PRECISION ACOUSTICS

Fibre-optic Hydrophone System Version 2 User Guide

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Versions

Ver.	*Comments*	*Date*
1.0	First released version to accompany relaunched Fibre-optic Hydrophone System Version 2 (FOH-V2)	03/06/22

Introduction

The following document provides an outline for the installation and use of the Precision Acoustics Fibre-optic Hydrophone System (FOHS). It is assumed that the reader has knowledge of making measurements with other hydrophone devices (such as PVDF needle and membrane hydrophones). Further information on making acoustic measurements with hydrophones can be found on our website (https://www.acoustics.co.uk). In addition, Precision Acoustics Ltd offer training courses covering many aspects of acoustic measurement techniques and practices.

Safeguard system advisory notices

The Fibre-optic Hydrophone System (FOHS) contains a class 1M laser device emitting invisible laser radiation. The optical output power from the connector on the front panel of the system does not exceed 1mW at an optical wavelength of 1550nm and as such should be "eye safe". However care should always be taken to avoid looking directly at the output when the laser is on.

WARNING: DO NOT DIRECTLY VIEW THE OUTPUT FROM THE SYSTEM WITH MAGNIFYING OPTICAL INSTRUMENTATION.

Overview of Operating Principles

The fibre-optic hydrophone works on the principle of interferometric detection of changes in the optical thickness of a thin polymer film deposited at the tip of an optical fibre downlead. Changes in the thickness may be induced acoustically (through the acoustic pressure) or thermally. The system is capable of differentiating between the two and making simultaneous measurements of both. A full description of the operating principles can be found in "A Fabry-Perot fibre-optic ultrasonic hydrophone for the simultaneous measurement of temperature and acoustic pressure", P Morris *et al,* J. Acous. Soc. Am. Vol 125(6) pp. 3611-3622, June 2009.

Handling the Sensor

The optical fibre used in the sensor downlead comprises a thin glass fibre (OD 125 μm) surrounded with a thin acrylate primary buffer layer (OD 250 μm) and encased in a flexible plastic jacket (OD 900 μm). Optical fibre is very flexible in nature, however, it is important to remember that the light carrying part of the fibre is made of glass and careful handling is important to ensure the longevity of the sensor downlead. If the glass fibre is broken, light will no longer reach the sensing element and measurements will be impossible.

In particular, when handling the fibre downlead the following guidelines should be observed:

- Avoid tight bends in the fibre to prevent sensor damage
    - Bend radii less than 10 mm should be avoided.

- Avoid knotting the fibre.
    - Tangles and knots in the fibre should be careful undone without pulling the fibre taut.
- When in use, ensure the fibre is kept clear of mechanical equipment (such as translation stages etc) so that it does not become entangled in moving parts.

Unpacking the Fibre-optic Hydrophone System

Package Contents

In addition to the Fibre-optic Hydrophone System control unit. You should receive the following items:

1. Neoclean-E fibre optic connector cleaner cassette.
2. IEC mains power lead for your specific region.
3. Fibre-optic hydrophone sensors.
4. Fibre-optic hydrophone mount.
5. IEC mains power lead.
6. JDSU Visual Fault Locator.

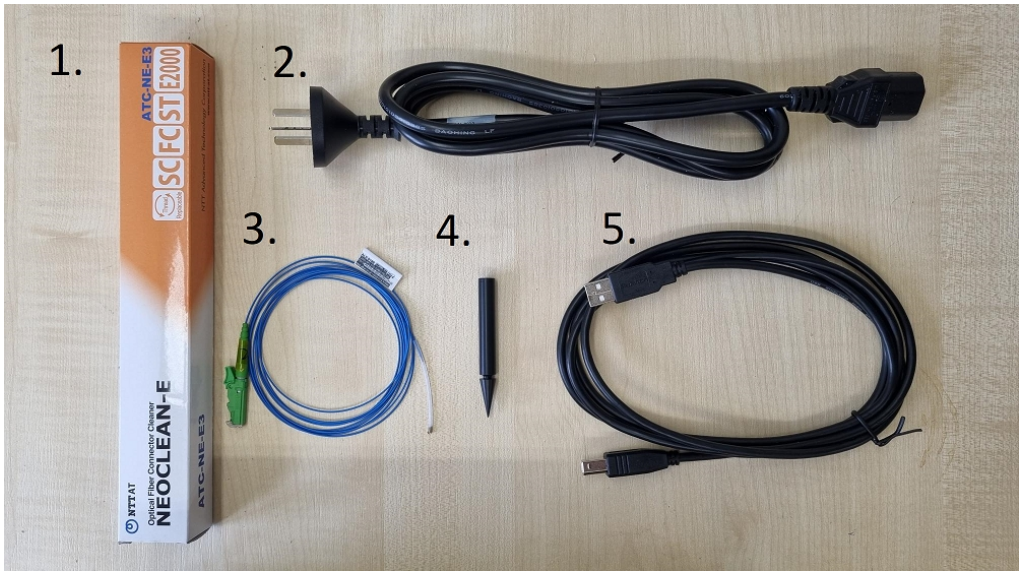


Figure 1. Additional contents of the Fibre-optic Hydrophone System

Installation

Software Installation

This document provides user guidance for the operation of the software application to be used in conjunction with the Precision Acoustics Ltd Fibre-optic Hydrophone System. The software accompanying a system facilitates for the following:

1. Measure and display the Interferometric Transfer Function (ITF) for a connected Precision Acoustics' manufactured Fibre-optic Hydrophone.
2. Bias the system based on the measured ITF to allow measurement of acoustic pressure using a Precision Acoustics ' manufactured Fibre-optic Hydrophone at maximum sensitivity.
3. Detect and display induced temperature changes detected by a sensor from an incident acoustic field.

Prior to any operational use, Precision Acoustics has provided a simple and easy to use installer on the storage device of the system. The installer launches a Setup Wizard interface which will automatically configure certain hardware parameters for optimum system performance and carry out a series of communication checks to ensure your system is fully operational and ready for use.

Before running the Installer, it is necessary for the Fibre Optic Hydrophone System to be powered up and connection to be made between the system and a PC running Windows 10 via the supplied USB cable.

IMPORTANT: The Setup Wizard must be Run with Local Administrator privileges to enable all necessary changes to be made.

After launch please read and follow the instructions carefully provided by the Setup Wizard.

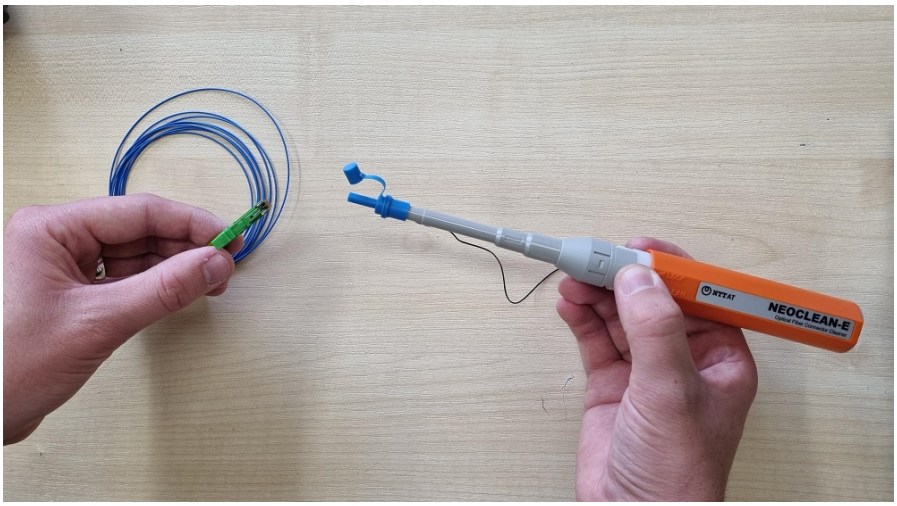
Connecting to an Oscilloscope

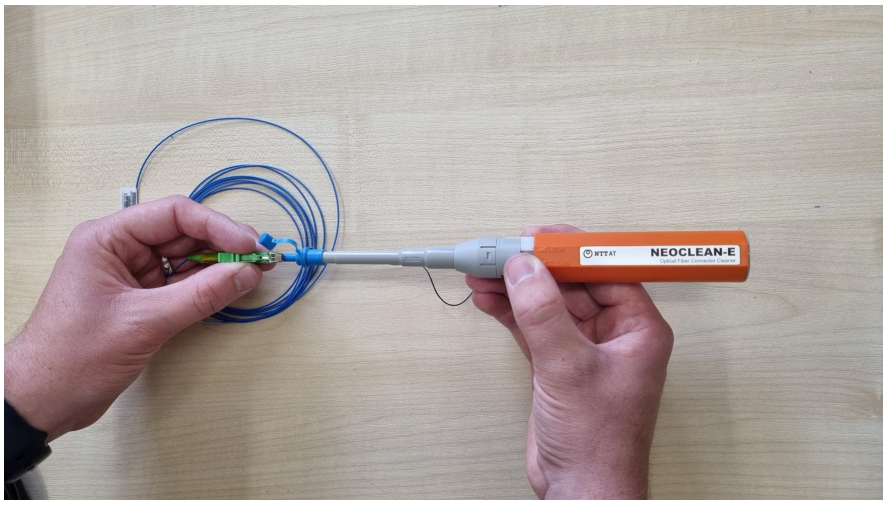
In order to make acoustic measurements, the hydrophone system must be connected to an oscilloscope via the "Signal out" connector on the front panel. The system is designed to have an output impedance of 50 Ohm, thus an oscilloscope with a 50 Ohm input is required. If your oscilloscope does not have this facility, an inline terminator should be used.

Note. Thermal measurement is made by the FOHS Application software, thus no additional connection is required for this function.

Connecting to Sensor Downlead

Before using the system a sensor downlead must be connected to the adaptor on the front panel. To do this, remove the dust cap from the adaptor on the front panel of the FOHS. Using the supplied Neoclean-E cleaner, prepare the tip of the fibre connector by revealing the fibre top as shown below before applying pressure on the handle end of the cleaner whilst holding the fibre steady. Then carefully insert the connector into the adaptor. A click should be felt when correctly inserted.





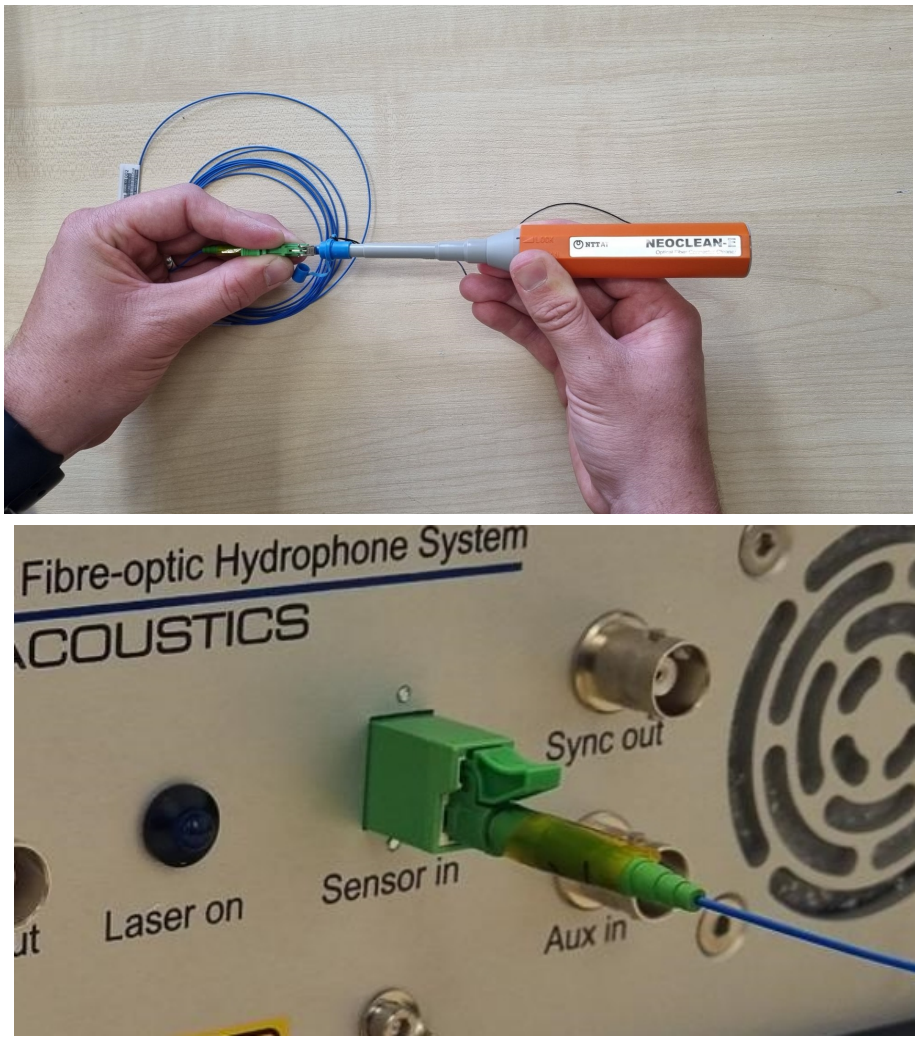


Figure 2. Cleaning a fibre-optic hydrophone before connection to the fibre-optic hydrophone system.

The connection to the downlead is optical. Thus it is vitally important that both the connector end-face and the adaptor remain clean. **Any contamination of the interface between the sensor downlead and the system will lead to degradation of the acoustic sensitivity of the system.** Please adhere to the following guidelines to ensure optimum performance of the hydrophone system.

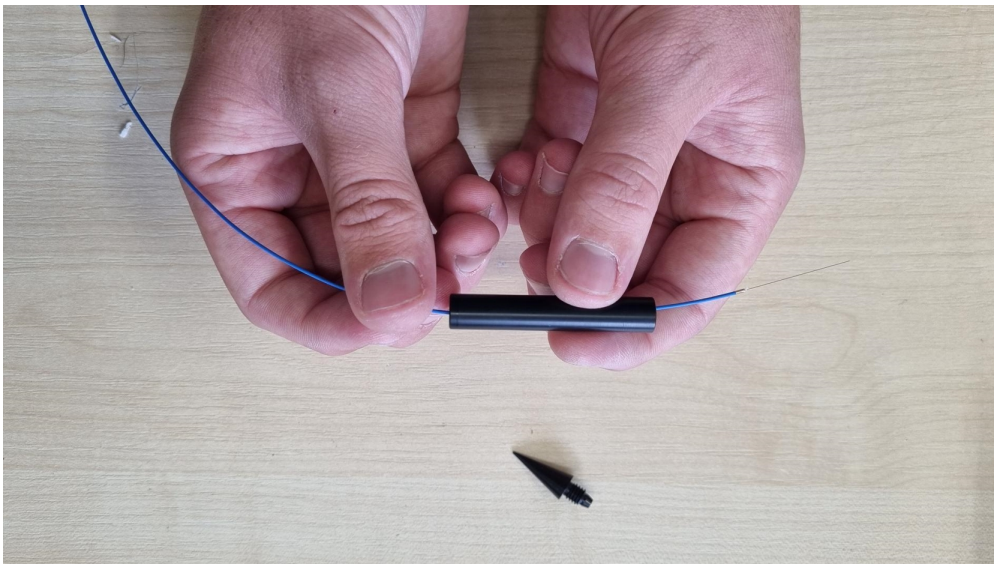
- Avoid contamination of the connector
  - Always ensure the dust-cap mechanism fully covers the fibre tip of the sensor when not attached to the system.
  - DO NOT allow the connector to get wet or submersed in water*.
- Avoid contamination of the front panel adaptor
  - When the system is not in use, the front panel adaptor dust cap should be attached at all times.
  - DO NOT insert anything other than a fibre connector into the adaptor.

* If the connector is dropped into water or gets wet, allow to dry thoroughly and then use one of the supplied emergency optical wipes to clean the connector ferrule thoroughly. Allow to dry again and then use the Neoclean-E cleaner prior to connecting the sensor to the system.

Mounting the Hydrophone

The fibre-optic hydrophone system is supplied with a black removable mount compatible with Precision Acoustics Ltd needle hydrophone mounts. To load the hydrophone into the mount first detach the cone section from the shaft of the mount, then thread the fibre through the shaft. Ensure the plastic sleeve is removed from the tip of the hydrophone and very carefully thread the tip through the cone section. Do **NOT** force the tip through the cone section if resistance is met. Instead retract the fibre a small distance and attempt insertion at an altered angle of entry. Screw the shaft section back onto the cone, just tight enough for the fibre to be gripped.

DO NOT OVER-TIGHTEN THE SHAFT – doing so may damage the hydrophone. Similarly over tightening with no fibre installed will damage the cone section.



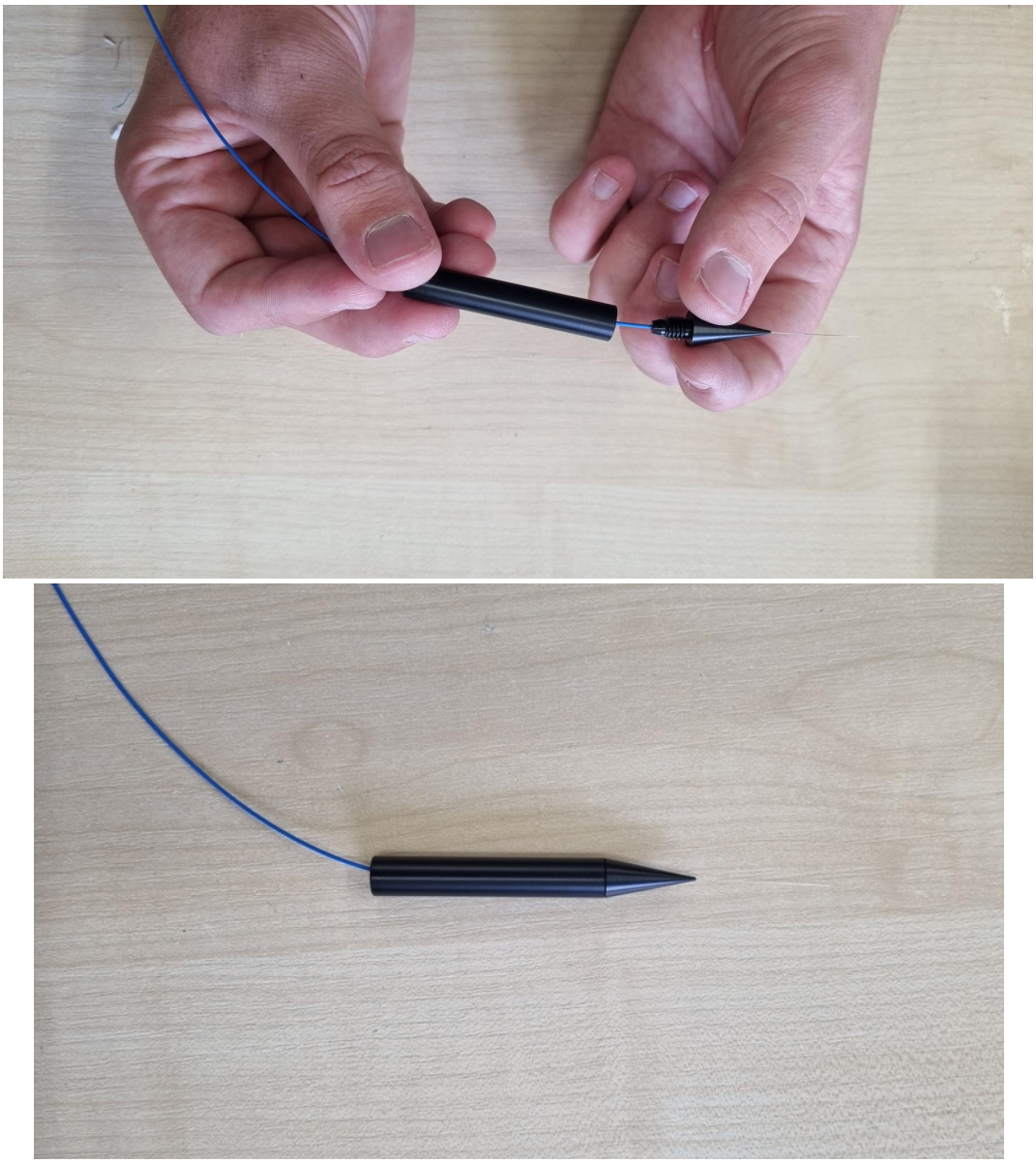


Figure 3. Mounting a fibre-optic hydrophone in the Precision Acoustics Ltd supplied removable mount.

Using the System

Initialisation

Once the system is switched on connected to the PC and relevant software installed as described in the previous Installation section, the control software application titled 'FOHS Application' should be launched by double clicking the desktop shortcut or locating the item from the Windows start menu

under the folder 'Precision Acoustics Ltd'.

As the system undergoes initialisation, a status indicator will flash orange. This indicator should turn green as depicted after no more than 30 seconds. If the indicator continues to flash orange for longer than this, please consult the **Troubleshooting** section of this manual.

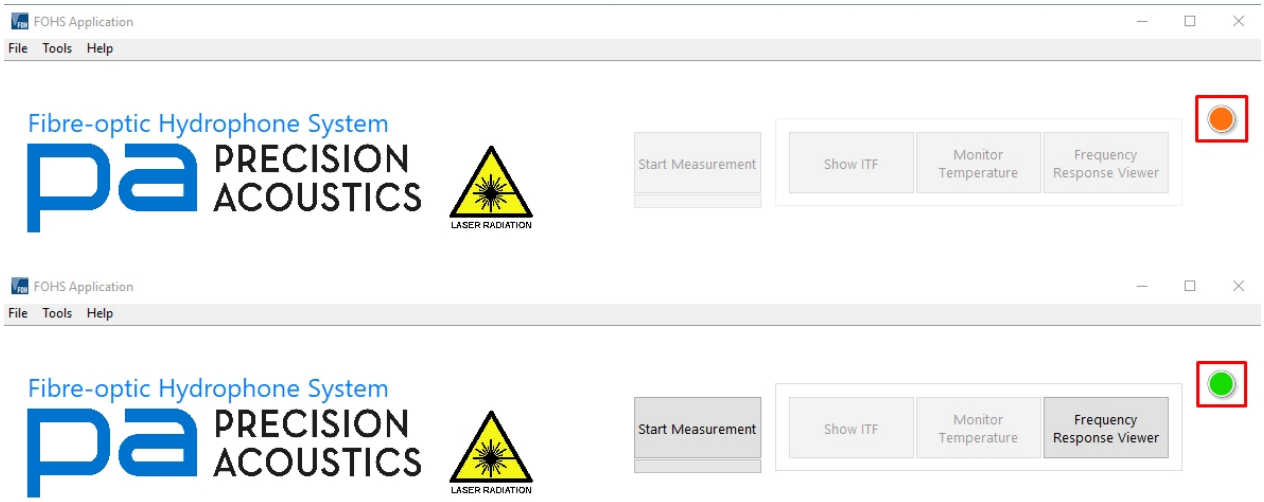


Figure 4. Highlighting initialisation status LED.

Starting a Measurement

The 'Start Measurement' button highlighted below carries out a sequence of functions to allow the operator to utilise a FOH connected to the control unit at optimal sensitivity. Visual progress feedback is delivered to a user through a progress bar overlay on the application icon of the Windows taskbar and a progress bar beneath the 'Start Measurement' button.

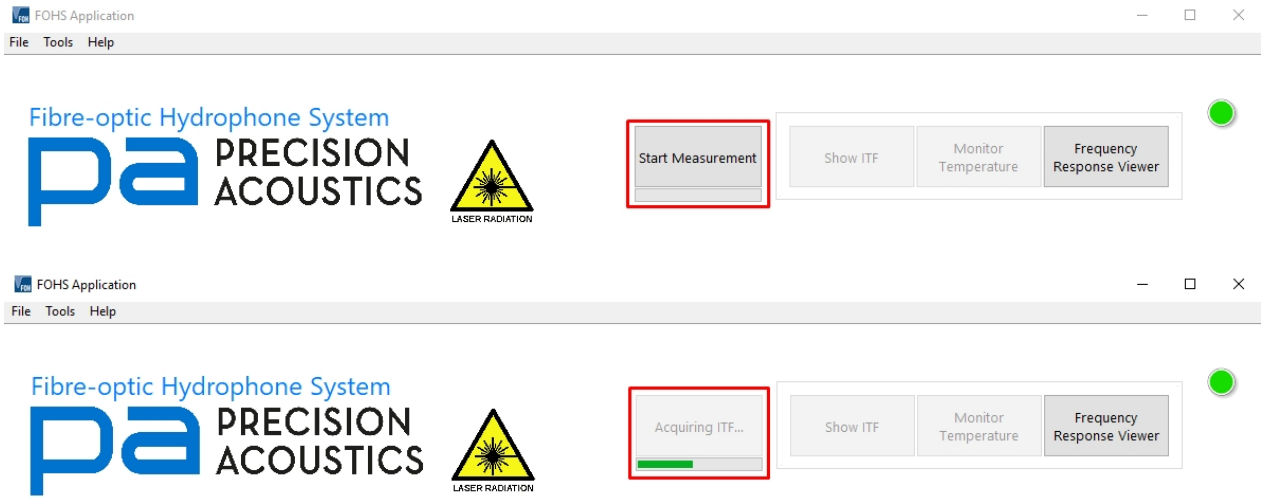


Figure 5. Progression of the 'Start Measurement' sequence.

Upon completion additional system status information will be presented to the FOHS user such as

laser status and the system will be set to automatically bias the plugged in hydrophone to maximum sensitivity.

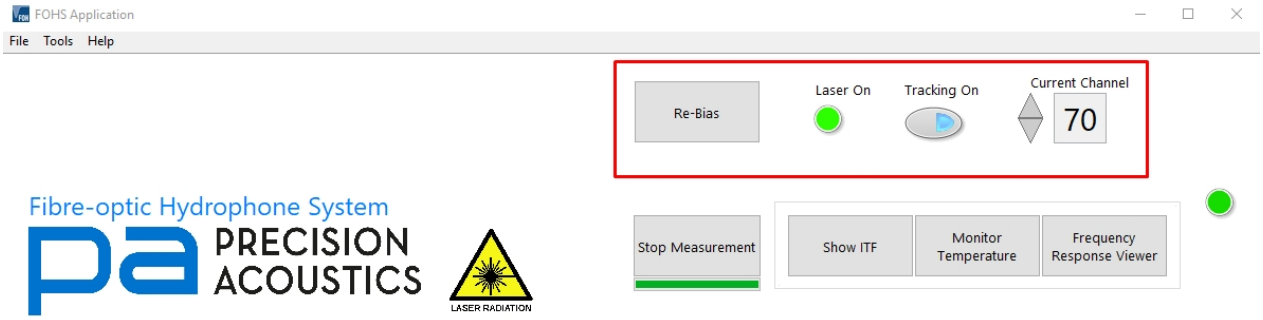


Figure 6. Available controls and indicators following completion of the 'Start Measurement' sequence.

In order to restore the FOHS to a resting initialised state that is ready to measure again press the 'Stop Measurement' measurement button which will have replaced the 'Start Measurement' button after it has been pressed.

Displaying the Interferometer Transfer Function

After commencing a measurement via the **'Start Measurement'** button, the ITF most recently captured and which is currently being used to bias the hydrophone is available via the 'Show ITF' function highlighted in the below picture. When pressed, a graph displaying data corresponding to sensor reflectivity at each laser channel will be presented. Use the 'Re-Bias' button to trigger the system to remeasure another ITF and bias with respect to the remeasured ITF.

Figure 7. Typical ITF measured by the Fibre-optic Hydrophone System v2.

Temperature Measurements

The temperature monitoring functionality of the Fibre Optic Hydrophone System can only be initialised following the start of a measurement.

Temperature monitoring can be launched through pressing of the **'Monitor Temperature'** button which is highlighted for convenience below and through the system tray icon discussed previously.

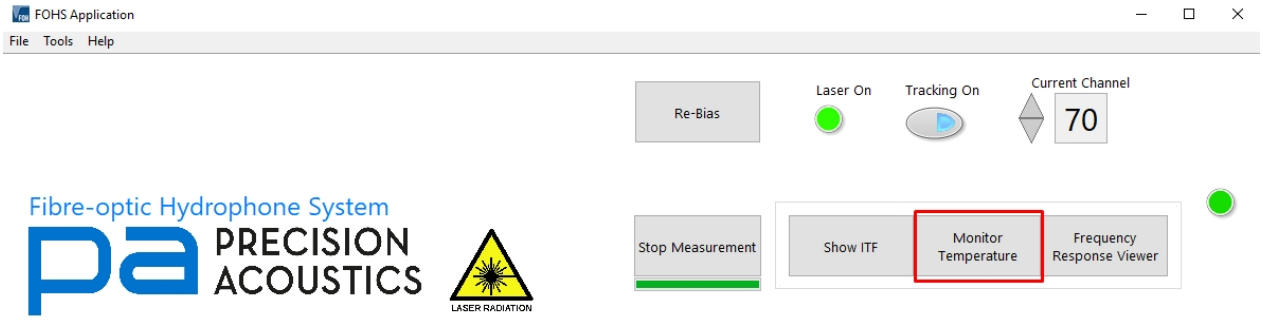


Figure 8. Highlighting position of the **'Monitor Temperature'** button.

After pressing '**Monitor Temperature**' the application will present a graph plot for temperature monitor and its associated controls as highlighted in the below image.

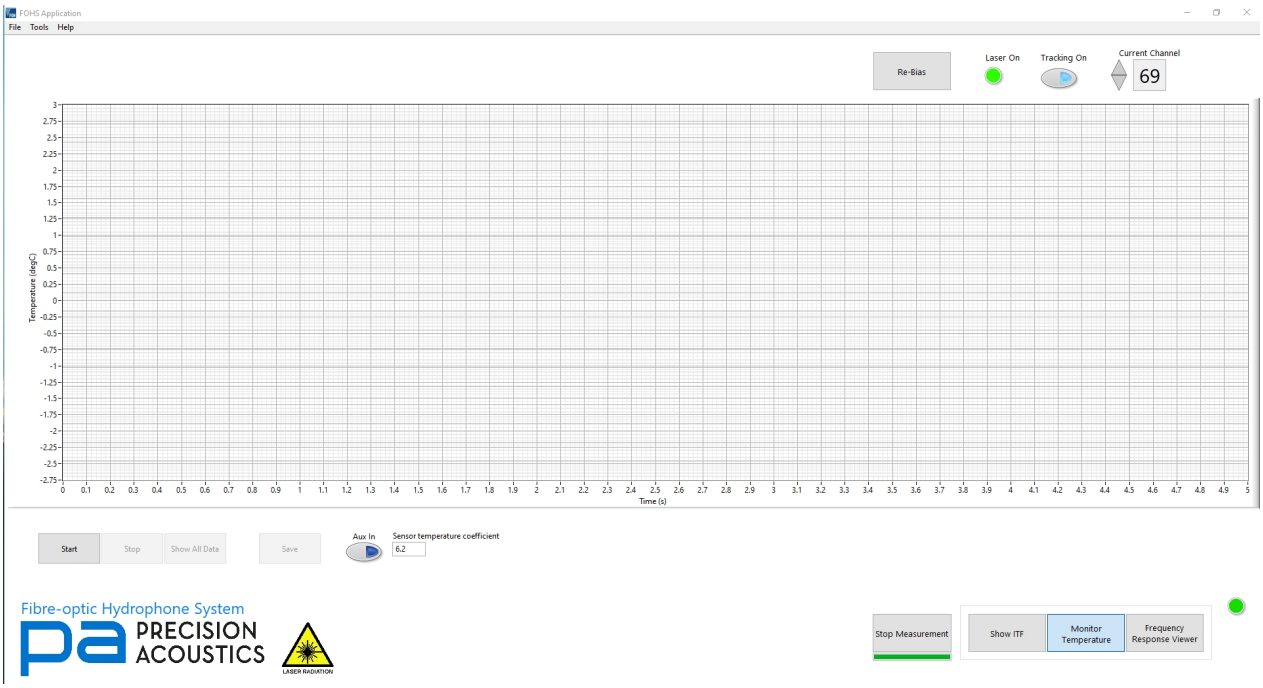


Figure 9. Temperature measurement UI.

From this display, a user has the capabilities to start temperature monitoring as and when is required

alongside stopping an already running temperature monitoring sequence. Once a period of temperature to save logged acquired temperature measurement data.

For improved user experience, the application logs temperature data in a temporary .tdms file which has a default path to the system temperature logs folder. This can be used to retrieve temperature data in the event of a crash or other unexpected closure of the application.

Sensor Temperate Coefficient Recalibration

When using the Fibre Optic Hydrophone System to perform relative temperature measurements, a temperature coefficient (K/nm) associated with frequency shift in the returned laser signal is utilised.

If recalibration of this coefficient is required the following procedure should be carried out:

1. Open the Precision Acoustics Ltd FOHS Application.

2. On the application press **Start Measurement.**

3. After ITF acquisition and bias sequence press **Monitor Temperature.**

3. After the temperature monitoring options become available, set the temperature coefficient value to 1.

4. Fill two appropriately sized containers with distilled water of known yet different temperatures.

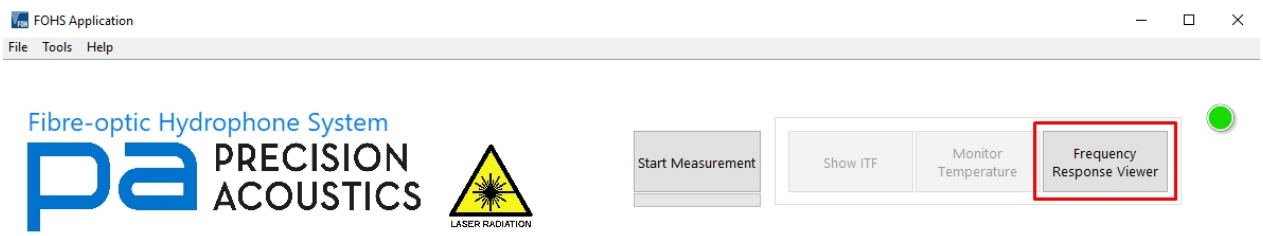
5. Proceed to place the sensor in either container of water and leave for 20 seconds to allow the sensor to reach thermal equilibrium.

6. Begin temperature monitoring (double check live plotting is relatively flat and stable) before moving sensor to the other water container.

7. The new temperature coefficient can be determined by dividing the actual temperature difference between the two volumes of water by the 'temperature change' recorded by the system after sensor between the two water containers.

Viewing Sensor Frequency Response

Clicking the '**Frequency Response Viewer'** button shows the frequency response of the hydrophone selected from the drop-down menu 'Sensors'. Frequency response data for the sensors supplied with the system are stored on the system itself.



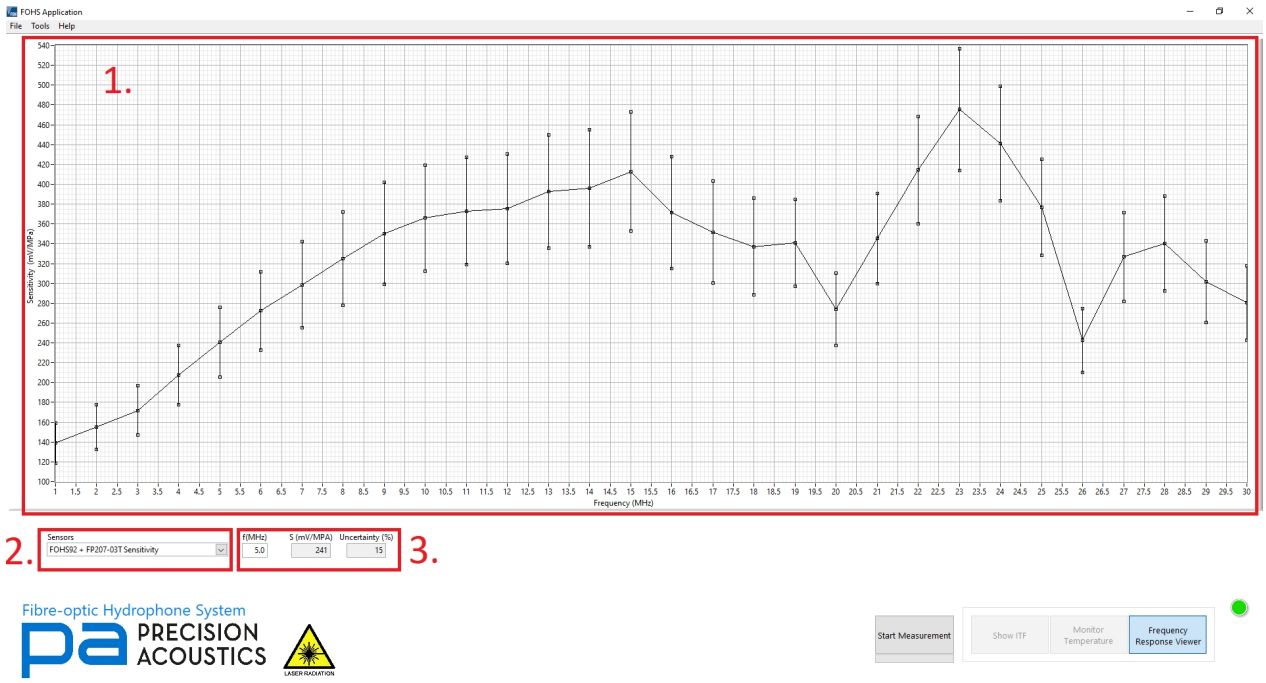


Figure 10. Frequency Response Viewer button and UI used to review stored calibration data of fibre-optic hydrophones on the system.

To retrieve the sensitivity of the selected sensor at a particular frequency, enter the desired frequency in the control below the graph (**f (MHz)**). The sensitivity in mV/MPa and associated percent uncertainty are then displayed alongside.

The following image depicts the Frequency Response Viewer UI with a test data set.

1. Display Area - Displays calibration data with error bars for specified sensor.

2. Sensors Drop Down - Select which sensor data file to load from the system directory.

3. Frequency to Sensitivity Calculator - Provides the user an input field for frequency (MHz) and returns the expected sensor sensitivity and uncertainty at the specified frequency for the open data file.

Aux In

The front panel of the hydrophone system includes a BNC connector labelled **'Aux In'**. This is connected internally to an A-D card enabling external analogue signals to be recorded alongside any temperature measurements. This may be useful for the synchronization of temperature and pressure measurements if a “gate” signal is recorded to indicate the switching on/off of the ultrasound field.

Please consult the **'Supplier details'** section of this manual to get in touch if you would like more information on usage of this feature.

Sync out

In addition to the Aux input, the hydrophone system provides a **'Sync out'** signal from the front panel. The sync output provides a square wave TTL signal with a low-high switch occurring for each measurement point on the temperature time curve. This signal is provided to facilitate the synchronous acquisition of acoustic waveforms and temperature rises. It is important to note that there is a low-high switch (i.e. rising edge) for each measurement point, but that some measurement points are recorded by the system as “not a number” (NaN). This is to minimize the effect of artefacts in the temperature measurement arising from the tuning of the laser during temperature acquisition. Synchronisation of temperature and pressure acquisitions is maintained by recording the time value of each measurement point/pulse, but recording NaN in the temperature measurement data when the measurement coincides with a laser tuning event.

Please consult the **'Supplier details'** section of this manual to get in touch if you would like more information on usage of this feature.

Changing the Sensor

If the user wishes to change the sensor or disable the laser output for any reason, clicking the **'Stop Measurement'** button in the main controls will disable the laser and return the system to a waiting state. The sensor can then be changed safely and a new measurement task started.

Troubleshooting

Initialisation Issues

Please use the following general steps if you encounter any issues with system/control software initialisation.

1) Reboot the system via the power switch on the rear of the system. Ensure the green power on LED is lit and the system is connected to the computer via the supplied USB. If the green on LED is not lit and you cannot hear the system fan begin its spin up when turned on. Please consult the **'Supplier details'** section of this manual to get in touch.

2) Following procedure detailed in step 1). Ensure the system storage drive is discoverable via the windows file explorer. The system drive should be accessible and have the name 'FOH_SYSTEM'. If it is not discoverable, please consult the **'Supplier details'** section of this manual to get in touch.

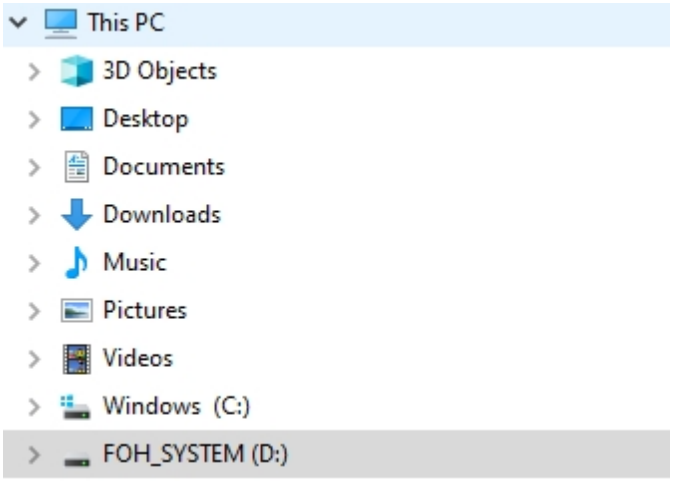


Figure 11. Example of FOH_SYSTEM drive visible on file explorer as drive D:

3) Open the FOHS Application. Head to tools > Configuration as depicted in the picture below.

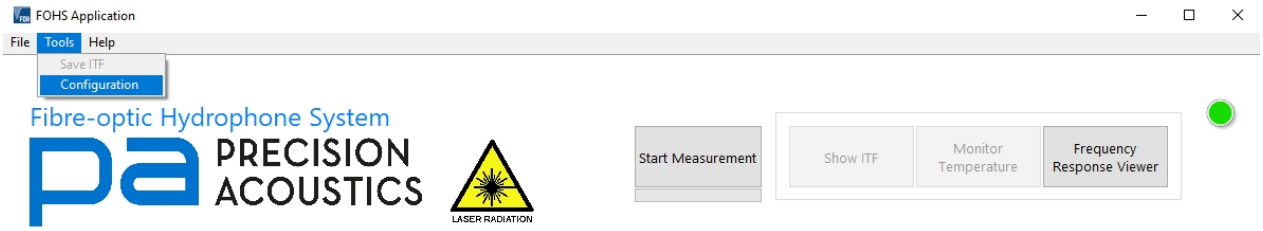


Figure 12. Location of configuration menu.

Navigate to the configuration page titled **'FOHS Control'**. Verify that the page is configured sensibly as shown below.

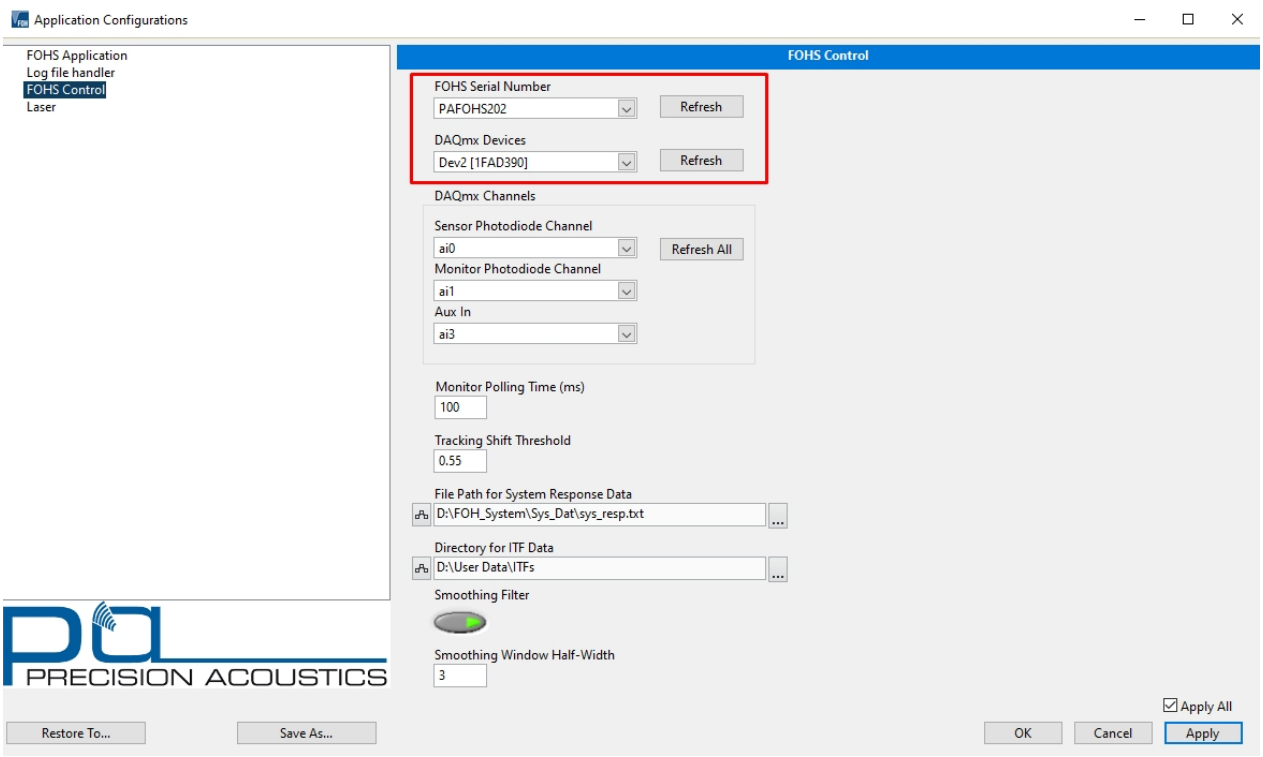


Figure 13. Example PAFOHS202 serial number configuration.

If the highlighted fields are blank please use the drop down menus and refresh button to select appropriately. After making selection press 'Apply' on the configuration window and then press 'OK'. Reboot the software application to reattempt intialisation.

If the drop down menus of 'DAQmx Devices' and FOHS Serial Number are not populated, close software, reboot the system and check again. If problem persists, please consult the **'Supplier details'** section of this manual to get in touch.

Fibre Integrity Check with Visible Light Source

The hydrophone is (optionally) supplied with a visible light source for fault checking and to aid alignment. If it is suspected that a sensor is broken, the visible light source can be used to verify this.

1. Attach the Visible Light Source

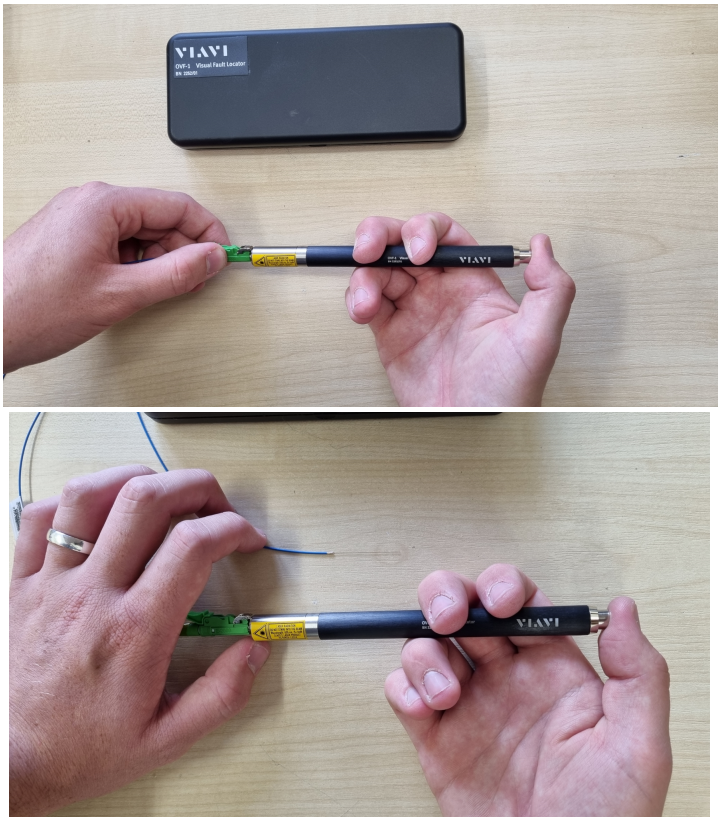


Figure 14. Attaching the JDSU visible light source to a fibre-optic hydrophone.

Once the visible light source is connected to the hydrophone and switched on, a red glow will be visible both at the tip of the fibre and where at the connector end. This is normal.

2. Check the Hydrophone Tip

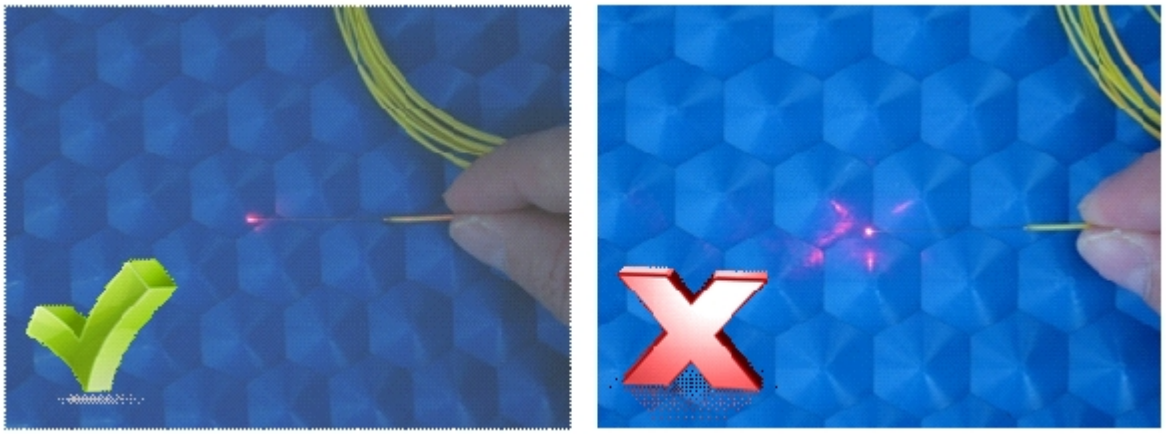


Figure 15. Comparison image of a working fibre-optic hydrophone (left) and a broken tip fibre (right).

An undamaged hydrophone tip will glow slightly with the red light from the visible source. If the tip has been damaged, significantly more light will be visible leaving the hydrophone tip.

3. Check for Bends

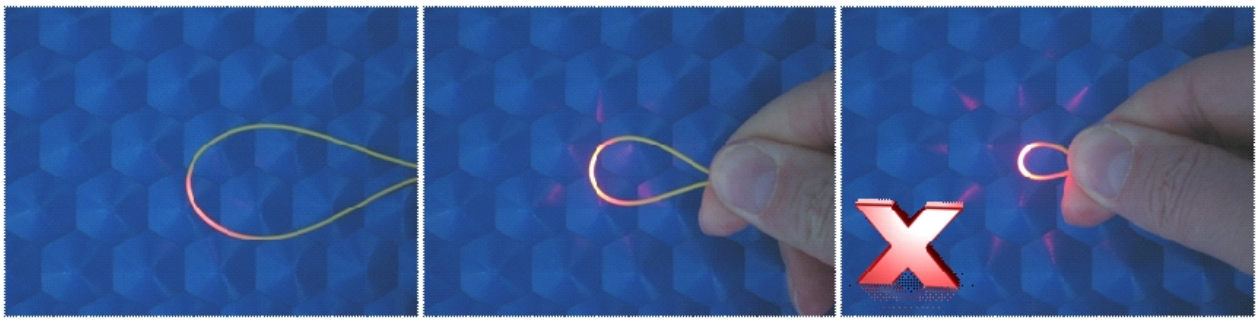


Figure 16. Comparison images of light leakage in a bent fibre.

A bend in the fibre causes light to escape. All bends should be avoided, but the tighter the bend the more light is lost, and the higher the risk of breaking the fibre.

4. Check for Breaks

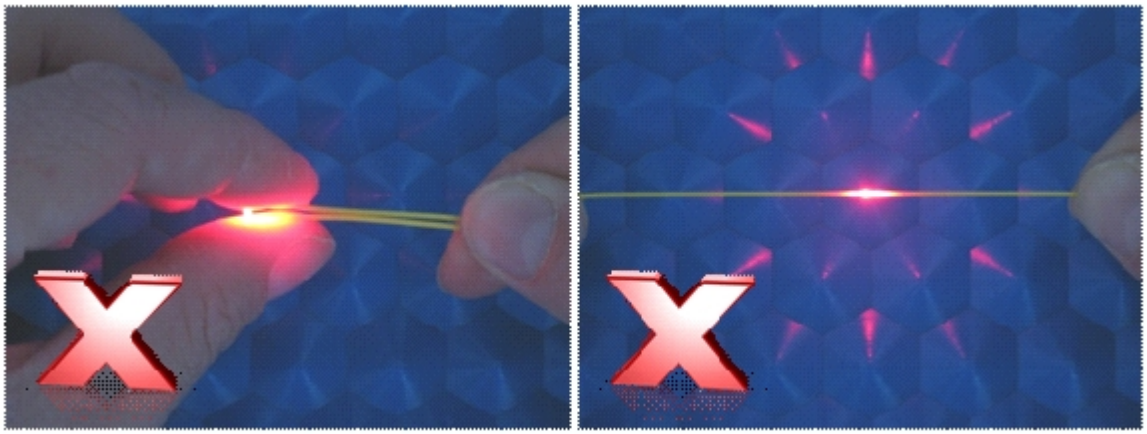


Figure 17. Light leakage in a fibre broken.

If the fibre is bent too far, it will snap internally. In this case all of the light will escape and a bright point of light will be seen through the fibre jacket.

Warranty

Products are covered against defect of manufacturing or workmanship only.

Warranty period: Control unit and accessories 12 months.

If a warranty claim is made on devices that have been calibrated at NPL London a charge will be made for the used part of the calibration (e.g. failure of fibre probe at 3 months charge for recalibration at NPL is 50% of calibration charge).

Supplier details

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