6 ON/OFF button
- 7 Optical connectors detachable panel (FC/APC or SC/APC connectors)
- 8 Air exit fan

### 3.2 Status Indicators

On the bottom of the screen panel the user can find three indicators. Number 1 on Fig. 3.2 refers to the power status of the equipment, number 2 refers to the battery status and number 3 refers to the optical module status.

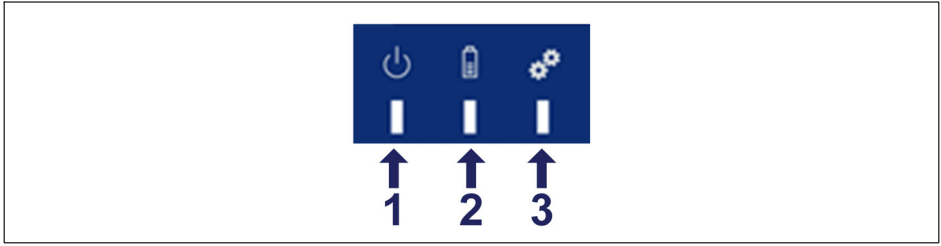






Fig. 3.2 Status indicators

Number 1 and number 3 in Fig. 3.2 can only assume one color. When led 1 is green the interrogator is powered on and when led 3 is green the optical module is ready to start reading the optical sensors connected.

The battery status (Led number 2 in Fig. 3.2) assumes different colors depending on charge level, according to the following table.

Battery LED		
	Solid green	Charge level > 15 %
	Solid red	Charge level > 7 %
	3x blink red	Charge level < 7 % and not plugged in
	Blinking red	No batteries or battery error

 **Important**

*The device will shut down via Windows when battery level goes below 7 %. There will be a hard power outage when battery level reaches 5%.*

### 3.3 Power Supply

The interrogator must be used with a dedicated power supply source and not shared with other equipment when powering with a direct source and not with the power adapter.

### 3.4 Switching ON

Pressing the "ON/OFF" button (see in Fig. 3.1 on page 11) for a minimum of 200 and a maximum of 1500 milliseconds will start the engine. The interrogator software will be automatically launched.

#### **i** Information

*When switching the device on, the battery LED will update to indicate that the startup process has initiated. Please be patient as the monitor may take some time to turn on while the device powers up.*

To connect fiber Bragg grating based sensors to the Portable BraggMETER PI FC/APC or SC/APC connectors must be used (see in Fig. 3.1 on page 11). Attention should be paid to the cleaning of the connector. A dirty connector can compromise the measurement and will degrade the interrogator. It is advisable to frequently clean the connectors using appropriate tools.

### 3.5 Switching OFF

To switch off the interrogator proceed in one of the following ways:

1. While running the BraggMONITOR PI software:

▶ Press the **Exit button** (see Fig. 3.3) and confirm the action on the pop-up.



Fig. 3.3 Switching off via software

▶ Alternatively, press and release the **ON/OFF** button (see Fig. 3.4) for a minimum of 200 and a maximum of 1500 milliseconds. A pop-up will appear to confirm the action.

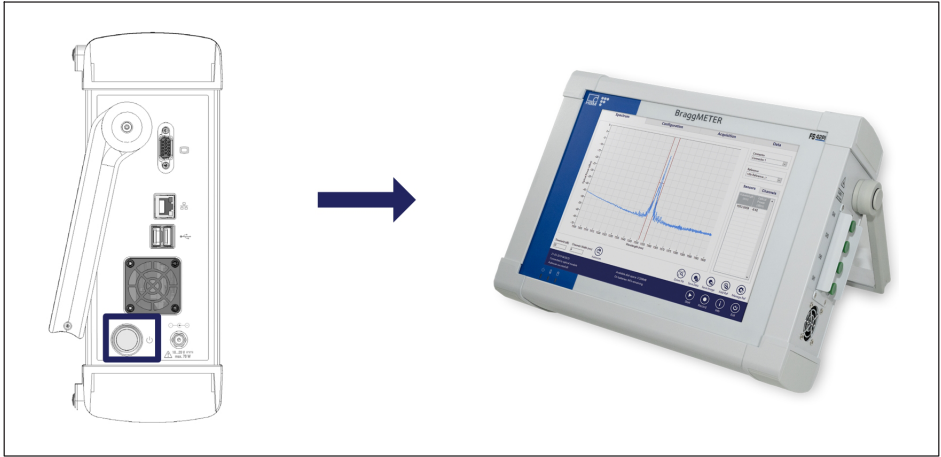


Fig. 3.4 Switching off via hardware

2. While at Windows™ environment:

- ▶ Select the **Windows** button and press **Power > shutdown**.
- ▶ Alternatively, press and release the **ON/OFF** button for a minimum of 200 and a maximum of 1500 milliseconds. A pop-up will appear to confirm the action. To force shutdown of the Interrogator, press the **ON/OFF** button for more than 4 seconds.

#### Notice

*Upon restart the interrogator image will be updated to the factory default. This means that all changes performed under the Windows 10 IoT partition C: will be reverted. To ensure no data is lost, ensure that it is backed up or saved on partition D:. For more details please refer to section 5.1 on page 35.*



#### Important

*If the interrogator is shut down during data recording, unsaved files are saved on the temporary location D:\BraggMONITOR PI Data\temp.*



#### Information

*If the interrogator needs a forced shutdown, press the ON/OFF button continuously until the interrogator powers down. All unsaved data will be lost.*

### 3.6 Protection and Carrying Bag



Fig. 3.5 Protection and carrying bag

To place or remove the protection and carrying bag, proceed as follows:

- ▶ Remove the handle fixation protection cover;
- ▶ With a Torx screw driver 20 unscrew the handle;
- ▶ Remove the handle;
- ▶ Place/Remove the bag from the interrogator;
- ▶ Put back the handle on its place respecting its orientation;
- ▶ Screw the handle.
- ▶ Place back the handle fixation protection cover

### 3.7 Battery Pack

The FS42PI Portable BraggMETER is supplied with a replaceable battery pack located in the back panel of the equipment, identified with a blue rectangle in Fig. 3.6. The used battery pack is a commercially available model (RRC2054-2S) and can be accessed through the back of the interrogator (number 1 in Fig. 3.6).



#### Information

Details on the battery pack can be found on the suppliers' website (<https://www.rrc-ps.-com/en/battery-packs/standard-battery-packs/products/RRC2054-2>).

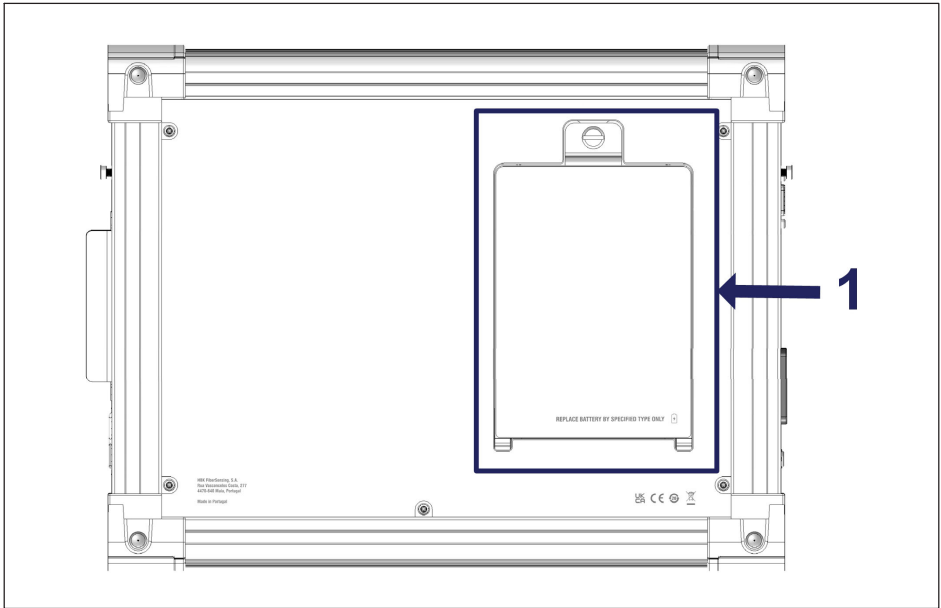


Fig. 3.6 Battery pack cover

Before turning on the Portable BraggMETER PI for the first time, the batteries should be fully charged. Connect the Portable BraggMETER PI directly to 100~240 V power line using the provided 20 V AC adapter. Once the interrogator starts charging, the right side fan (see Fig. 3.1) might start working.

The estimated time to fully charge the battery pack is about 3 hours. The interrogator will last an average of 5 hours continuously running on batteries.



### Information

*The battery is expected to maintain at least 80% of its capacity after 800 loading cycles.*



### Important

*It is advisable to fully recharge and remove the battery pack before periods of inactivity, see chapter 3.7.2 "Removing the Battery Pack". The Battery Pack warranty period is one year. Follow the guidelines and recommendations in this manual to ensure proper operation and maximize durability.*



### 3.7.1 Battery Safety Instructions



#### Information

Please check the battery manual from the original supplier at their website (<https://www.rrc-ps.com/en/battery-packs/standard-battery-packs/products/RRC2054-2>) for further details.

- Do not open or dismantle a battery.
- Do not expose the battery to heat or fire. Avoid storage in direct sunlight.
- Do not short-circuit a battery.
- Do not store the battery haphazardly in a box or drawer where they may short-circuit each other or be short-circuited by other metal objects.
- Do not subject the battery to mechanical shock.
- In the event of a battery leaking, do not allow the liquid to come in contact with the skin or eyes. If contact has been made, wash the affected area with copious amounts of water and seek medical advice.
- Do not use any charger other than that specifically provided for use with the equipment.
- Observe the plus (+) and minus (–) marks on battery and equipment and ensure correct use.
- Keep the battery out of the reach of children.
- Keep the battery clean and dry.
- The battery needs to be charged before use.
- Use only the battery in the application for which it was intended.
- When possible, remove the battery from the equipment when not in use.
- Do not store a battery longer than 1 month in a discharged state.
- Do not storage a battery longer than 1 year without recharge.
- The battery must be recycled or disposed of properly.

### 3.7.2 Removing the Battery Pack

Changing batteries is a simple process that must be performed following the procedure here described, since irreversible damage can be caused due to incorrect use.



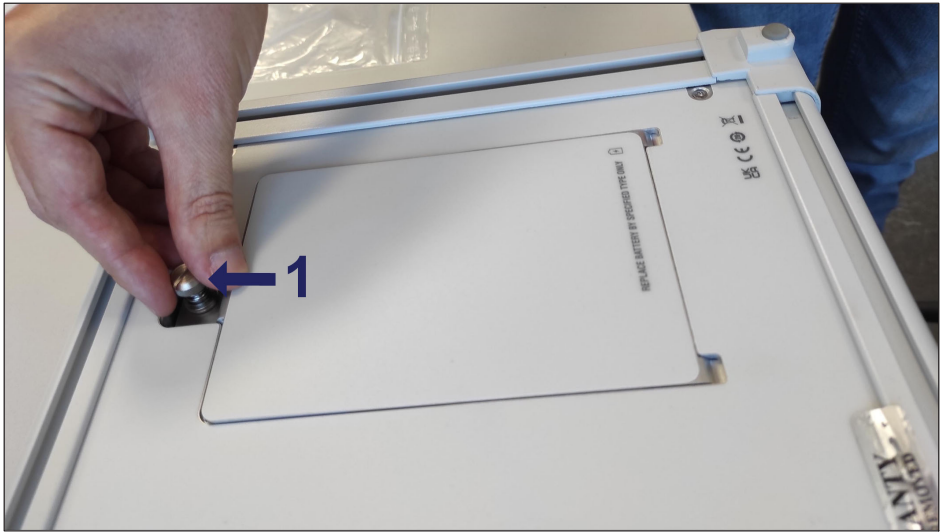
#### Important

*Take the necessary precautions to avoid Electro Static Discharge (ESD).*

To change the batteries, proceed as follows:

- ▶ Shut down the interrogator and wait until the power LED is off.

- ▶ Unplug the power supply cable if connected to the interrogator.
- ▶ Remove the protection bag (see procedure in *section 3.6*).
- ▶ Unscrew the self-clinching fastener counterclockwise (number **1** in *Fig. 3.7*).



*Fig. 3.7 Unscrew the securing pin for cover removal*

- ▶ Lift the cover, tilting over the bottom length as shown on number **1** in *Fig. 3.8*, and pull it out (number **2** in *Fig. 3.8*)

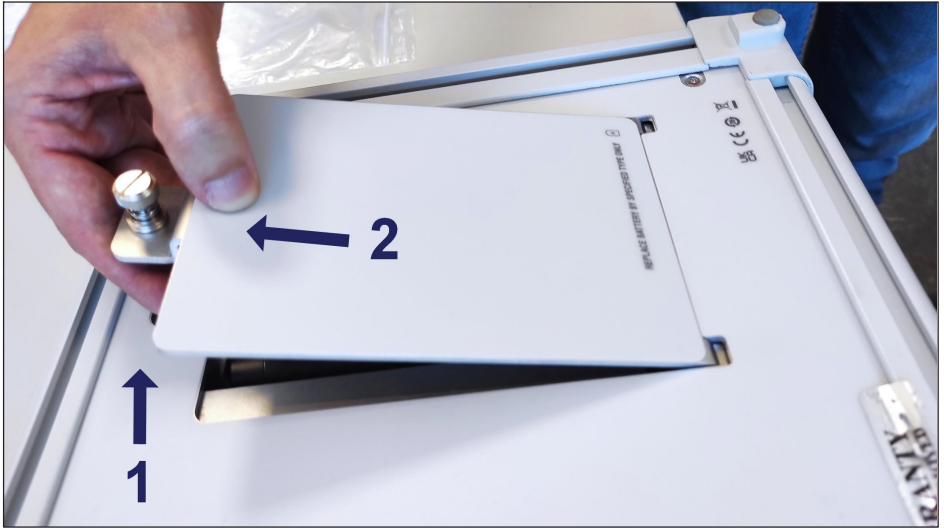


Fig. 3.8 Removing the battery cover

- Use the Pull-out flap of the battery pack to easily lift it for removal (number 1 in Fig. 3.9)



Fig. 3.9 Removing the battery pack

### 3.7.3 Connecting the Battery Pack



#### Important

Make sure the interrogator is switched off before placing the batteries.

To connect a battery pack, proceed as follows:

- ▶ Align the Battery Pack in the Back Panel slot, as in Fig. 3.10.



Fig. 3.10 Aligning the battery pack

- ▶ Ensure the pull-out flap is below the lock holder, to give access to the securing pin.



Fig. 3.11 Positioning the pull-out flap

- ▶ Reinsert the lid by sliding it to the bottom (number **1** in Fig. 3.12), press it down to place (number **2** in Fig. 3.12), and secure it by screwing the locking pin (number **3** in Fig. 3.12).

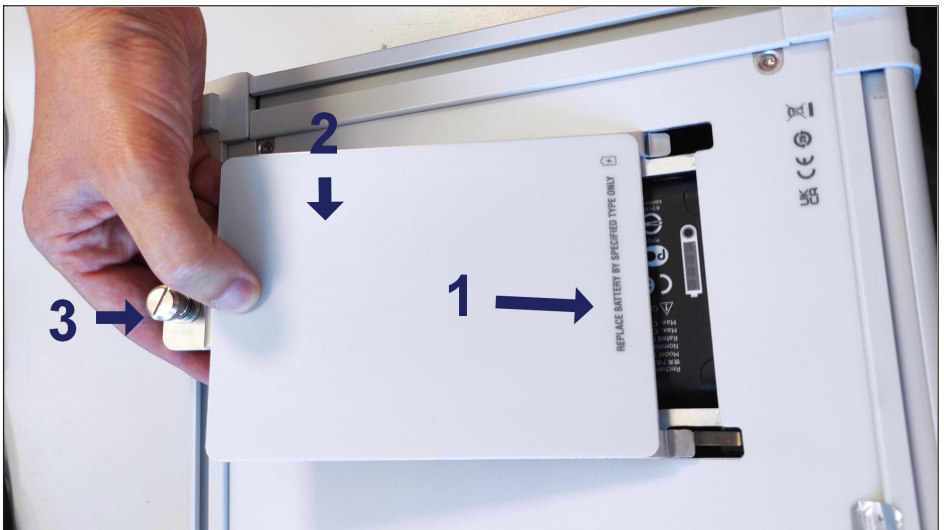


Fig. 3.12 Closing the battery pack lid

### 3.8 Touch Screen Calibration

If a cover is applied to the FS42PI touch screen, it might be necessary to repeat the calibration of the touch screen by following the next procedure:

- ▶ Go to Windows start menu (**1** in Fig. 3.13) and under eGalaxy Touch folder, press **Configure Utility** (**2** in Fig. 3.13);



Fig. 3.13 Selecting eGalaxy Touch

- ▶ After loading the utility, select the tab **Tools** (**3** in Fig. 3.14) and then press the **4 Points Calibration** button (**4** in Fig. 3.14) to start the screen calibration.

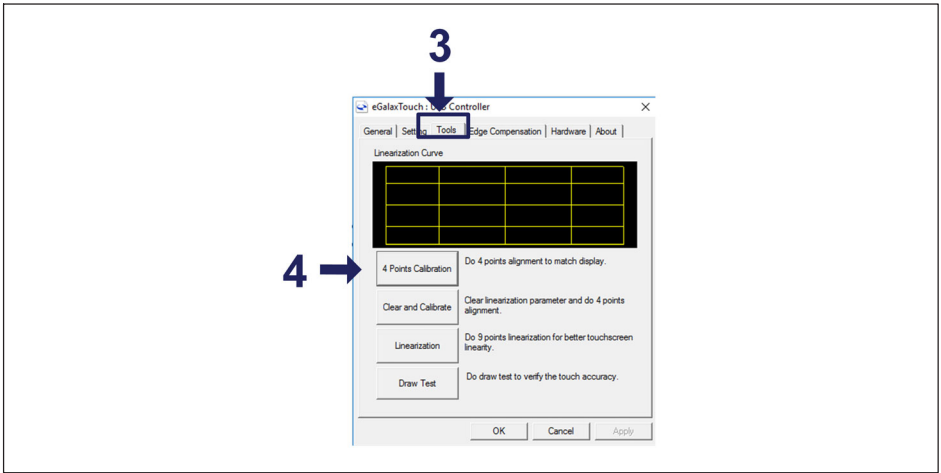


Fig. 3.14 Screen calibration setup

► Follow the steps as presented on screen.

**i Information**

*Once the interrogator is shut down or restarted the new calibration is lost and the default calibration is loaded.*

**3.9 Active Cooling System**

The Portable Interrogator thermal management is achieved with an active cooling system that includes air intake and air exit fans (see Fig 3.1 numbers 4 and 8). While the interrogator is on, fans will start working once the internal temperature reaches 50 °C [122 °F]. The fan operation will be shut down when internal temperature reaches 45 °C [113 °F]

The air intake fan (number 4 in Fig. 3.1) is protected by a filter that prevents major dust to get into the device. When it is visibly dirty it is advisable that it is cleaned or replaced. Dirty filters compromise ventilation/cooling of the device that can lead to malfunction or damage the equipment.

**Notice**

*Overheat of the device can permanently damage the equipment.*

### 3.9.1 Cleaning the Filter

To clean the filter

- ▶ Remove the four screws and take the filter.



Fig. 3.15 Fan filter fixation

- ▶ Blow with a compressed air can or similar from the side that was facing the device outwards. Repeat as many times as needed until it gets clean.
- ▶ Reapply the filter fixing the four screws.

### 3.9.2 Replacing the Filter

On case the filter is damaged or cannot be conveniently cleaned it should be replaced. There is one extra fan filter delivered with the device that can be used for replacement..





Fig. 3.16 Extra fan filter

- ▶ To replace the filter, remove the four screws and take the filter.
- ▶ Apply the new filter fixing the four screws.

### 3.10 Optical Connectors Detachable Panel

Optical connectors are assembled on a detachable panel aimed to protect the connectors from mechanical damage and to ease adapter replacement in case adapters get damaged (see section 4.3.2 “Broken Connector” on page 32)

#### 3.10.1 Adapter Replacement

In case an adapter gets damaged, you should replace it. Order 1-FS80-100 for FC/APC adapters and 1-FS80-300 for SC/APC adapters.



#### Important

*Always perform these actions with the device steady on a clean surface.*

- ▶ To detach the panel, unscrew the four screws (number **1** in Fig. 3.17) and gently pull the panel out (number **2** in Fig. 3.17). Be aware that fragile optical cables might follow and these cannot be forced as they might break.

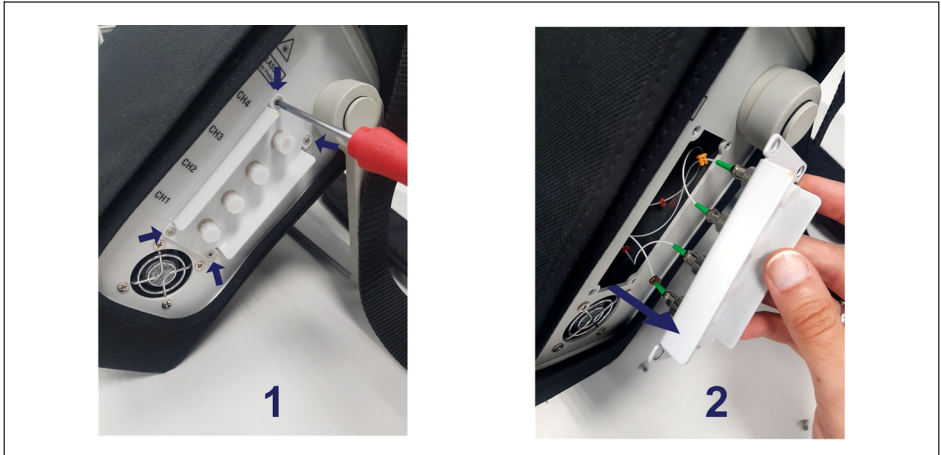


Fig. 3.17 Detachable connector panel

- ▶ Disconnect the connector(s) from the adapter(s).
- ▶ Remove the adapter from the panel
  - FC/APC adapter: unscrew the nut and remove
  - SC/APC adapter: unscrew the screws and remove
- ▶ Apply the new adapter.
- ▶ Align the panel and screw the screws back.

## 4 MEASURING

### 4.1 Typical Configuration

Typically, a fiber Bragg grating sensing network is divided into lines of sensors connected in series. In Fig. 4.1 there is a scheme of a usual FBG line of sensors, each line corresponds to an optical connectors.

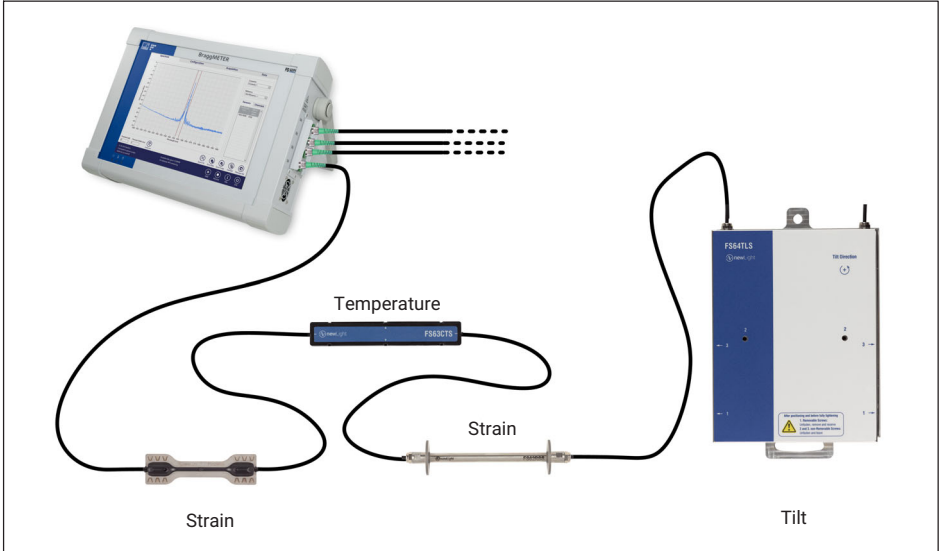


Fig. 4.1 Typical sensing network

Each optical connector can accommodate sensors with wavelengths from 1500 nm to 1600 nm. The number of sensors in a channel can vary if there is previous knowledge about the spectral range the sensors will cover. The major concern is the wavelength's overlap of adjacent sensors. The available optical channels have simultaneous acquisition, meaning that the sensing network can have a large number of fiber Bragg grating sensors interrogated at the same time. HBK FiberSensing recommends a maximum of 18 newLight standard sensors per optical channel (e.g. 9 strain and 9 temperature standard sensors).

The employed technology allows multi-functionality meaning that on the same optical connector it is possible to measure Strain, Temperature, Displacement, Pressure, Acceleration, etc..

The sensing network can be up to 10 km away from the interrogator for there are no EM/RF interferences or significant losses of light in the optical fiber.

Each FBG sensor has a characteristic central wavelength ( $\lambda_0$ ) that depends only on the measurand. This means that with this technology there is no need for recalibrations every time the system is shut down.

The Portable BraggMETER PI is a portable interrogator designed to be autonomous (uses battery) and easy to carry (small size and reduced weight) to be plainly used in different projects.

## 4.2 Definitions

The following definitions are applicable to this equipment.

### 4.2.1 Wavelength

The Wavelength value corresponds to the wavelength at the peak of the fiber Bragg grating reflection spectrum, commonly referred as Bragg wavelength (*Fig. 4.2*).

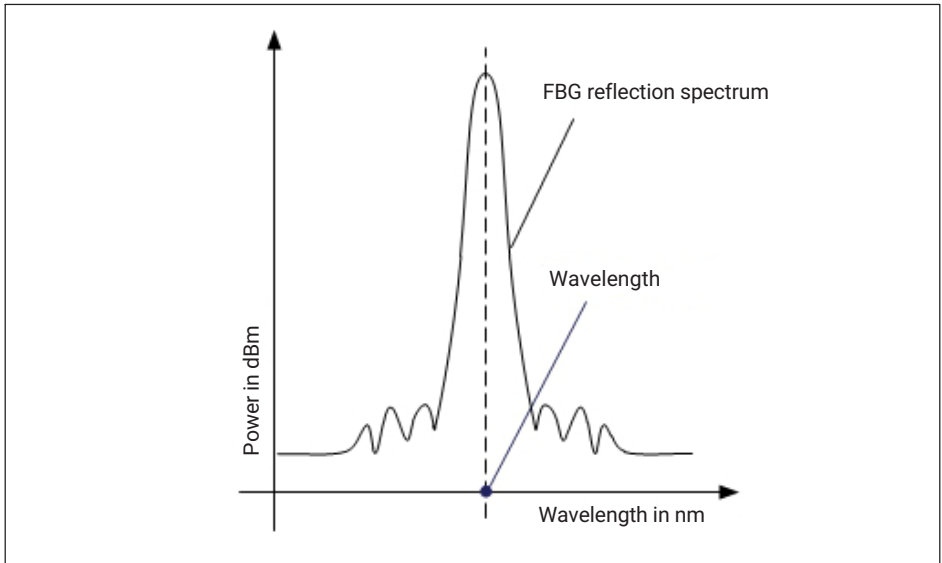


Fig. 4.2 Wavelength

### 4.2.2 Power

The Power value corresponds to the optical power reflected by the fiber Bragg grating at the peak wavelength (Fig. 4.3).

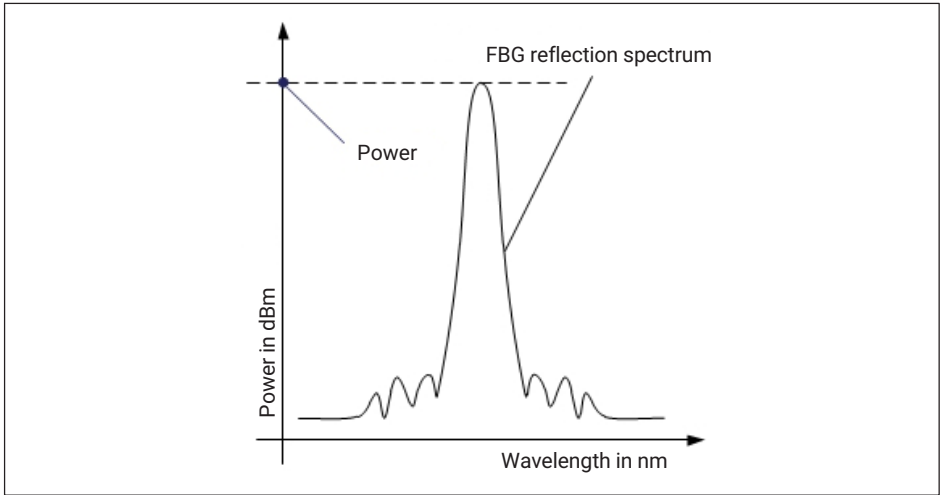


Fig. 4.3 Power

### 4.2.3 Smart Peak Detection (SPD)

SPD allows the effective use of the high dynamic range offered by the interrogator through the introduction of individual and adaptive thresholds, referenced to the peak on each sensor's configurable range (refer to Fig. 4.4).

The threshold value corresponds to the considered power level for the FBG peak computation and it is defined in dB for each optical channel individually. The threshold value is referenced to the highest peak of each range, operating individually in every range.

Within each sensor range, only one FBG sensor will be computed. This prevents measurement problems that can occur either permanently or occasionally while ensuring signal stability by not considering the influence of these undesired peaks on the signal computation.

Briefly, this feature is especially suited to overcome the limitations found in the conventional methods of using a single threshold line for the full spectrum. In cases where low and high reflectivity FBGs coexist, signal losses are often a problem. SPD therefore improves the stability and accuracy of the measurements, contributing to the system's efficiency.

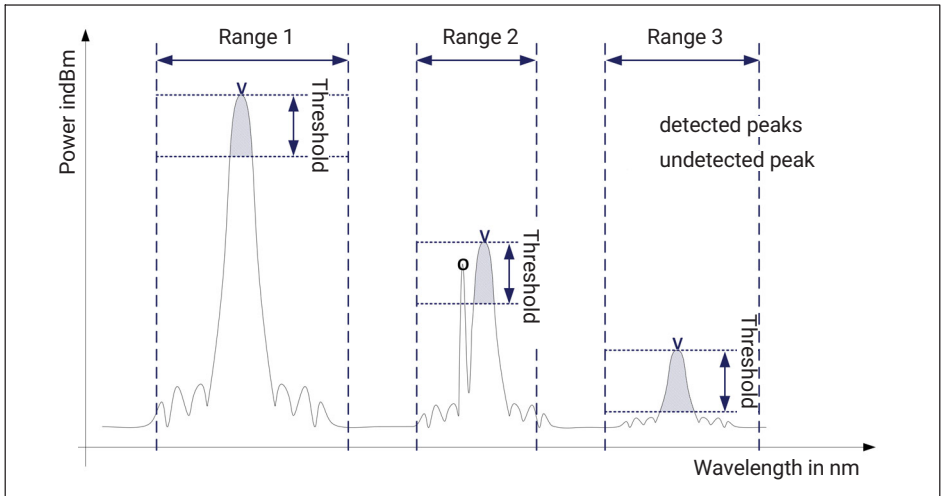


Fig. 4.4 Threshold (with Smart Peak Detection)

### 4.3 Common Measuring Difficulties

There may be the possibility of having measuring malfunctions due to several problems in the sensing network or optical connections. A list of some of the usual problems is described below with the explanation for its occurrence and correction.

#### 4.3.1 Dirty Connector

When an interrogator is repeatedly being plugged in and out with optical connectors, it is very important that the connectors are cleaned prior to any connection. Otherwise, dust and moisture can be deposited in the interrogator adaptor and this will compromise measurements. In Fig. 4.5 a picture of a magnified connector is presented. The dark gray circle corresponds to the fiber cladding and the small light gray circle is the core of the fiber. One picture for a clean connector and one picture for a dirty connector are presented.

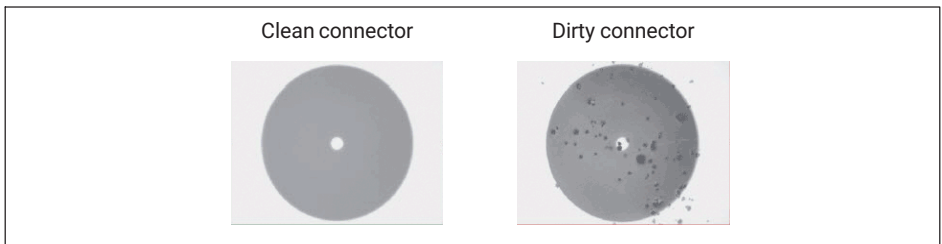


Fig. 4.5 Dirty connector

The most common effect of dirt on the connections is a large amount of broad band light being reflected at the connection, in both directions, meaning that the dynamic range for measurements becomes smaller.

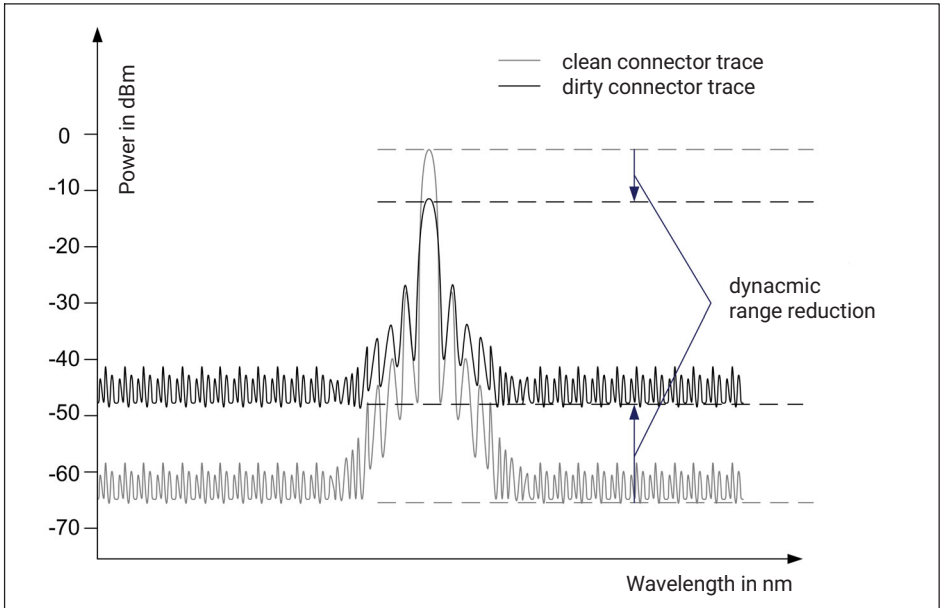


Fig. 4.6 Signal reduction due to dirt on connector

To clean an optical interrogator adapter, use an appropriate cleaner (1-FS-CLEANER from HBK or similar). Insert it in the optical adapter, as in Fig. 4.7, and rotate always in the same direction.



Fig. 4.7 *Cleaning the adapter*

### 4.3.2 Broken Connector

It may also occur that the interrogator adapter ferrule breaks. In this case, when an optical connector is inserted it does not get proper alignment and measurements are compromised. A broken ferrule will look as shown in Fig. 4.8.

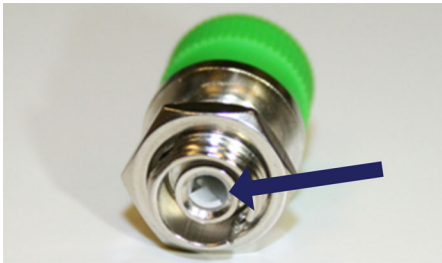


Fig. 4.8 *Broken ferrule on the adapter*

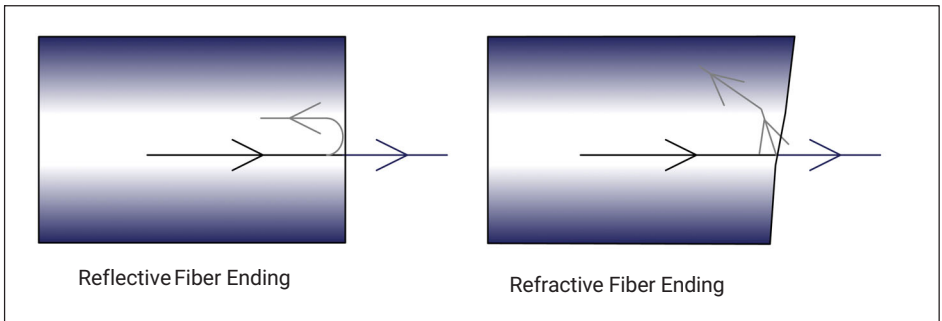


To solve this problem you should proceed as explained in *chapter 3.10.1 "Adapter Replacement on page 25"* or contact HBK FiberSensing.

### 4.3.3 Reflective Fiber Ending

Even when all connections have been performed correctly, it may occur that the interrogator does not find any sensor on the array. One of the reasons may be the excess of reflected light saturating the detectors.

When a fiber is perfectly cut (*Fig. 4.9* on the left) a large amount of light is reflected right back to the fiber core in the right direction, heading to the interrogator detectors. When this occurs, an index matching gel or an angled termination must be used. If these are unavailable, the tip of the fiber can be smashed with a metallic tool. This will destroy the perfect geometry (*Fig. 4.9* on the right) and the light that is reflected will take random directions ending up outside of the core.



*Fig. 4.9 Reflective fiber ending*

### 4.3.4 Cut Fiber

When the fiber, for any reason, is broken between sensors in a series, the sensors that are after the fault may disappear from the optical spectrum and will not be detected.

There may also be the case that the fiber is cut, but not completely spread apart (e.g. the fiber is damaged in an area covered with glue). This will cause a Fabry-Pérot effect – the light will suffer multiple reflections inside the cavity creating sinusoidal background reflection. *Fig. 4.10* shows a schematic representation of the reflected spectrum for these three presented cases.

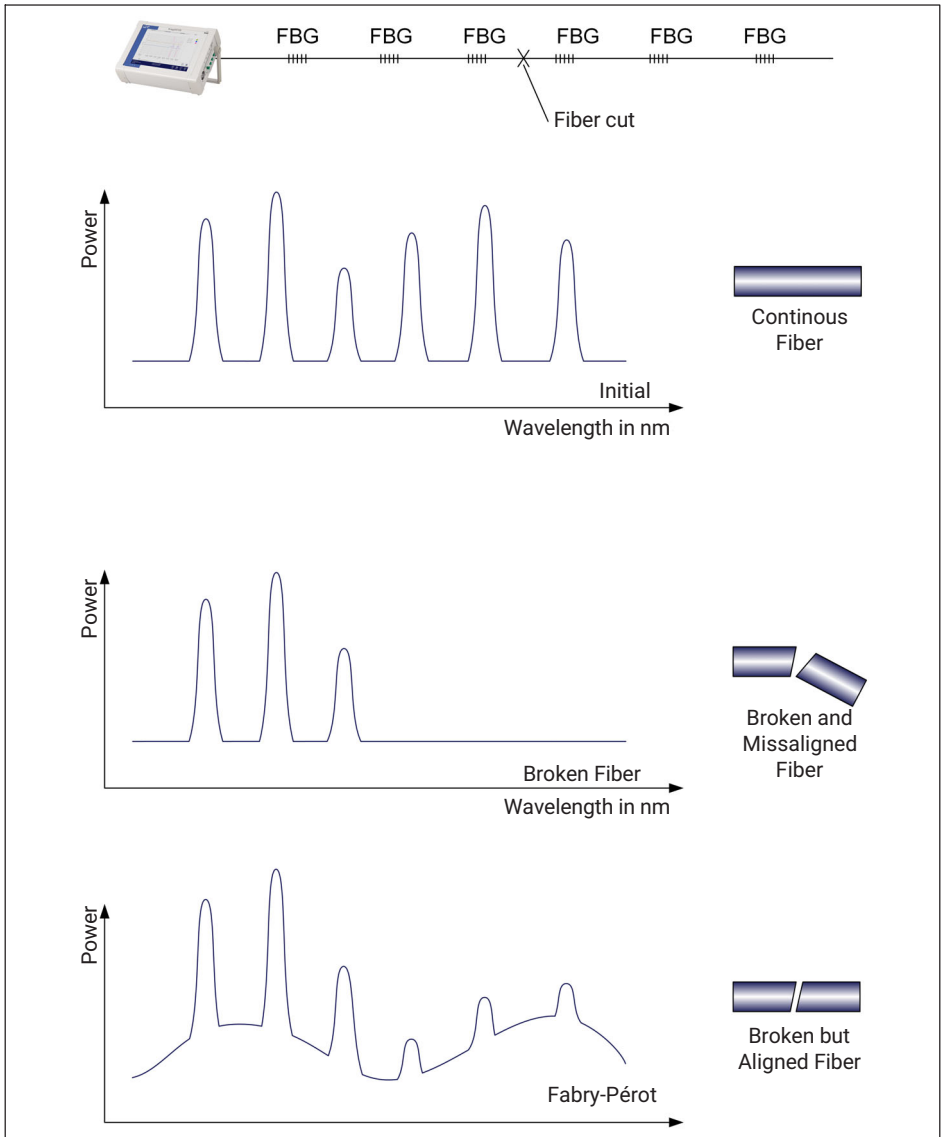


Fig. 4.10 Signal behavior due to a broken fiber

The FS42PI operating system is Windows 10 IoT and the software included is BraggMONITOR PI. Through this combination the customer can use the Windows 10 IoT features and can access to the BraggMONITOR PI software directly to configure the measurements, acquire, store and display data.



### Information

*To correctly use Windows 10 IoT there is the need to connect regular PC accessories (keyboard and mouse) through the USB interfaces. Alternatively, the Windows On Screen Keyboard will start-up with the interrogator by default.*

For more details on how to operate Windows 10 IoT please refer to Microsoft support.

### 5.1 Disk Image

For protection against disk image corruption, the image of the interrogator is restored to the default version upon startup.

This means that all changes performed on partition C: are deleted when the interrogator starts.

Data is stored on partition D; so no data is lost. However, if you save any files on partition C: ensure to backup on an external drive or to partition D: not to lose data.

### Notice

*All changes performed under the Windows 10 IoT partition C: will be reverted upon restart. To ensure no data is lost, ensure that it is backed up or saved on partition D:. For more details please refer to section 5.1 on page 35.*

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## 6 REMOTE OPERATION

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The FS42PI device can be operated remotely via Ethernet. To operate the device you must ensure:

- that the interrogator is powered on;
- that the PC you are using is on the same subnet;
- that the acquisition on the device is stopped.



### Information

*To assure no connectivity issues please use only certified Ethernet cables under 30 m in length. (ISO/IEC 1108)*

## 6.1 IP Setting

### 6.1.1 Automatic IP (DHCP)

By default, upon connection of a LAN cable (RJ45) to the device, the IP is set automatically with DHCP. When in DHCP the IP can be checked via Windows environment. For example, via right click on top of the connection icon.

### 6.1.2 Manual IP

To manually set the device's IP, use the provided interface of BraggMONITOR PI (see *Fig. 7.4 in chapter 7 "BraggMONITOR PI Software"*). Whenever a LAN cable is connected, the IP settings on the info window are available.

- Press the info button (number **5** in *Fig. 7.1*)
- Select "Use following IP address"
- Write the desired IP address and subnet mask.

## 6.2 Remote Mode

### 6.2.1 Entering into Remote Mode

By sending a command to the interrogator, the device will enter into remote mode and lock the device's screen as seen in *Fig. 6.1*.



Fig. 6.1 Device under remote operation.



### Information

Any command sent to the interrogator while acquisition is running on BraggMONITOR PI will be rejected and the received answer is :NACK:REMOTE MODE NOT POSSIBLE.

## 6.2.2 Exiting Remote Mode

Exiting remote mode can easily be done by pressing on any position of the white screen, which means all area of the screen except for the general bar (see Fig. 7.1 on chapter 7.2.1 "General and Management Controls").

## 6.3 Communication Protocol Syntax

### 6.3.1 Command Syntax

Each command is an ASCII string with arguments separated by ":" and terminated with the "Line Feed" and "Carriage Return" characters ("End of Line").

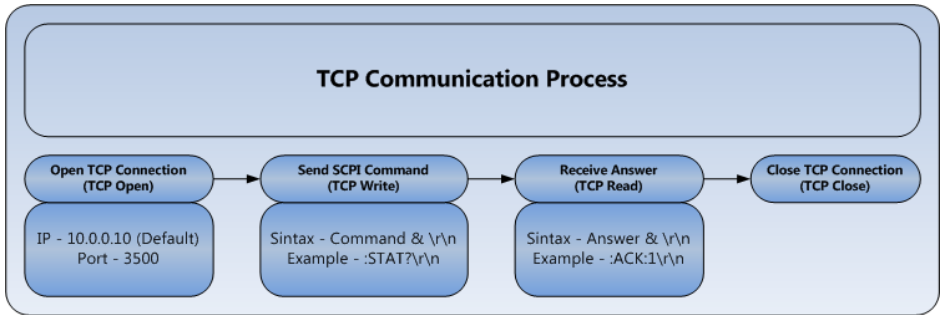


Fig. 6.2 TCP communication scheme.

Commands for the FS42PI are sent by port 3500. All commands, except for Continuous Acquisition (see chapter 6.3.5.2 on page 42), are received via the same port. Continuous Acquisition answers are retrieved via port 3365.

The letters on the presented command syntax for the FS42PI Portable interrogator have the following correspondence:

C	Optical connector	Integer. From 1 to 4
T	Threshold	Floating point. From 0 to 60 (dB)
FML	Formula	Polynomial. Considering "x" as the wavelength variation (in nm). Wavelength variation corresponds to the wavelength reference minus the measured wavelength.
YYYY.MM.DD	Date	Integer. YYYY – year. MM – month. DD – day.
HH.MM.SS	Time	Integer. HH – hours. MM – minutes. SS – seconds.

There are several possible answers with error messages:

:NACK:INVALID COMMAND

The command does not exist. Check if the spelling is correct

:NACK:'?' MUST BE THE LAST CHARACTER

The sent command should have a '?' at the end of the command string.

:NACK:ARGUMENT OUT OF RANGE

The defined value for the parameter that is being configured with the command is outside the possible interval.

:NACK:REMOTE MODE NOT POSSIBLE

The FS42PI device is running and acquiring. Locally stop acquisition and resend command.

### 6.3.2 Common Commands

#### :IDENTification?

Queries the instrument type and firmware revision. The return string is a list separated by ":" consisting of Manufacturer, Interrogator Name and Revision, Number of connectors, Serial Number and Software Date.

*Example:*

**Command** :IDEN?

**Answer** :ACK:HBK FiberSensing:FS42PIv5:04:046 840 200 815:20230731

### 6.3.3 System Commands

#### :SYSTem:REBooT

Restarts the device.

*Example:*

**Command** :SYST:REBT

**Answer** (no answer)

#### :SYSTem:BATTery?

Queries the current level of the batteries. The answer shows current battery level in percentage.

*Example:*

**Command** :SYST:BATT?

**Answer** :ACK:98.0

## 6.3.4 Status Commands

### **:STATus?**

Queries the instrument on the current running status. Answers with an integer value corresponding to the stage the interrogator is at: 0 – error; 1 – ready; 2 – (reserved, not yet implemented); 3 – warming up.

*Example:*

<b>Command</b>	:STAT?
<b>Answer</b>	:ACK:1

## 6.3.5 Acquisition Commands

### 6.3.5.1 Single Acquisition

#### **:ACQUisition:CONFiguration:THREshold:CHANnel:C:T**

Sets the threshold value for the peak detection algorithm in the C connector of the FS42PI. The threshold is a value from 0 to 60 dB.

*Example:*

<b>Command</b>	:ACQU:CONF:THRE:CHAN:2:20
<b>Answer</b>	:ACK

#### **:ACQUisition:CONFiguration:THREshold:CHANnel:C?**

Queries the threshold value for the peak detection algorithm in the C connector of the FS42PI. The threshold is a value from 0 to 60 dB.

*Example:*

<b>Command</b>	:ACQU:CONF:THRE:CHAN:2?
<b>Answer</b>	:ACK:20.0

#### **:ACQUisition:OSATrace:CHANnel:C?**

Acquires the optical spectrum trace of the fiber Bragg grating sensors in the C connector of the FS42PI. Returns the optical spectrum trace over the complete wavelength between 1500 nm to 1600 nm with a 5 pm sampling resolution.

*Example:*

<b>Command</b>	:ACQU:OSAT:CHAN:1?
<b>Answer</b>	:ACK:-41.064,-40.965,-40.719,-40.420,-40.116,-39.848,-39.651,-39.574,-39.624,-39.755,-39.919,-40.074,-40.176,-40.203,-40.182, (...)



### **:ACQUsition:WAVElength:CHANnel:C?**

Acquires the peak wavelength of the fiber Bragg grating sensors in the C connector of the FS42PI. Returns the peak samples of the fiber Bragg grating sensors accordingly to the threshold settings and defined ranges.

Note: Ranges cannot be defined remotely. Remote mode will use the ranges that are defined on the device at the moment.

*Example:*

**Command** :ACQU:WAVE:CHAN:1?

**Answer** :ACK:1523.6573, 1554.0709, 1566.7846

### **:ACQUsition:ENgINEering:CHANnel:C?**

Acquires the engineering values, according to the range formula (FML), in the C connector of the FS42PI. Returned value is always in accordance to the defined threshold for the connector.

*Example:*

**Command** :ACQU:OSAT:CHAN:1?

**Answer** :ACK:30.45,25.85,0.2582,3.2154

### **:ACQUsition:POWEr:CHANnel:C?**

Acquires the power of the fiber Bragg grating sensors in the C connector of the FS42PI. Returns the power value of the fiber Bragg grating sensors accordingly to the threshold settings.

*Example:*

**Command** :ACQU:POWE:CHAN:1?

**Answer** :ACK:-41.064,-40.965

### 6.3.5.2 Continuous Acquisition

#### **:ACQUisition:WAVElength:CONTInuous:STARt**

Continuously acquires the peak wavelengths of the fiber Bragg grating sensors in all channels of the FS42PI. This command is sent via port 3500 and corresponding data is received through port 3365. The answer is a string starting with the timestamp with the format «YYYY.MM.DD:hh:mm:ss» followed with the wavelengths in growing order of wavelength separated by “;”, from all connectors separated by “:”.

Note: if there are connectors with no sensors, the answer will have no wavelength between “:”.

*Example:*

<b>Command</b>	:ACQU:WAVE:CONT:STAR
<b>Answer</b>	Port 3500 » :ACK Port 3365 » :2011.10.07:16:04:52: 1523.6573, 1554.0709, 1566.7846:: 1567.6987, 1584.9825: 1534.9824

#### **:ACQUisition:OSATrace:CONTInuous:STARt**

Simultaneous and continuously acquires the optical spectrum traces of all connectors of the FS42PI.

This command is sent via port 3500 and corresponding data is received through port 3365 in binary format. The answer is a big endian binary stream representing a double precision (8 bytes) array with 20001 points times the number of optical connectors of the interrogator. The first 4 bytes of the binary stream indicate the number of data bytes to be read. To be in agreement with the communication protocol syntax of the interrogator, Carriage Return/Line Feed (CR/LF) are also included in the stream and, therefore, “2” must be added to the value returned by the first 4 bytes of the stream.

The returned data represents the power values of the OSA traces for all optical connectors with points from 1500 nm to 1600 nm sampled every 5 pm.

*Example:*

<b>Command</b>	:ACQU:OSAT:CONT:STAR
<b>Answer</b>	Port 3500 » :ACK Port 3365 »

## :ACQ:ENGI:CONT:STAR

Continuously acquires the engineering values, according to the range formula (FML), in all defined ranges of all connectors.

This command is sent via port 3500 and corresponding data is received through port 3365. The answer is a string starting with the timestamp with the format «YYYY.MM.DD:hh:mm:ss» followed with the values in growing order of wavelength separated by “,”, from all channels separated by “:”.

Note: If there are no sensors detected within a defined range the interrogator returns -998.

*Example:*

---

**Command** :ACQU:ENGI:CONT:STAR

**Answer** Port 3500 » :ACK

Port 3365 » :2019.07.07:16:04:52: 1523.6573, -998, 1566.7846::  
1567.6987, 1584.9825: 1534.9824

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## 7 BRAGGMONITOR PI SOFTWARE

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### 7.1 General Details

#### 7.1.1 Software Version

This document refers to HBK FiberSensing BraggMONITOR PI Software version v5.1.

#### 7.1.2 Software Update

The current version of the software can be seen by using the **Info** button (number **5** on Fig. 7.1).

The interrogator software can be updated. The update can be performed remotely with the support from HBK FiberSensing.

Please contact HBK FiberSensing for assistance.



#### Information

*To proceed with the update the FS42PI device must be connected to the internet via LAN.*



#### Tip

*You'll need to inform the device's serial number which can be found on the label glued on the backpanel.*



#### Important

*Operating system settings will not be changed by a software update.*

## 7.2 Graphical User Interface

The BraggMONITOR PI software divides the screen in two functional areas. A bottom toolbar with controls that are always available and an upper main area with several menus separated with tabs.

### 7.2.1 General and Management Controls

On the toolbar the controls that are always available are:

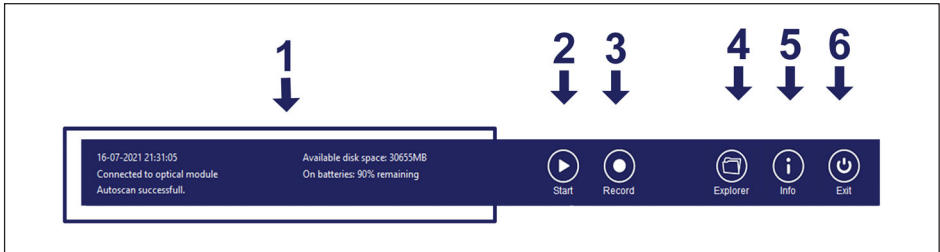


Fig. 7.1 General bar

#### 1 General information

On the general information area, different type of messages to the user are displayed. These are coloured following their level of alarm:

On the top left side, the date and time with the format DD-MM-YYYY hh:mm:ss. This corresponds to the time as defined on windows settings.

At the mid left side, information on the connection status of the interrogator is presented.

On the bottom left side, operation status is displayed. Examples of messages and meanings are presented below:

Measuring...	When in continuous acquisition
Saving data...	When data is being saved
Scanning...	When the auto scan process is ongoing
Testing...	When the testing button on the configuration tab is pressed down.

Error on sensor configuration	<p>When there is an error on the defined configuration:</p> <p>Overlapping ranges:</p> <p>Sensor «name» formula syntax error:</p> <ul style="list-style-type: none"> <li>- When a sensor was defined with a non-valid formula for computation. The reference «name» states the name of the sensor that shows the error.</li> </ul> <p>Incomplete configuration:</p> <ul style="list-style-type: none"> <li>- When there are sensors without a complete definition.</li> <li>- On optical sensors: Missing name, wavelength reference, range minimum, range maximum or formula</li> <li>- On computational sensors: Missing name or formula</li> </ul>
-------------------------------	---

On the top right side, available disk space is displayed.

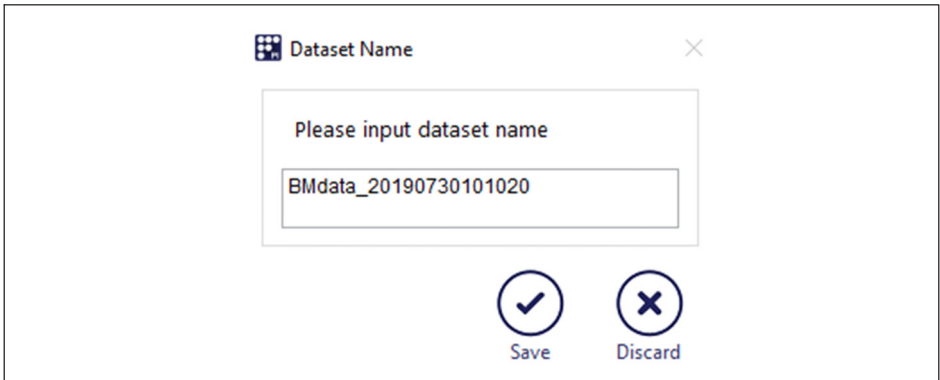
On the mid right side, the battery charge level and status are displayed.

By clicking on the area marked as **1**, see *Fig. 7.1*, a pop up appears with the log history.

**2 Start:** starts and stops acquisition.

**3 Record:** starts and stops recording of data.

By pressing this button while recording data, a pop up appears for dataset name configuration (see *Fig. 7.2*). Recorded dataset can also be disregarded by pressing the **Discard** button.



*Fig. 7.2* Dataset name

**4 Explorer:** Opens an Windows Explorer window, for easy access to saved files or other resources (see *Fig. 7.3*).

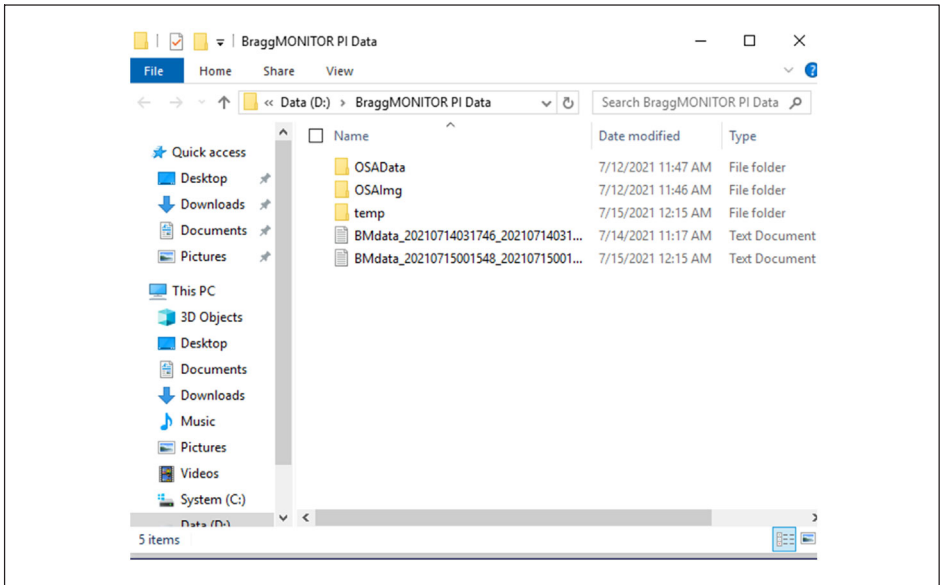


Fig. 7.3 Windows Explorer window

- 5 Info:** displays general information on the device (see Fig. 7.4) including the access to this user manual (by pressing button **1** on Fig. 7.4).



Fig. 7.4 Info window

The information window shows:

- Interrogator Model
- Interrogator SW version
- Interrogator SW release date
- Interrogator Serial Number
- IP address and subnet mask
- HBK FS contact information
- Button to call out user manual

**6 Exit:** Exits the application.

### 7.2.2 Graphical Area

The graphical area is divided into four different tabs:

- Spectrum
- Configuration
- Acquisition
- Data



### 7.2.2.1 Spectrum

The Spectrum tab is always accessible.

This tab represents the spectral response of the sensors connected to the interrogator.

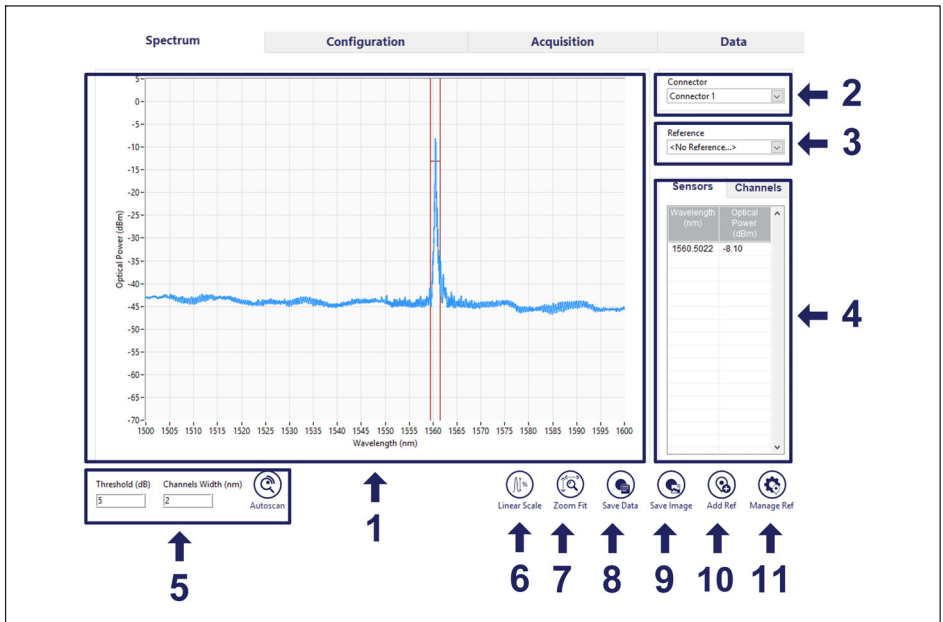


Fig. 7.5 Spectrum tab

- 1 Spectral representation containing 20000 data points with the reflected optical power in dBm from 1500 nm to 1600 nm with a 5 pm sampling resolution.
- 2 Optical connector selection. Only one optical connector is presented at a time.
- 3 Reference selection. A previously saved spectrum image can be plotted on the graph (number 1 in Fig. 7.5) by selection from the dropdown list. References can be saved by pressing the *Add Ref* button (number 10 in Fig. 7.5)
- 4 Configuration information. On this table, information on the detected peaks and defined detection ranges (channels) are presented.
- 5 **Autoscan** tool area

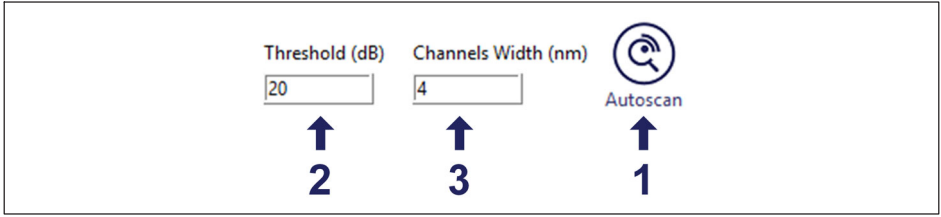


Fig. 7.6 Autoscan tools

By pressing the **Autoscan** button (number 1 in Fig. 7.6), the device scans on the selected connector for peak signals and automatically populates the list of sensors on the configuration tab (see section 7.2.2.2 “Configuration”, on page 54). The threshold (number 2 in Fig. 7.6) and channel width (number 3 in Fig. 7.6) values for the measurement will be considered as defined on the boxes. These values can be edited by clicking on the box, as a virtual keyboard will appear. Threshold corresponds to the value used during the measurement to distinguish real signal from noise and is measured in dB from the maximum peak down. The channels width is a value in nm that defines the width of the channel created around the detected peak. Channel width corresponds to the distance between the minimum and maximum limits of the defined channel.

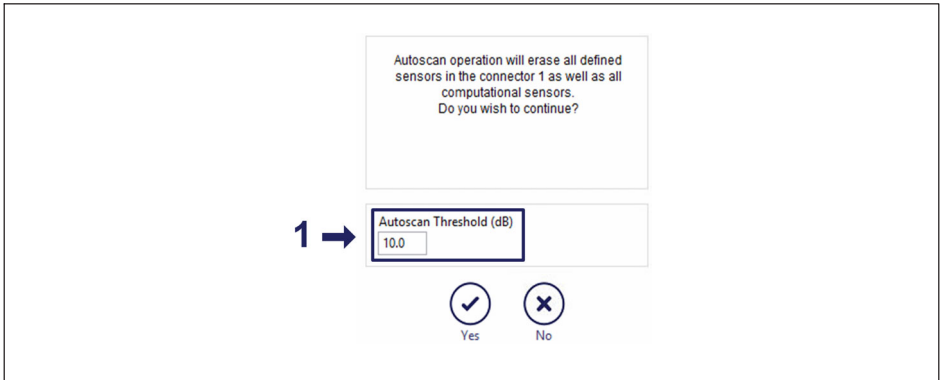


Fig. 7.7 Autoscan popup window

In the autoscan pop-up the user can also specify the threshold wanted for the autoscan process only, if needed (1 in Fig. 7.7). The used threshold for autoscan can be higher than the measurement threshold to support on the correct identification of peaks at a first trial because it eliminates the identification of side lobes as sensors.

## 6 Log/Linear Scale Button.

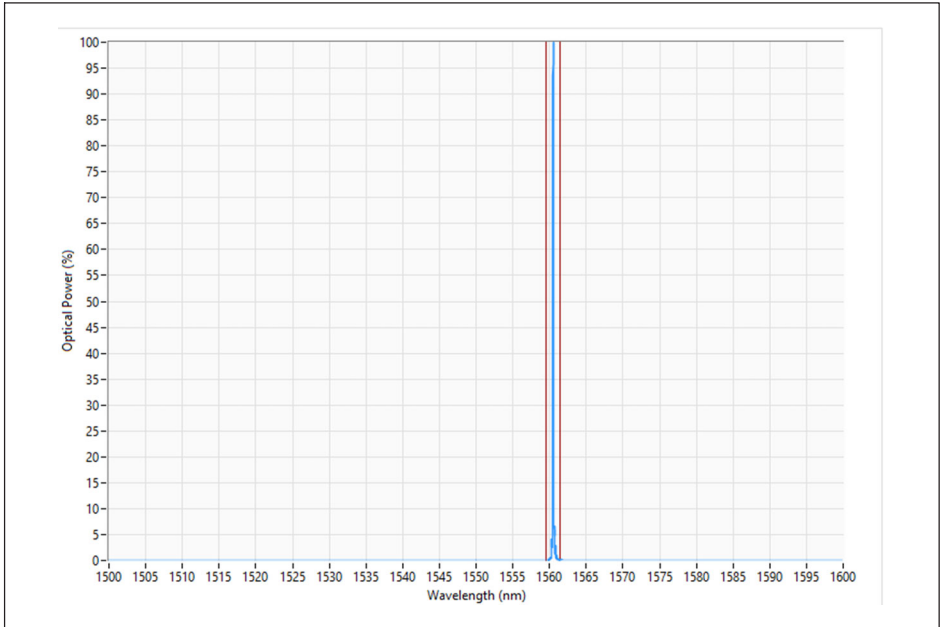


Fig. 7.8 Linear scale view

The vertical scale can be changed from logarithmic (default) to linear by pressing the **Scale** button (number 6 in Fig. 7.5).

By default, the spectrum is represented in logarithmic scale and the threshold value is represented in dB from the maximum peak acquired value. When toggled to "Linear" the amplitudes are normalized to the highest reflection peak available in the selected connector (Fig. 7.8) and the normalized threshold value is converted to match Optical Power units regarding maximum peak acquired value. The label on the button will change to match the alternative option, linear or logarithmic.

## 7 Zoom Fit button

**8 Save Data** saves spectrum as data button. The data can be exported to a ".txt" file.

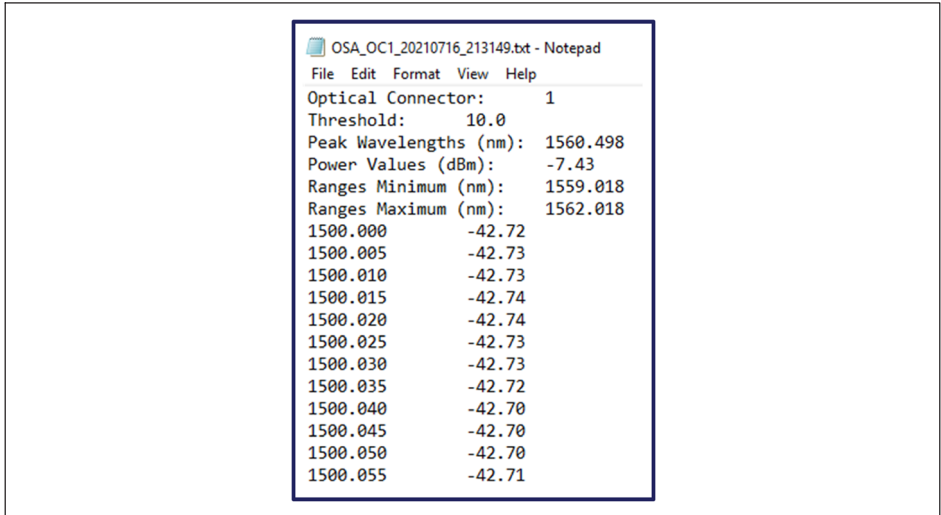


Fig. 7.9 Example of a saved spectrum data file

**9 Save Image** saves spectrum as image button. Saves an image containing the Spectral representation, the selected optical connector, reference, configuration information and the autoscan tool area.

**10 Add Ref** button. Saves the current spectrum for representation as a reference trace on the spectrum area together with the current measured spectrum.

**11 Manage Ref** button. Opens the list of previously saved references (Fig. 7.10).



Fig. 7.10 Reference manager

### 7.2.2.2 Configuration

Under the configuration tab there is a list of configured sensors.

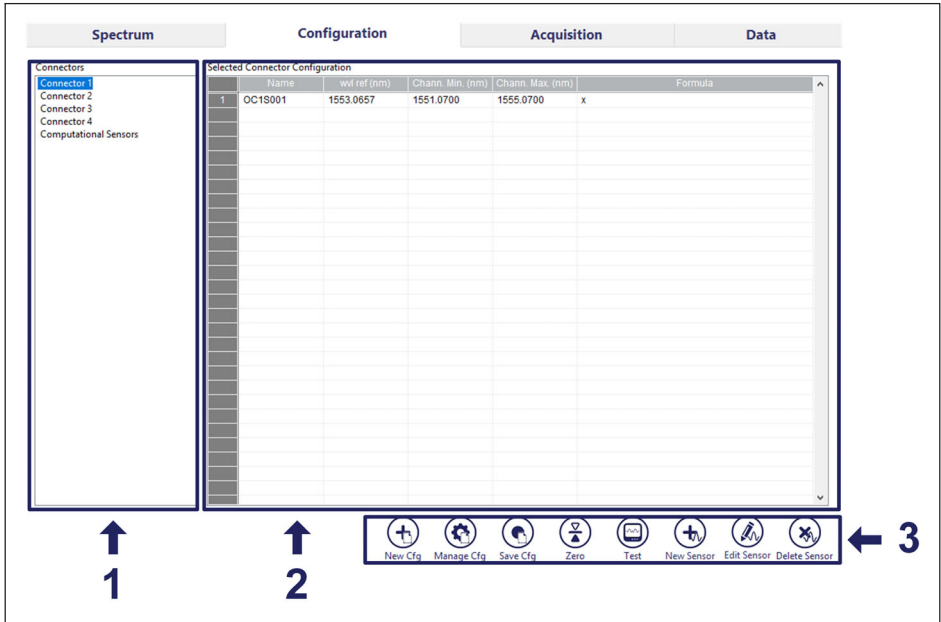


Fig. 7.11 Configuration tab

- 1 Optical connector selection. This is the list of available optical connectors plus a virtual connector for the list of computational sensors. The shown sensors on the sensor table are corresponding to the selected connector.
- 2 Configuration Table. On the configuration table, relevant information on the sensors configuration is shown:
  - Name: Lists the name of the sensors. When performing an auto scan, sensor naming is automatic with the following format:
    - OC3S004 -> meaning Optical Connector number 3, sensor number 4.
    - Upon the auto scan, the populated list is organized in ascending order of reference wavelengths.
  - Reference Wavelength (nm): Lists the sensor's reference wavelengths in nm.
    - The reference wavelength is the value against which the wavelength variation is calculated.
    - Upon the auto scan, the populated list is organized in ascending order of reference wavelengths. If a configuration is created by hand, edited by hand, or uploaded the list will reorganize itself to meet the reference wavelength order.

- Formula: Shows the calculation formulas for engineering values. The formula uses a mathematical function of wavelength difference ( $x$  in nm) between the sensors' defined reference wavelength (in nm) and the measured wavelength (in nm) at each instant.
  - Upon the auto scan, the formula is  $x$ .
  - On the computational sensors, the formula can be based on measured sensor values (in engineering units) or on the combination of measured values.
  - In case a wrong value is calculated from the formula, its result is -998.

By clicking on a sensor line, a popup appears with the current settings and values of the selected sensor.

**3** Configuration tools. On this area, the tools for operating the configuration settings are available.

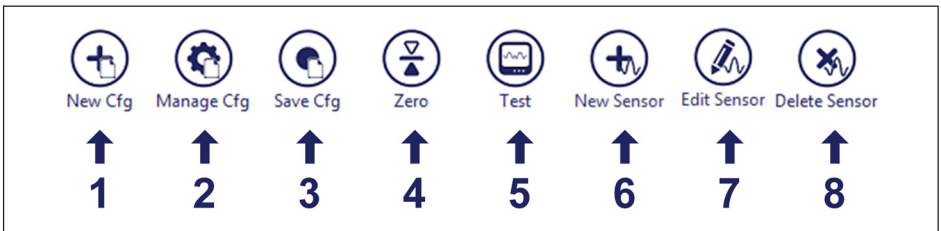


Fig. 7.12 Configuration tools

- 1 New Configuration (New Cfg):** Clears the existing configuration deleting all sensors on all channels, including the computation channels.
- 2 Manage configuration (Manage Cfg):** Edits settings of the configuration. The settings for the configuration correspond to the dataset name. These settings are saved when the configuration is saved and are updated when a configuration is opened.
- 3 Save Configuration (Save Cfg):** Saves the configuration on the database. Configuration files are compatible with the FS42PI and BraggMONITOR PI only.
- 4 Zero:** Applies an offset to “zero” the selected sensors. This means that the device performs a scan and updates the reference wavelength of the selected sensors to the current wavelength value. A pop up of sensor selection is shown after clicking.
- 5 Test:** Tests the current configuration by showing the measured wavelength (for optical sensors) and the computed engineering values showing them on the configuration table.
- 6 New Sensor:** Creates a new sensor. Opens a dialog for sensor definition.
- 7 Edit Sensor:** Edits the selected sensor on the sensor configuration table. Opens dialog for sensor editing.
- 8 Delete:** Deletes the selected sensor on the sensor configuration table.



## Information

Configurations created using open source JSON editors can also be used and loaded to BraggMONITOR PI.

### 7.2.2.3 Acquisition

On the acquisition tab there is the display of the acquired data in a graphical format or in a numerical format.

#### Graphical display

The Graphical display shows the acquired measurements in a time graph.

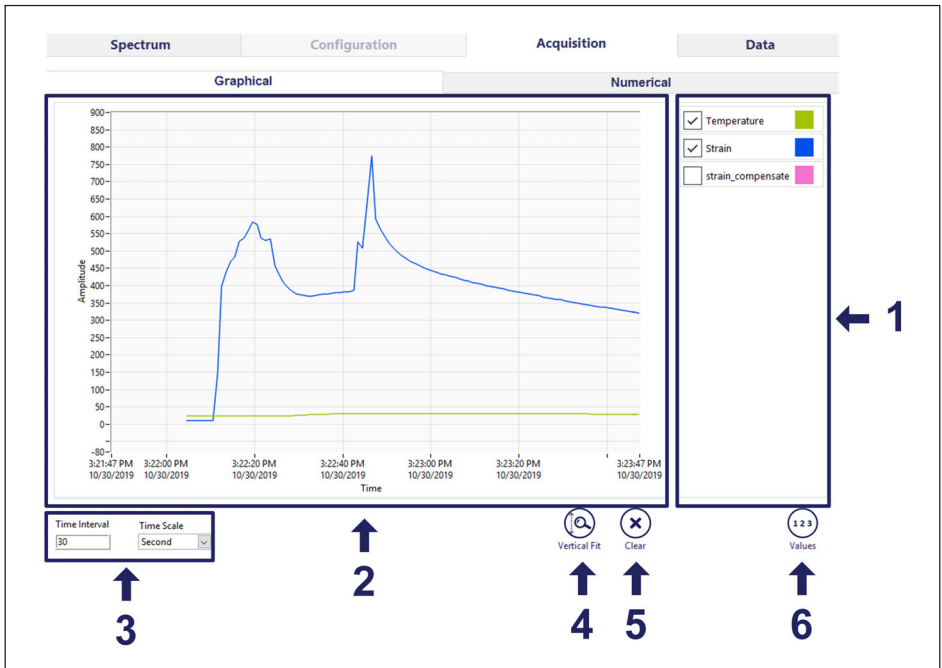


Fig. 7.13 Acquisition tab with graphical display

#### 1 Plot Selection Area

This is the area for defining the graphical representation of the data that is being acquired.

- Plot selection is performed on the right side with dropdown list of configured sensors (the list is shown by clicking over the sensor's name)



- Limited to 14 plots
- It is possible to have two or more plots of the same sensor
- Fixed colors
- Quick selection for plot

The plot selection is created automatically with the creation of a new configuration populating the list with the 14 first defined sensors. When there is a change on the plot order, sensor selection, or selected plots, this is saved so that the last representation configuration is stored with the configuration and can be called at other times.



### Important

*Names with "spaces" can be given to new or edited sensors (or virtual sensors). When exporting or editing data the name is as defined by the user. However, "spaces" in the sensor name (sensor or virtual sensor) are replaced by underscores in the Legend view of the "Acquisition" and "Data" tabs only.*

**2** Data Graph. Shows data in a time graph.

**3** Graph Time Scale

The represented time scale can be defined by selecting the interval and the unit of the interval. The possible values for the unit of the time scale are:

- Second
- Minute
- Hour

Values for the scale are validated in accordance to the selected unit:

- $1 \leq \text{Second} < 60$
- $1 \leq \text{Minute} < 60$
- $1 \leq \text{Hour} \leq 10$

**4 Vertical Fit.** Fits the shown data on the amplitude axis.

**5 Clear.** Clears the graph area.

**6 Values/Legend Button.** The user can switch between two different views:



Fig. 7.14 Graph legend vs graph values

- **Legend View (1 in Fig. 7.14):** shows the name, the assigned color and selection of the configured sensors.
- **Values View (2 in Fig. 7.14):** shows the name and current values of the configured sensors.



## 7.2.2.4 Data



Fig. 7.16 Data tab

- 1 Plot selection area: This is the area for defining the graphical representation of the data that is being shown.
  - Plot selection is performed on the right side with dropdown list of saved sensors (the list is shown by clicking over the sensor's name)
  - Limited to 14 plots
  - It is possible to have two plots of the same sensor
  - Fixed colors
  - Quick selection for plot
- 2 Data Graph: Shows previously saved data on a time graph.
- 3 Dataset selection: Opens the dropdown with the list of previously saved datasets for selection.
- 4 **Zoom Fit**: Fits all data on the graph.
- 5 **Manage data**: Opens a dialog for managing previously saved datasets.

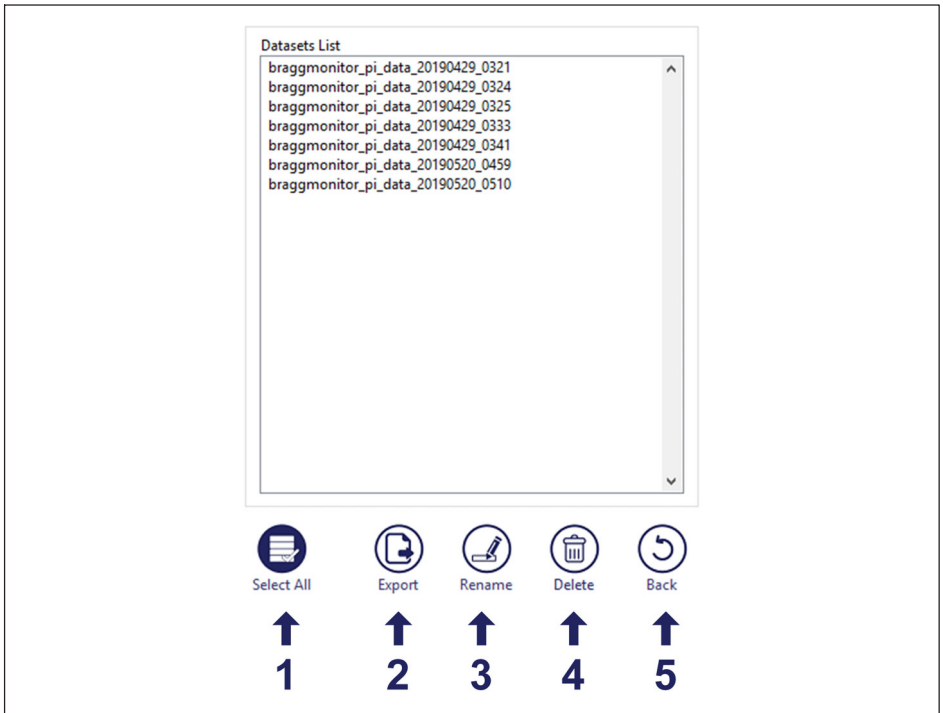


Fig. 7.17 Saved data management

- 1 **Select All:** Selects all datasets on the list.
- 2 **Export:** Exports the dataset in ".txt" format. Datasets are divided into ".txt" files of 30 min of data to prevent the handling of heavy files.
- 3 **Rename:** Renames the selected dataset.
- 4 **Delete:** Deletes the selected dataset(s)
- 5 **Back:** Returns without performing changes.

