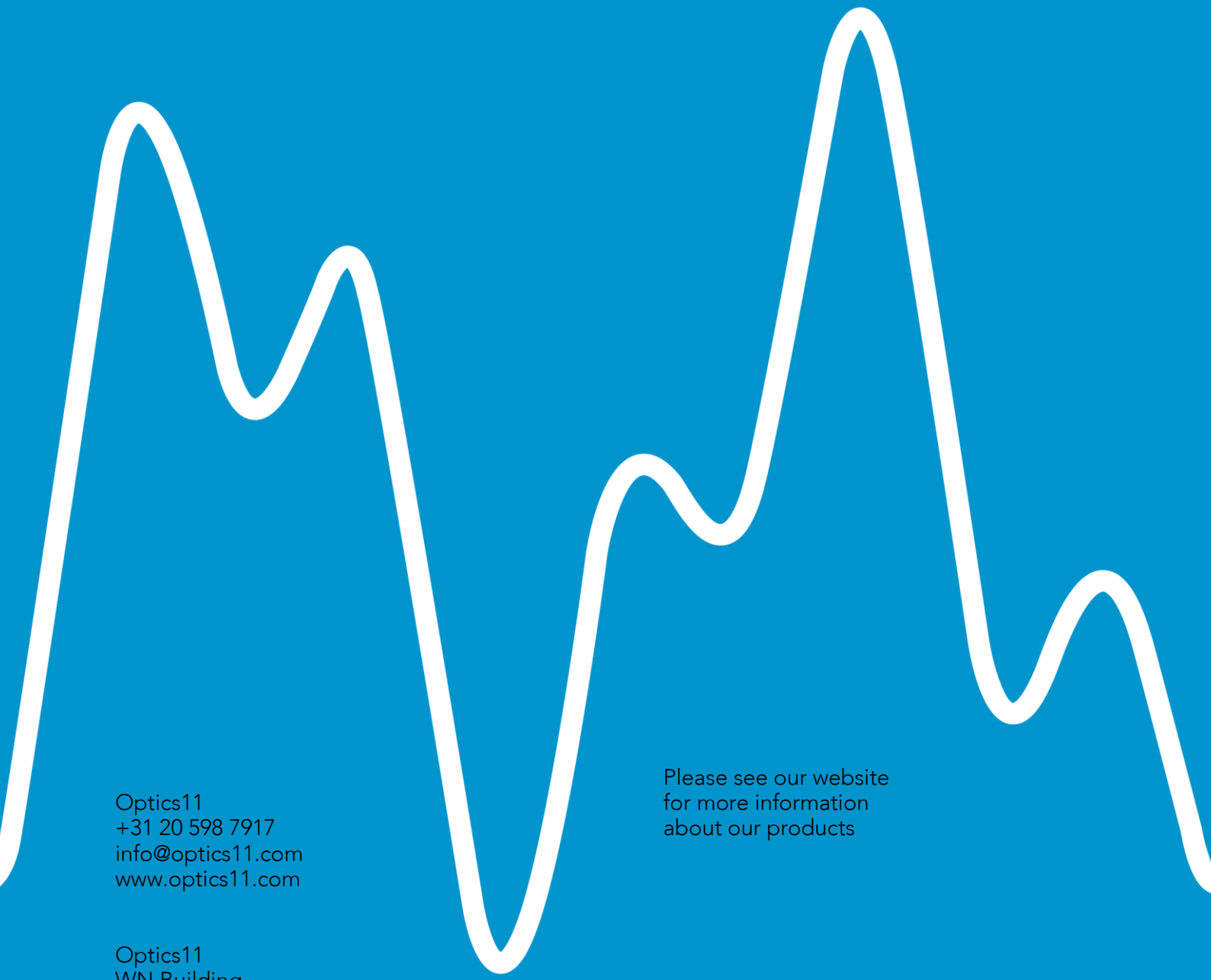
USER MANUAL

OPTICS11 – 14 SERIES



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for more information
about our products

CONTENTS

1 DOCUMENT INFORMATION

Document Revision History

ISSUE	*ISSUE DATE*	*CHANGE*
Rev01 (this document)	22nd March 2021	New Document

2 SAFETY

WARNING: If equipment is used in a manner not specified by the manufacturer, its safety may be impaired. There are no internal user-serviceable parts.

LASER RADIATION
DO NOT VIEW DIRECTLY WITH OPTICAL INSTRUMENTS
CLASS 1M LASER PRODUCT

The I4 series interrogators include a laser that is classified as class 1M per IEC standard 60825-1 (2007-03). This laser complies with FDA/CDRH, 21 CFR 1040.10 and 1040.11 except for deviations pursuant to Laser Notice No. 50, dated June 24, 2007.
CAUTION: Invisible Laser Radiation - Do not view directly with optical instruments (magnifiers). Viewing the laser output with certain optical instruments (e.g., eye loupes, magnifiers, and microscopes) within a distance of 100 mm may pose an eye hazard. Laser power up to 100 mW at 1.55 µm could be accessible if optical connector is open or fibre is broken. Use of controls, adjustments, and procedures other than those specified herein may result in hazardous laser radiation exposure.

3 INTRODUCTION

This document describes the features of the graphical user interface to the Optics11 I4 series of optical interrogators, and the basic operation of the system.

4 I4 SERIES INTERROGATORS FEATURE COMPARISON

The I4 Series interrogator family of premium quality Fiber Bragg Grating (FBG) monitoring instruments are used in many industries. The main feature differences may be summarised as follows.

Product	Fibre Channels	Sweep Range	Sensor Scan Frequencies	Enhanced Timing Supported? [2]	Polarisation Switch Supported?	Spectral Rate
I4G	4	39.2 nm	1kHz, 2kHz, 4kHz, 8kHz [1]	YES	YES (1kHz only)	4Hz (4 Channels) 16Hz (1 Channel, spectral Sensor)
I4-16	16	39.2 nm	250Hz	NO	YES	1Hz (16 Channels) No spectral sensor Support (same as I4G in 4-channel mode).
I4W	4	35 nm	1kHz	NO	NO	4Hz (4 Channels) 16Hz (1 Channels, spectral Sensor)
I4W-16	16	35 nm	250Hz	NO	NO	1Hz (16 Channels) No spectral sensor Support.

[1] See details of scan frequencies for I4G in Appendix of this document.

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5 I4 SERIES SPECIFICATIONS AND IDENTIFICATION

5.1 I4G Interrogator System Specification Table

Parameter	Min	TYP	MAX	UNIT	Comments
Communications Interface		100		Mbps	Primary communications over Ethernet
Input voltage		12		V	Auto detect 90 to 255AVC → 12V supply block included
Power Consumption		<25		W	
Input Trigger High Level (Gate In)	0.8	1.5		V	The input impedance of "Gate In" is 50 ohms
Input Trigger Low Level (Gate In)		0.4	0.7	V	The input impedance of "Gate In" is 50 ohms
Input Trigger Min/Max Voltage (Gate In)	-0.2		3.0	V	
Dimensions (W x D x H)		421.65 * 330.2 * 43.7		mm	
Operating Temperature	0	25	55	°C	

5.2 I4-16 electrical spec.

Parameter	Min	TYP	MAX	UNIT	Comments
Communications Interface		100		Mbps	Primary communications over Ethernet
Input voltage		12		V	Auto detect 90 to 255AVC → 12V supply block included
Power Consumption		<26		W	
Input Trigger High Level (Gate In)	0.8	1.5		V	The input impedance of "Gate In" is 50 ohms
Input Trigger Low Level (Gate In)		0.4	0.7	V	The input impedance of "Gate In" is 50 ohms
Input Trigger Min/Max Voltage (Gate In)	-0.2		3.0	V	
Dimensions (W x D x H)		324 * 276 * 116		mm	
Operating Temperature	0	25	55	°C	

5.3 I4W electrical spec.

Parameter	Min	TYP	MAX	UNIT	Comments
Communications Interface		100		Mbps	Primary communications over Ethernet
Input voltage		12		V	Auto detect 90 to 255AVC → 12V supply block included
Power Consumption		<25		W	
Dimensions (W x D x H)		323.3mm x 276mm x 87.25mm			
Operating Temperature	0	25	55	°C	

5.4 I4-16W electrical spec.

Parameter	Min	TYP	MAX	UNIT	Comments
Communications Interface		100		Mbps	Primary communications over Ethernet
Input voltage		12		V	Auto detect 90 to 255AVC → 12V supply block included
Power Consumption		<26		W	
Dimensions (W x D x H)		323.3mm x 276mm x 116mm			
Operating Temperature	0	25	55	°C	

5.5 Recommended client PC specification

Operating System	Minimum Windows 7, 64 bit.
Processor	3.4 gigahertz (GHz) or faster
RAM	8 GB RAM
Disk Space	Minimum 5 GB
Display	Minimum screen resolution for FemtoSense: 1440x900

5.6 Product Numbering Reference

	Product	Level	Variant	MAX
FZ	I400	00	AA	4 Channel High Speed Tuneable Laser Interrogator - 1U Chassis, C-Band Laser (I4E)

FZ	I401	00	AA	4 Channel High Speed Tuneable Laser Interrogator - 2U high Chassis, C-Band Laser, with Polarization Switch (I4G)
FZ	I401	00	AC	4 Channel High Speed Tuneable Laser Interrogator - 2U high Chassis, C-Band Laser, Passive Depolariser (I4G)
FZ	I416	00	AA	16 Channel High Speed Tuneable Laser Interrogator - 3U high Chassis, C-Band Laser, with Polarization Switch (I4-16)
FZ	I401	00	WA	4 Channel High Speed Tuneable Laser Interrogator - 2U high Chassis, C-Band Laser (I4W)
FZ	I416	00	WA	16 Channel High Speed Tuneable Laser Interrogator - 3U high Chassis, C-Band Laser (I4-16W)

6 I4 SERIES SYSTEM SETUP

Connection to the system is established via a minimum 100Mbps Ethernet cable from the client PC to the IX interrogator.

The picture below shows the I4G interrogator, but system setup is identical of all the I4 series of interrogators.

Connect a 12V power supply to the *12V DC IN* connector on the rear of the interrogator. Also connect an RJ45 Ethernet cable to the *Ethernet* port at the rear of the unit. Turn the system on using the *Power* switch.

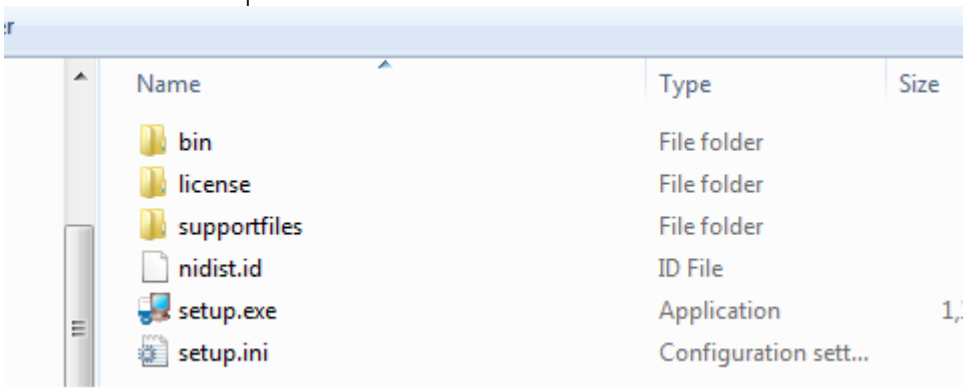
Note: It is recommended that a shielded ethernet cable is used. This is especially important in environments where strong Electromagnetic Interference (EMI) is present.

7 FEMTOSENSE INSTALLER

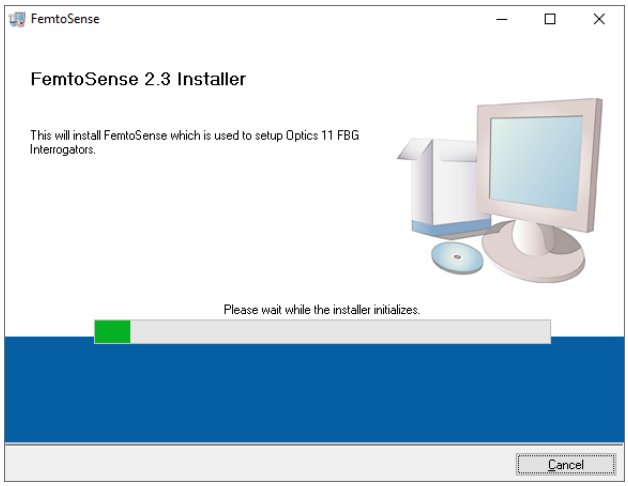
The FemtoSense installer is supplied with the interrogator and can be run on a client windows PC or Laptop.

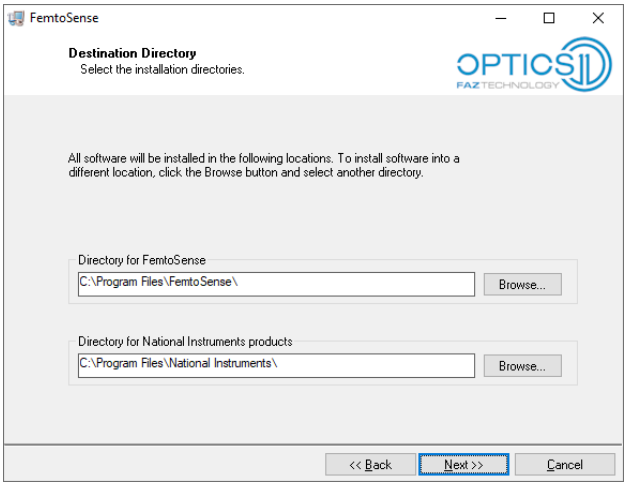
7.1 Running the Installer

Double-click “setup.exe” to start the installer:

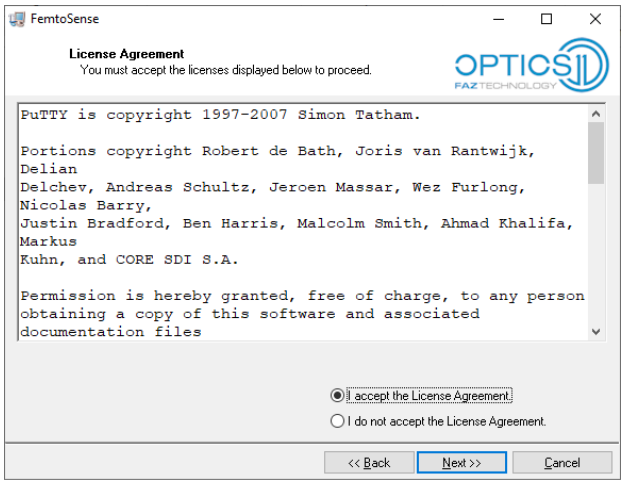


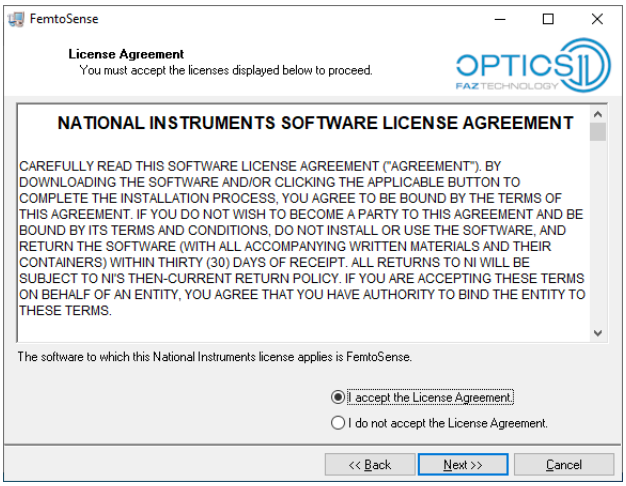
The Installation process will initialize and you will be prompted to select installation directories. Follow the instructions and click *Next* to progress through installation steps.



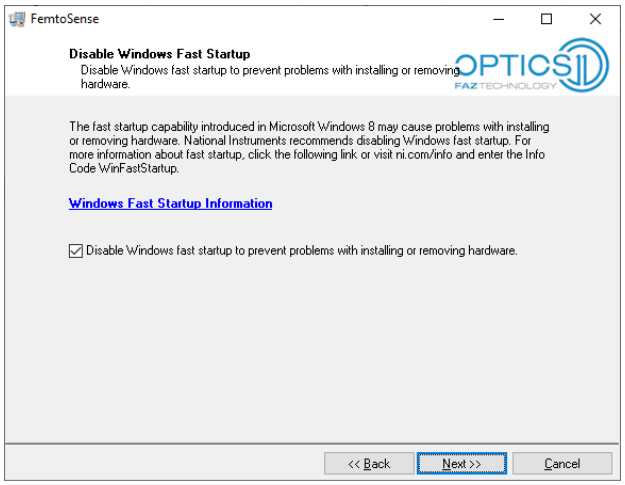


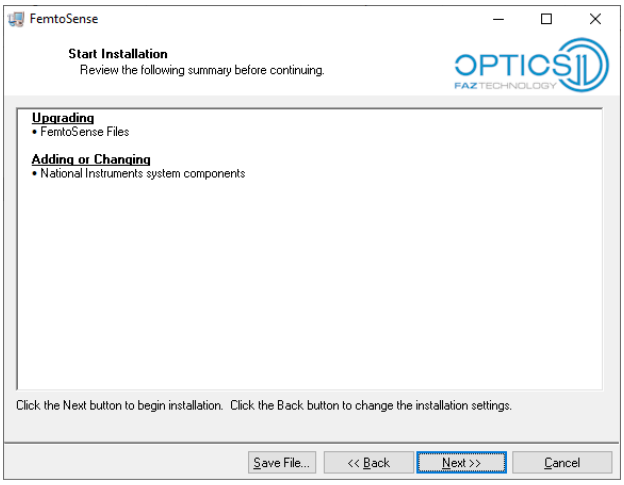
Accept the required license agreements to proceed the installation.



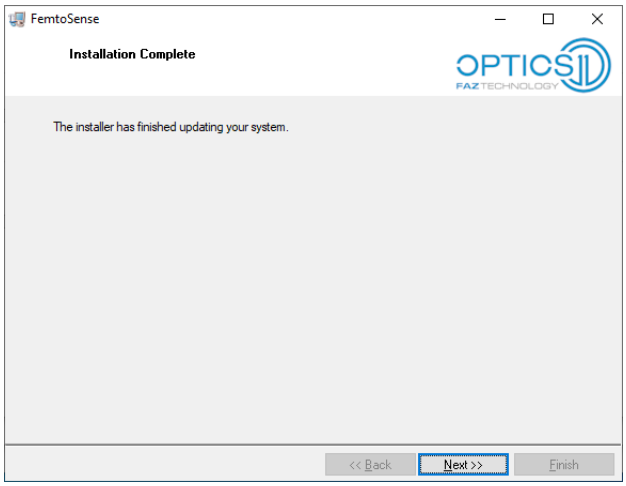


Follow the further instructions and continue to click on *Next* to begin the installation.





When the installation is complete the final window will be displayed to confirm the successful installation of FemtoSense.

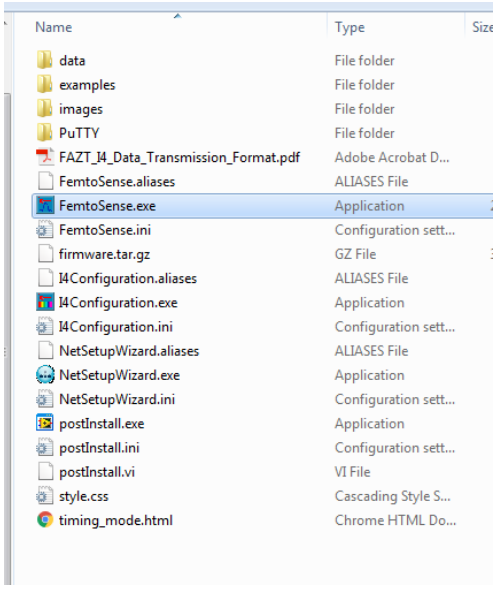


Click *Next/Finish,* restart the PC if prompted, and navigate to the installation directory: *C:\Program Files\FemtoSense .*

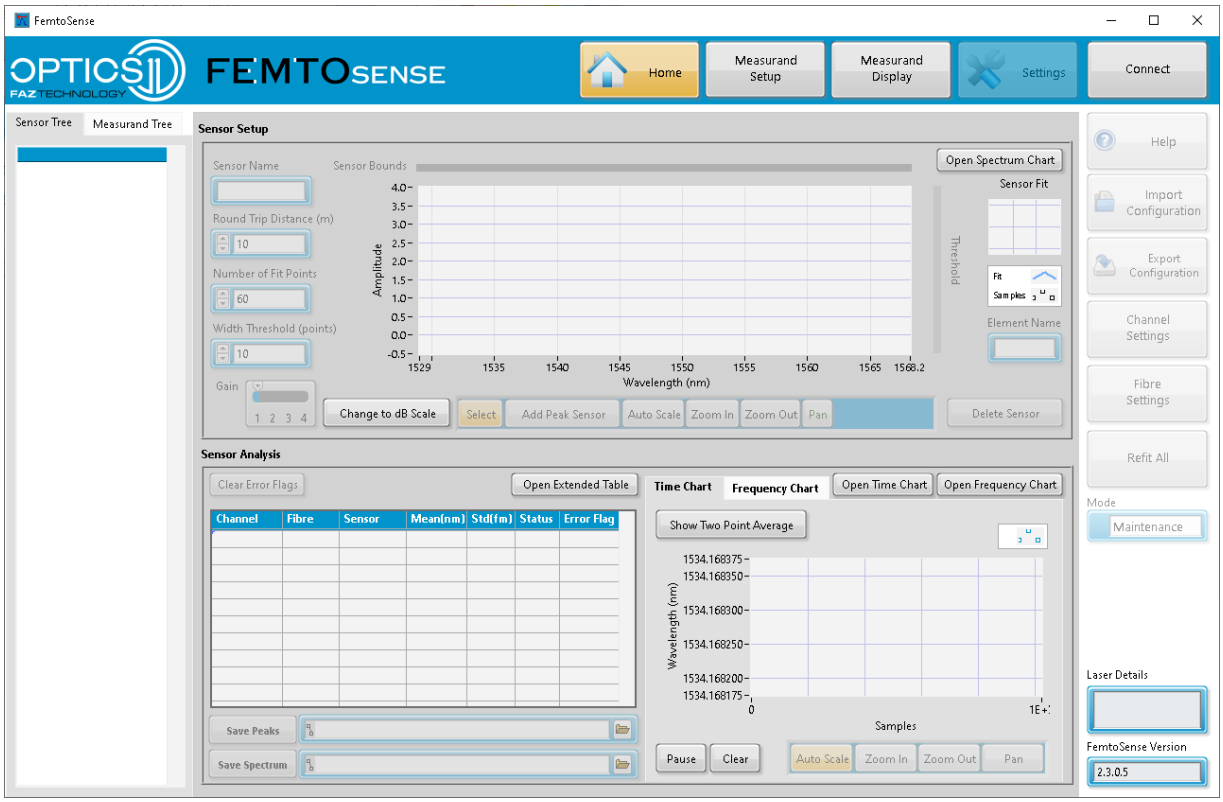
Note: a shortcut to FemtoSense will also be installed in the start menu for the client PC.

7.2 Starting FemtoSense

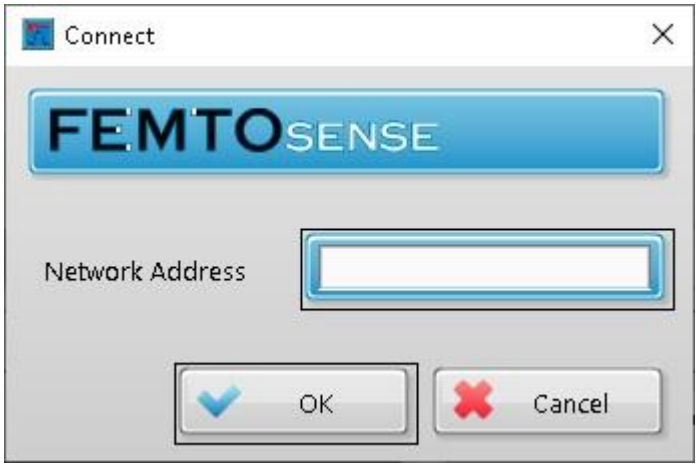
While in the installation directory double-click the "FemtoSense.exe" icon.



FemtoSense software will open in an idle state, without a connection to a I4 Series interrogator.



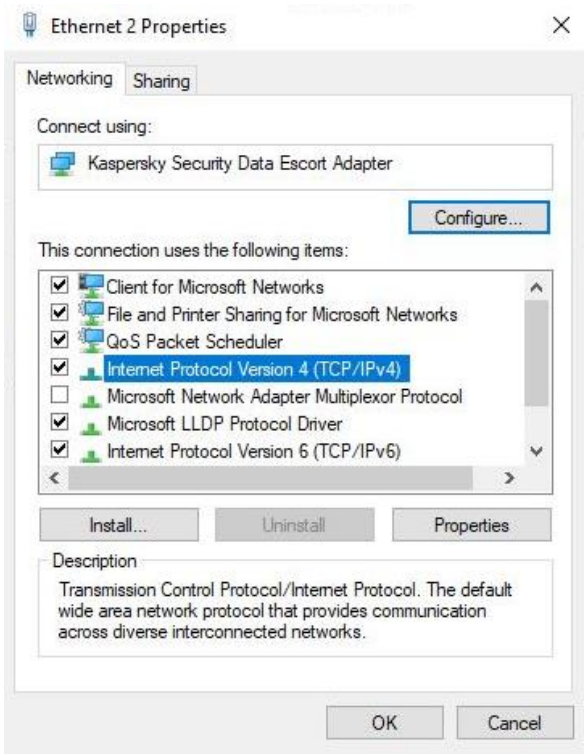
Click on a *Connect* button in the top right corner of the main screen to open a connection pop-up window.

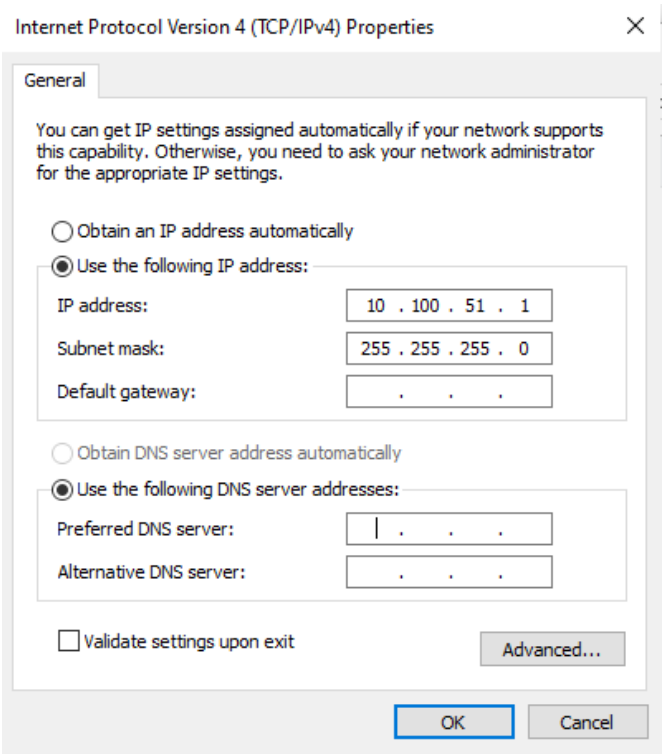


Enter the IP address of the interrogator unit in the *Network Address* box and click *OK*. The default address will usually be in the form "10.100.51.x" where x corresponds to the numerical value of the last digits of the interrogator serial number, e.g. "086" means that the IP address is "10.100.51.86".

Also note that if you have an isolated network where the interrogator is connected to a PC or Laptop using a point to point network cable, then you will need to set appropriate network properties on your PC/Laptop as isolated networks require a fixed IP address. For Windows PCs, these can be set up through the following (or similar) steps:

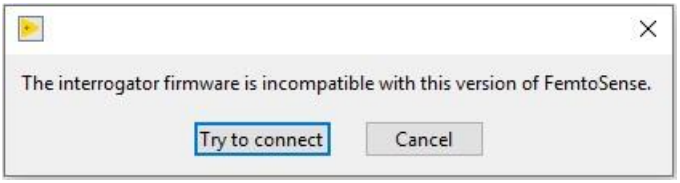
- Select **Start** > **Control Panel/Settings** > **Network and Sharing Center/Network & Internet**.
- Select correct **Local Area (Ethernet) Connection** > **Properties**.
- From the Local Area Connection Properties screen highlight **Internet Protocol version 4** and select **Properties**.
- Change the protocol properties as depicted below and click the "OK" button to confirm.



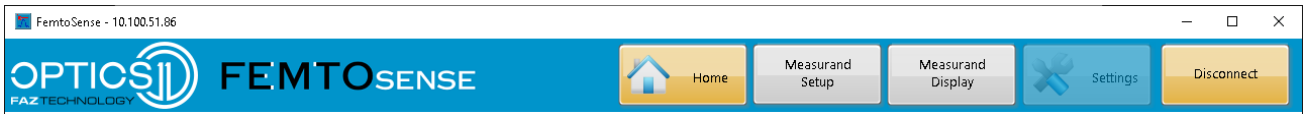


If interrogator firmware version is incompatible with FemtoSense version running on a client PC, a warning window is shown during the connecting process. Click *Upgrade* to start firmware upgrade process. Refer to the Appendix 1 at the end of this document for further information on Firmware Upgrade Procedure.

Note: Firmware downgrade (reverting to older version) is not supported. In this case, the *Upgrade* option is not accessible, and user should install latest version of FemtoSense software.



Once the connection between the interrogator and client PC is successfully established, the pop-up connection window will disappear, the *Connect* button will change into *Disconnect* button highlighted in yellow and the front panel LED will turn green.



Note: The internal IP address of the interrogator can be changed if necessary. Please refer to Appendix 2 "Changing the interrogator Network Address" for further instructions.

7.3 Front I4 Panel Status LED

While starting up, the front panel *Status LED* will normally transition through the following sequence:

Red – booting Embedded Linux OS.

White/Light Blue – starting the Interrogator based application software (SDS) – light may appear turquoise or light blue due to the nature of the tri-colour LED.

Blue – SDS has started and is waiting for a client connection.

Connecting to the I4 series Interrogator using FemtoSense sotware when the *Status LED* is blue makes it turn **green** indicating that the connection was successfully established. When FemtoSense is disconnected the *Status LED* reverts to **blue**.

7.4 Open Source Software

Some software components of this product incorporate source code covered under GNU General Public License (GPL), GNU Lesser General Public License (LGPL), and other open source licenses. To obtain the source code covered under the open source licenses, please contact Optics11 (support@optics11.com).

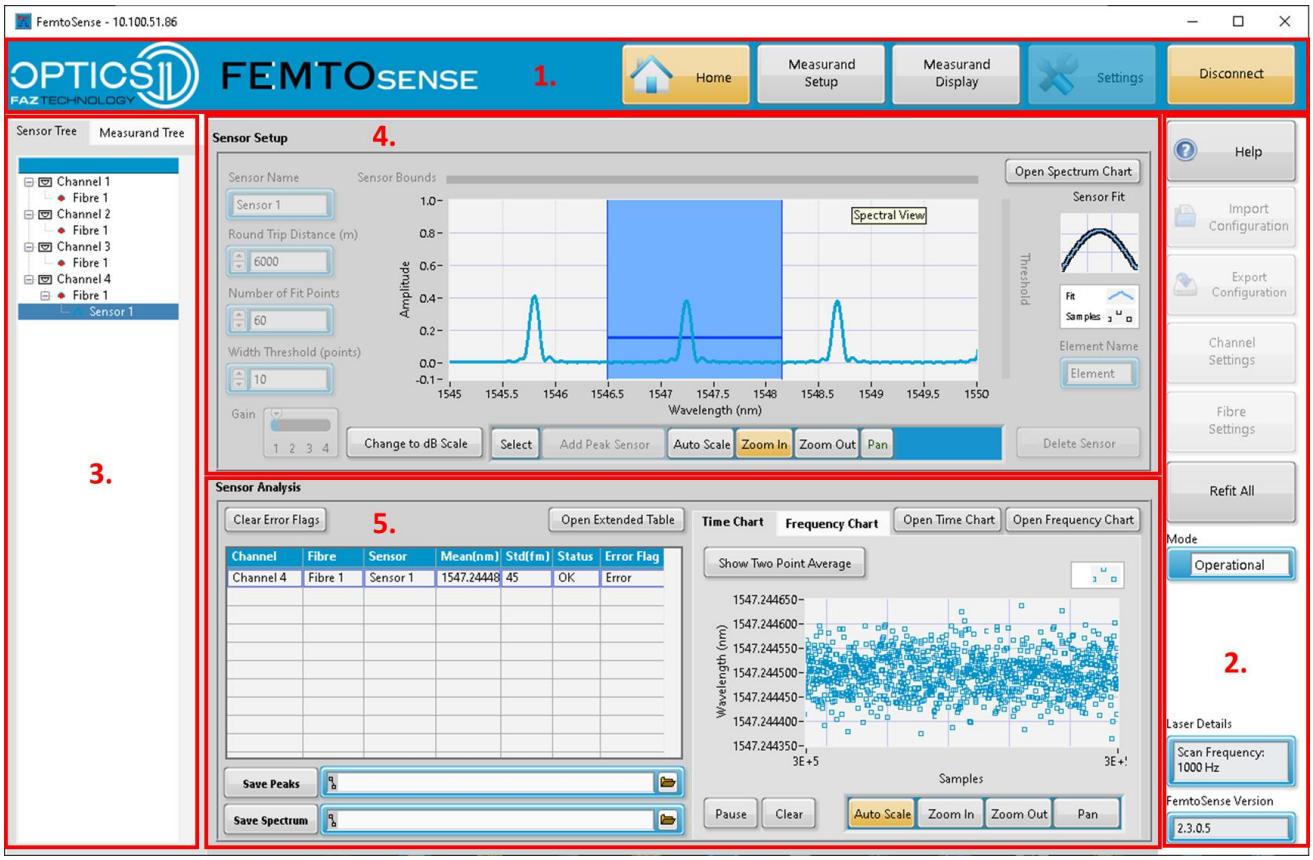
8 FEMTOSENSE FEATURES

FemtoSense is used to set up and monitor the interrogators. It includes functionality to:

- Set up and monitor optical wavelength sensors such as the wavelength of an FBG peak or the wavelength of a gas-cell trough.
- Set up and monitor spectral sensors; the spectrum detected by the interrogator is delivered to the user at a constant rate for one or more of the channels.

The functionality of the FemtoSense user application is broken down into the groups shown outlined on the figure below:

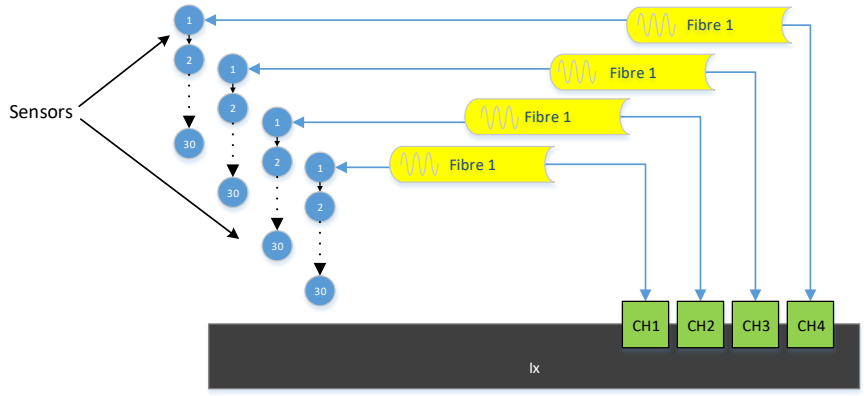
1. Main software ribbon allowing user to switch and access different tabs.
2. Basic functions and information pane.
3. Sensor/Measurand tree pane to view and select defined sensors/measurands.
4. Sensor/Measurand setup pane.
5. Sensor/Measurand analysis pane.



8.1 Channels and fibres

The terms "fibre" and "channel" are employed to support the use of optical multiplexers. In this release a single "fibre" connects to a single "channel" of the interrogator, but when the is used with a supported optical switch multiple "fibres" may connect to a single "channel".

The topographical layout of the system is described in the following terms:
"Channel" 1 – 4
- "Fibre" 1 - N
➢ "Sensor" 1 – 30

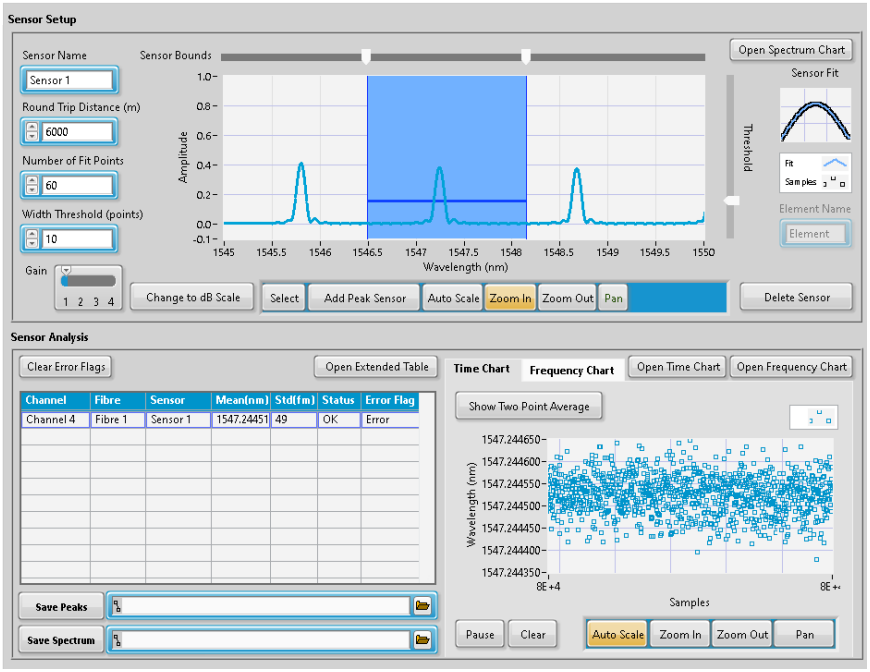


8.2 Main Software Ribbon

Main software ribbon allows user to switch between different application tabs.

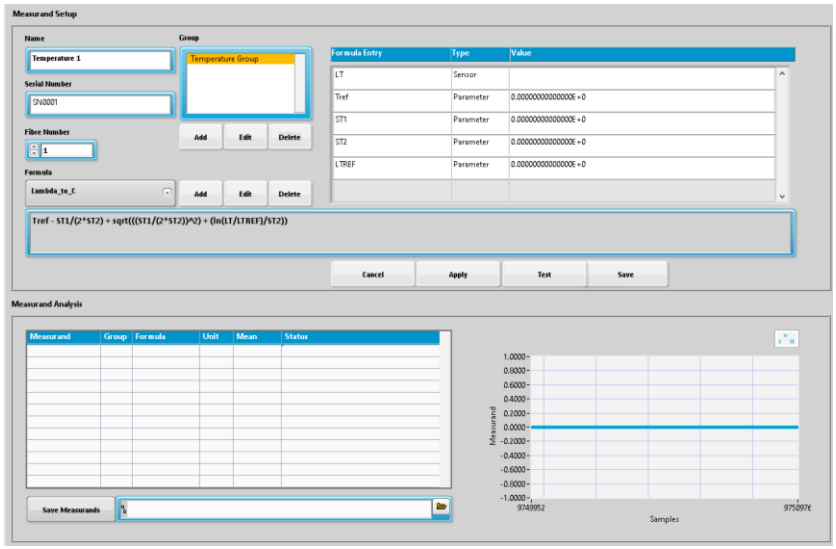
8.2.1 Home

Switches to the main *Home* (Sensor) FemtoSense tab where individual channels and sensors (FBGs) can be added and configured. Refer to chapter 8.5 for further information.



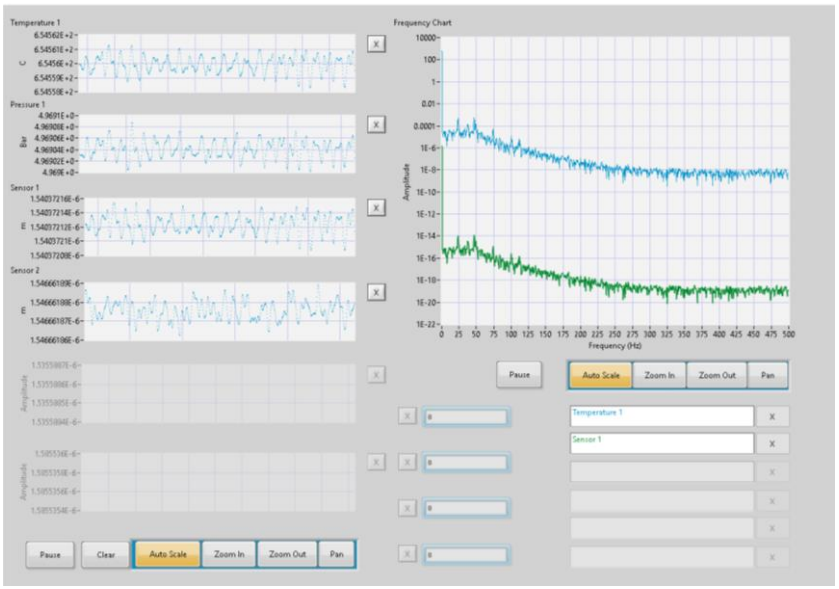
8.2.2 Measurand Setup

Switches to *Measurand Setup* FemtoSense tab where different measurands can be added and configured based on sensor data. Refer to chapter 8.6 for further information.



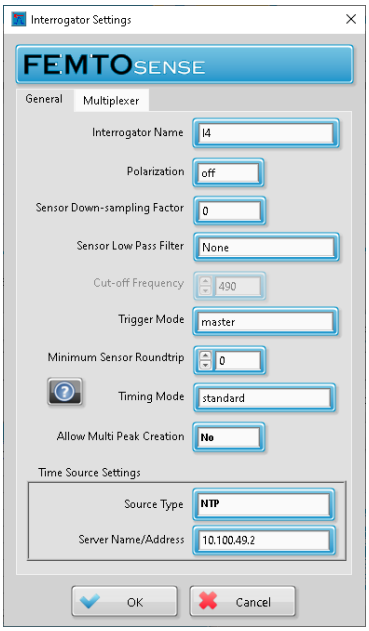
8.2.3 Measurand Display

Switches to *Measurand Display* FemtoSense tab where defined sensors and measurands can be conveniently monitored and compared. Refer to chapter 8.7 for further information.



8.2.4 Interrogator Settings

The high-level settings for the system can be accessed and changed via the *Settings* button. The settings under *Multiplexer* tab on this window are related to optical switches and are described later in Appenidx 4.



Use this tab to adjust following *General* interrogator setting:

8.2.4.1 Interrogator Name

This is a unique name for the Interrogator and is stored permanently in the interrogator's file system.

8.2.4.2 Polarization Off/On

This option allows the user to activate the interrogators polarization switch. When the switch is set to 'on' orthogonal polarization states are applied on alternating laser sweeps. The effect of this can usually be seen in the spectral view.

8.2.4.3 Sensor Down-sampling Factor

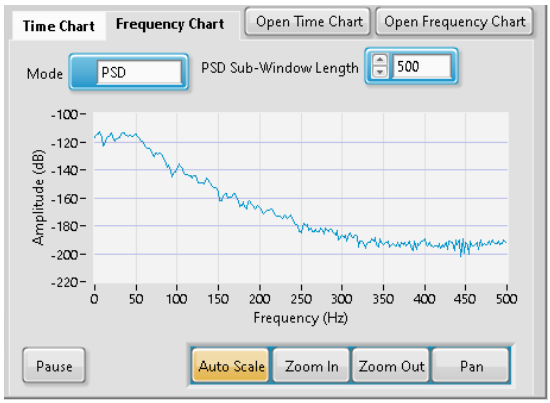
If a *Down-Sampling Factor* >1 (n) is applied to the data, the system will return peak data every nth sample. A *Down-Sampling Factor* of 0 or 1 has no effect on the data stream.
The FBG sample window will also update slower when the down-sample factor is higher. The highest down-sample factor is 1000.
Note: The data samples are first passed through the low pass filter block, and then through the down-sampling block.

8.2.4.4 FBG Low Pass Filter

The sampled FBG data can be filtered within the interrogator using a low-pass 4th order Butterworth filter. If other filter types are required, they can be applied by the user through post-processing of the data stream.
Note: The data samples are first passed through the low pass filter block, and then through the down-sampling block.

8.2.4.5 Cut-off Frequency (Hz)

The cut-off frequency can be set for the low-pass filter once the *Low Pass Filter* option has been enabled. The maximum cut-off frequency allowed is limited by the Nyquist frequency for the sweep rate, e.g. for 1 kHz sweeps the cut off frequency is limited to 499Hz.
The effect of this filter can be seen in the power spectral density (PSD) window; see below for an example of a 50Hz filter applied to the data from a stationary sensor.



8.2.4.6 Trigger Mode

Two trigger modes are supported by the I4G:

- *Master Mode* where the sweeps are triggered by the internal timing of the interrogator and run at a constant rate of 1 kHz.
- *Slave Mode* where the interrogator waits for an external signal before each sweep is triggered.

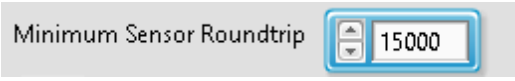
In *Slave Mode*, the external clock must be applied to the *Gate In* SMA connector on the rear panel of the I4G and has:

- Electrical characteristics as described in the I4G Specification Table in this document.
- A clock frequency greater than or equal to 950Hz and less than or equal to 1 kHz
- A high to low duty cycle of at least 45% and not more than 55%

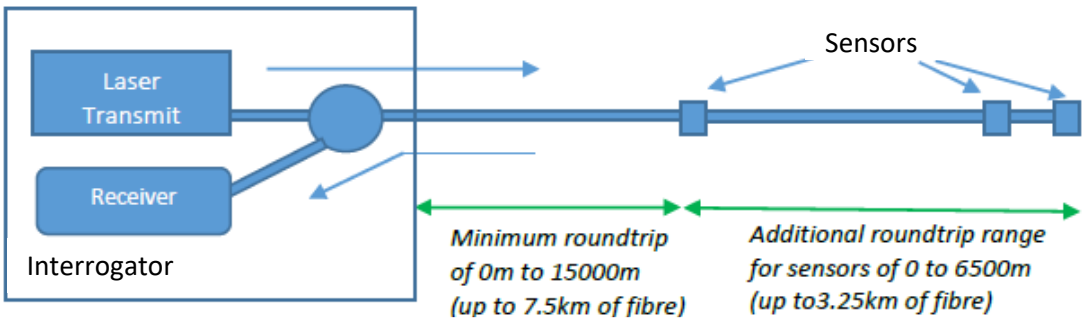
Note: Settings updates are restricted in *Slave Mode* in order to avoid unpredictable behaviour that may occur when a sweep clock is absent. In general, settings should be changed in *Master Mode* and then the interrogator should be switched to *Slave Mode*.

8.2.4.7 Minimum Sensor Roundtrip

The I4 series interrogators optimise measurement accuracy and repeatability by taking into account the round-trip time for light to travel from the laser to the sensor and back to the interrogator. The maximum round trip distance is normally limited to 6500 m (fibre length of 3250 m), but longer fibre to sensor round-trips can be supported for that group of applications where there is a significant length of fibre between the interrogator and the first sensor.
This *Minimum Sensor Roundtrip* setting can be set to a value in the range from 0 m to 15000 m. The user will not be able to set any round-trip distance for a sensor to less than the *Minimum Sensor Roundtrip* setting.

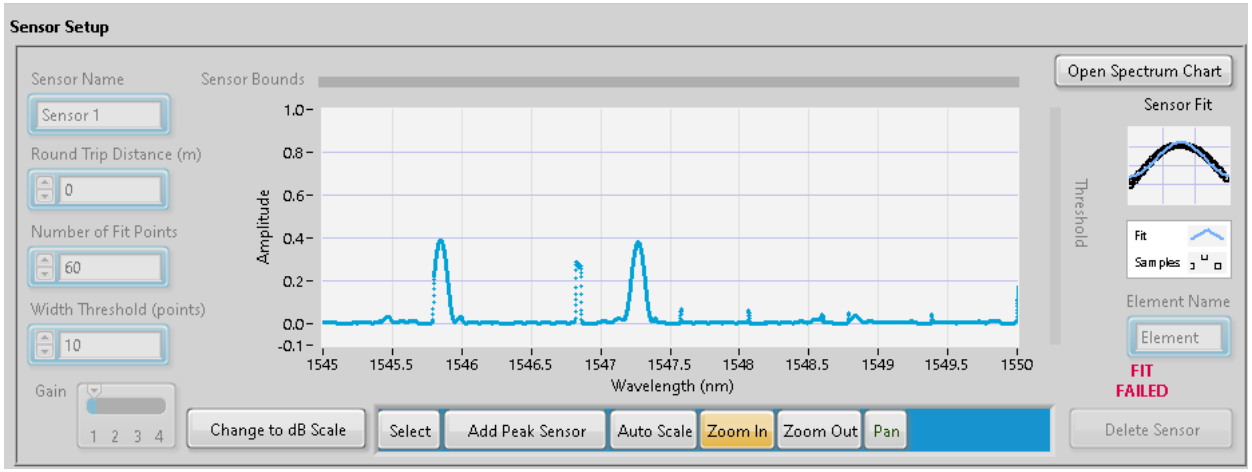


For example, with a *Minimum Sensor Roundtrip* setting of 1000 m, we must ensure that the minimum roundtrip distance for light to travel when it travels to and reflects from any sensor is 1000 m, and the maximum roundtrip distance is (1000 + 6500) = 7500 m.
Similarly, with a *Minimum Sensor Roundtrip* setting of 15000 m, we must ensure that the minimum roundtrip distance for light to travel when it travels to and reflects from any sensor is 15000 m, and the maximum roundtrip distance is (15000 + 6500) = 21500 m.



The *Minimum Sensor Roundtrip* value applies to all "Channels" and "Fibres" in the *Sensor Tree* tab.

When making and removing large changes to the Minimum Sensor Roundtrip value, there is a consequent change in the *Default Round-Trip Distance* for the fibres that will affect how the measured spectrum is displayed. Distortion of the spectrum similar to the following may be seen if the fibre *Default Round-Trip Distance* greatly mismatches the actual fibre path to the sensors.



8.2.4.8 Timing Mode

The *Timing Mode* option provides the user with a choice of 3 approaches to the way that peak timing is reported.

The interrogator does not sample every sensor at the same instant within the sample period. Instead, it sweeps the sensors from low to high frequency (long to short wavelength). This means the sampling time instant for a sensor depends upon the sensor's current frequency/wavelength. In addition,

sensors that are further away from the interrogator are measured later due to the speed of light through the connecting optical fibre. The interrogator can produce timestamps that report the sensor sampling instant more accurately, and it can compensate for sensor distance and current wavelength automatically. The timing mode setting tells the interrogator how to produce the timestamps and what to do with them. The timing modes available are:

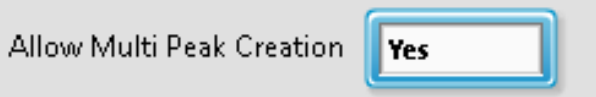
Standard: The interrogator estimates the sampling time instant for a measurement based upon the setting for roundtrip distance and the current wavelength. It does this by knowing details of how the sweep occurs.

Enhanced: The interrogator produces more accurate timestamps by recording the times that the sensors were sampled. In enhanced timing mode there is a limitation on the number of sensors being tracked due to the use of hardware-based timing. Note that the maximum width of the FBGs is limited to ~120pm.

Aligned: This is the same as Enhanced mode except that the timestamps are used to resample the measurements so that all sample times are effectively aligned to the start of each sweep. In aligned timing mode there is a limitation on the number of sensors being tracked due to the increased computational load. Note that the maximum width of the FBGs is limited to ~120pm.

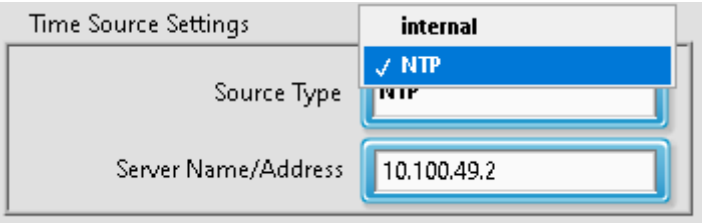
MAXIMUM ALLOWED SENSOR PEAKS PER INTERROGATOR	TIMING MODE STANDARD	TIMING MODE ENHANCED	TIMING MODE ALIGNED
1 KHZ	120	80	48
2 KHZ	100	50	24
4 KHZ	50	25	12
8 KHZ	20	10	6

8.2.4.9 Allow Multi Peak Creation



When *Allow Multi Peak Correction* is "Yes", an optional button on the *Sensor Setup* pane of *Home* FemtoSense tab called "Add Multi Sensor" is displayed. See chapter 8.5.1.10 for further information.

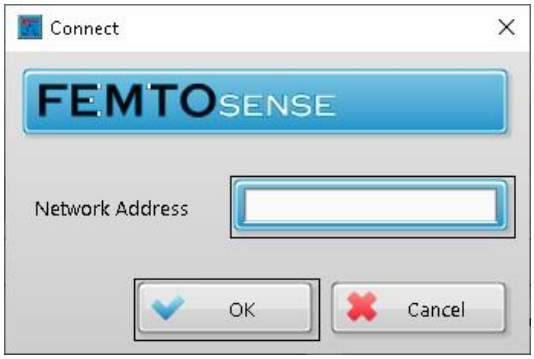
8.2.4.10 Time Source Settings



The clock within the interrogator can be set up to synchronise time and date to an external NTP server (Network Time Protocol), or to free run in "internal" mode.
When in NTP mode, the IP address of the NTP server is entered in the *Server Name/Address* box. A restart (power off and on) of the interrogator is required before changes to *Time Source Settings* take effect.

8.2.5 Connect/Disconnect Button

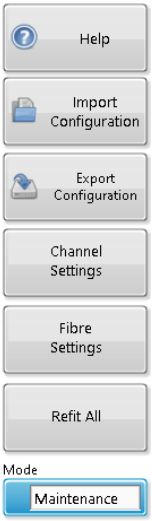
Serves to connect or disconnect FemtoSense software with the interrogator. If an interrogator is not connected yet, click on the *Connect* button, enter interrogator IP address in the pop-up window, and click *OK* to establish connection. See chapter 7.2 for more details regarding setting up the network configuration and connecting the interrogator with a client PC.

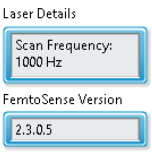


Once connected to an interrogator, the *Connect* button will change to *Disconnect* button.

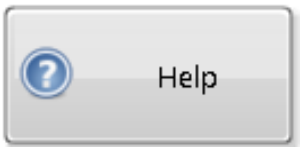
Use this button to terminate the Ethernet connection to the interrogator. This will return FemtoSense to its idle state.

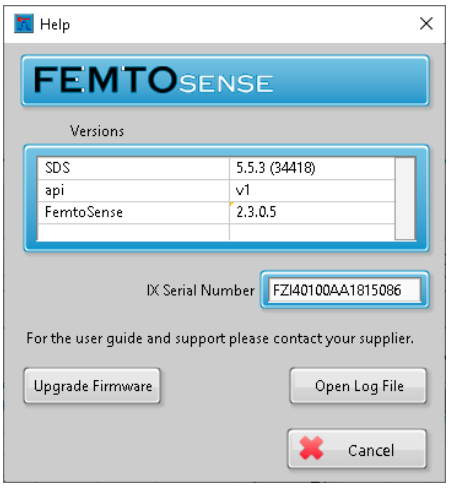
8.3 Basic Functions & Information Pane





8.3.1 Help



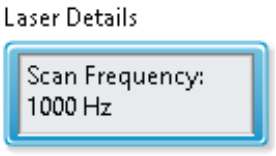


Use *Help* button to access information about the versions of software components in use on the system. Refer to an Appendix 1 of this document for information on firmware upgrade.

Open Log File button can be used to conveniently access the record of messages and errors. Refer to an Appendix 2 of this document for further information on sensor errors and log.

8.3.2 Laser Frequency

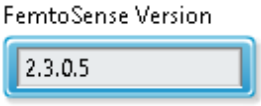
When set to 1kHz scan rate, the scan rate of the laser is displayed on FemtoSense as "1000Hz" as shown below. When set to other scan frequencies, this indicator will change.



Note: This text does not change when using *Slave Trigger Mode* to set the effective scan frequency. The real scan frequency is determined by the input signal and that may be less than the value printed on screen.

8.3.3 FemtoSense Version

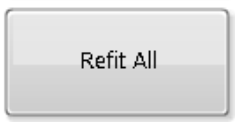
The FemtoSense version is always displayed in the bottom right corner of the application screen.



8.3.4 Import/Export Configuration

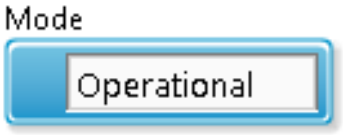
Use this feature to export and later import JSON configuration files for use with the Interrogator. The JSON files will contain sensor topology data for the sensors connected to the system.

Note: If a configuration is imported that does not match the sensors that are currently attached to the interrogator then it is likely that the optimised "fit" parameters stored for the sensors will be incorrect. In this case, the user will need to check the "Sensor Fit" again for each sensor, the *Refit All* button is made available to make this process easier.



8.3.5 Maintenance and Operational Modes

It is necessary to ensure that the *Mode* of operation of FemtoSense is "Maintenance" in order to see sensor setup information and to access some of the control options of FemtoSense. If the *Mode* field of the FemtoSense window shows as "Operational", then click on it and select "Maintenance" in order to set up sensors.

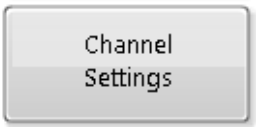


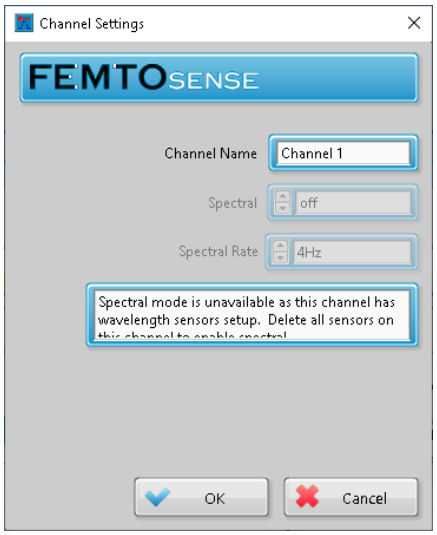
Maintenance: This mode is used to set the system up. Sensors can be added, deleted and optimised in this mode. This mode also provides simultaneous display of spectral data and peak data.

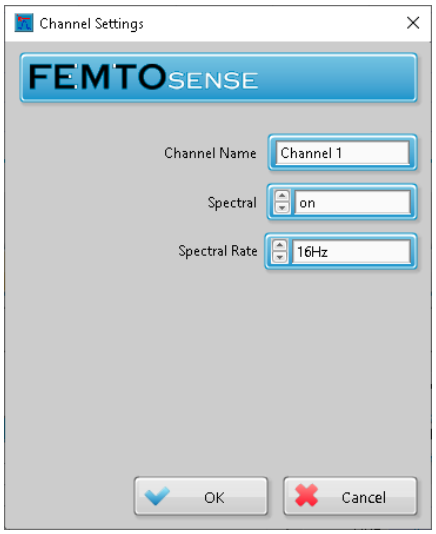
Operational: This is a restricted mode that optimises data throughput by removing the spectral data streams that do not have sensors and reduces the risk of accidental changes to the setup of FemtoSense by disabling interrogator control features.

8.3.6 Channel Settings

The channel settings can be accessed from the *Basic Functions* pane. First select a "channel" from the *Sensor Tree* tab and click *Channel Settings* button to access the channel setup features.







8.3.6.1 Channel Name

This is a unique name for the selected interrogator "channel" and is stored permanently as part of the system's configuration.

8.3.6.2 Spectral

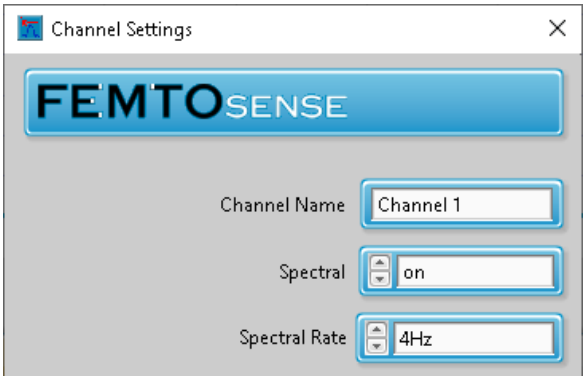
This option is used to set the selected channel to support either the "Spectral" sensor mode (spectrum data) when is set to ON or the 'Wavelength' sensor mode (peak/trough data) when is set to OFF.
When the *Spectral* sensor mode is enabled, the data returned from the interrogator to FemtoSense corresponds to the spectrum data captured with a 1pm resolution at a rate of ~4Hz for 4 channels or ~16Hz for a single channel.
If wavelength sensors exist on a channel, they must be removed using the *Delete* button on the *Sensor Setup* pane before adding spectral sensors. When *Channel Settings* is opened again the *Spectral* sensor option will now be available.

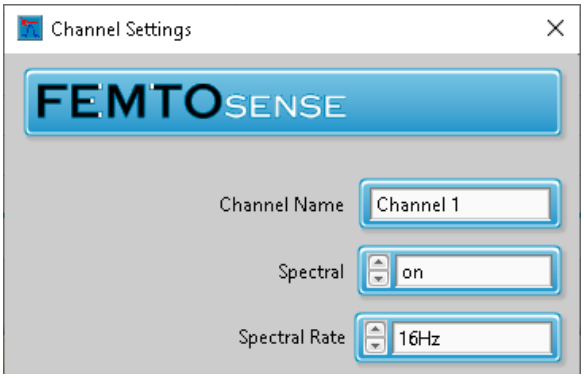
8.3.6.3 Spectral Rate

The system is designed to allow a single spectral sensor on each interrogator channel. Spectral sensors can be added in the following manner:

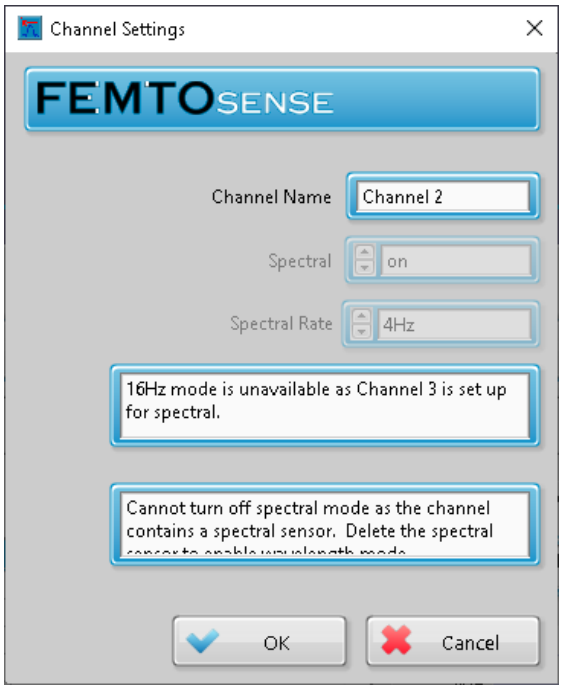
- 4 spectral sensors @ 4.01606Hz (1000Hz/249) on each of the 4 channels in "Maintenance" or "Operational" modes.

- 1 spectral sensor @ 16.3934Hz (1000Hz/61) on a single channel in "Operational" mode.



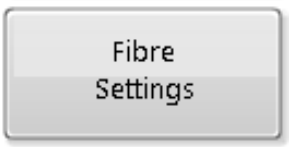


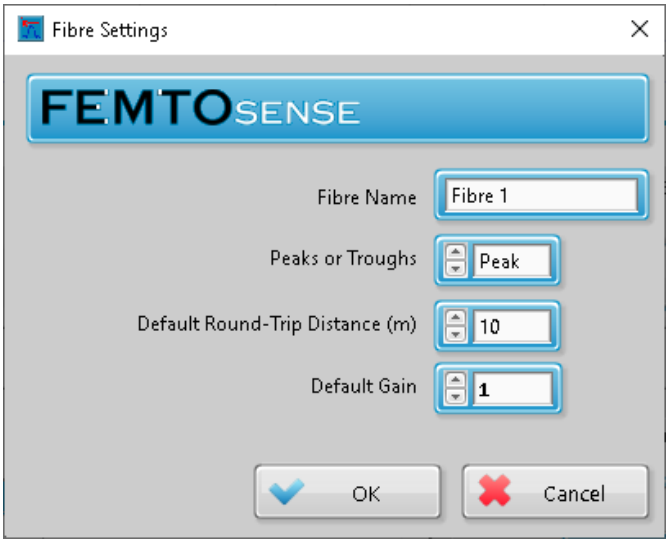
Note: To add a 16Hz sensor to any channel, all other spectral sensors must be deleted. When adding sensors, messages will be displayed to notify the user if any other spectral sensors already exist on the system.



8.3.7 Fibre Settings

A "fibre" usually contains a number of sensors and each "fibre" is connected to an active "channel". The fibre settings can be accessed from the *Basic Functions* pane.





Firstly select a "fibre" in the *Sensor Tree* tab and then use the *Fibre Settings* button to change the fibre name and to set the system to process peaks or troughs for this fibre.

Note: This setting has no effect if the channel has been set up to "Spectral Mode".

8.3.7.1 Fibre Name

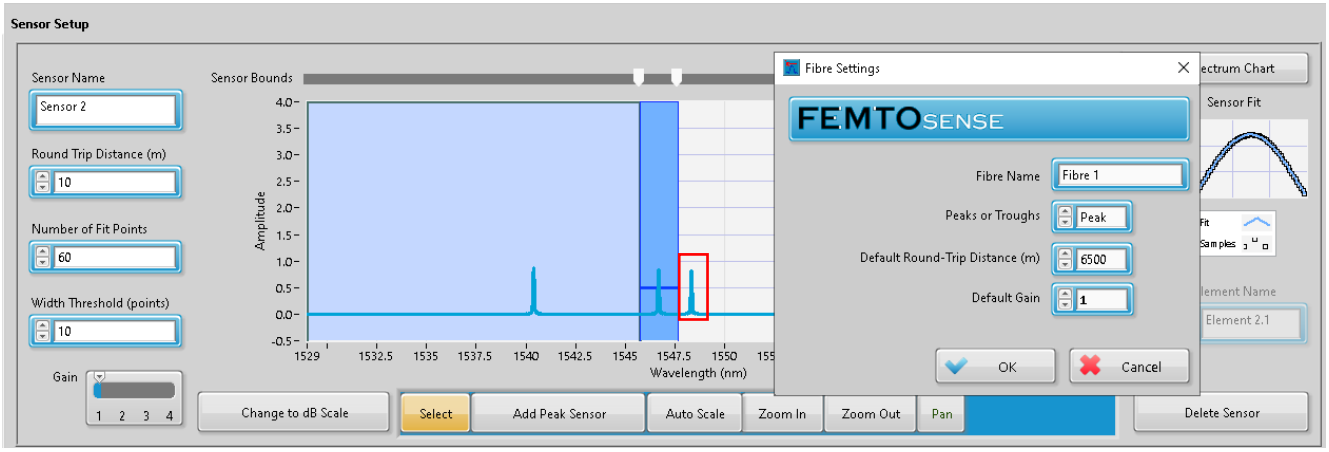
This is a unique name for the selected "fibre" and is stored permanently as part of the system's configuration.

8.3.7.2 Peaks or Troughs

The Optics11 I4 series interrogators can interrogate either FBG peaks or gas cell troughs.

8.3.7.3 Default Round-Trip Distance

In order to ease the setup of the interrogator, each fibre has a selectable default for the Round-Trip distance of the fibre path between the interrogator and any sensors on the fibre.
Note the value of this setting will be affected by changes to *Minimum Sensor Roundtrip* in *Interrogator Settings*. Any parts of the spectrum that depend on the *Default Round-Trip Distance* of a "channel" must be similar to the distance of adjacent sensors or unexpected effects on the appearance of peaks in the Spectrum Chart can occur.



For example, in the screenshot above, the peak highlighted in red is not real. It appears because the *Default Round-Trip Distance* has been erroneously set to 6500 m but the true round trip distance to the sensors in 10 m.

8.3.7.4 Default Gain

In order to ease the set-up of the interrogator, each fibre has a selectable default for the *Gain* that is applied to the signal received from each fibre.

8.4 Sensor/Measurand Tree Pane

8.4.1 Sensors and Measurands

Within FemtoSense, the term "Sensor" refers to a device that produces a series of wavelength values; one value per sweep for a "Peak" or "Trough" sensor, and a vector of amplitudes per sweep for a "Spectral" sensor. Sensors are:

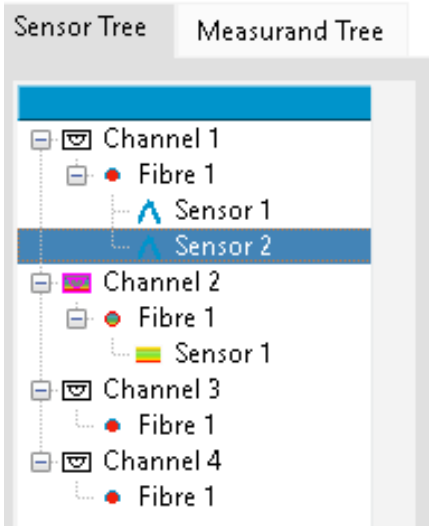
- Set up in the *Sensor Setup* pane (see chapter 8.5.1)
- Viewed and selected in the *Sensor Tree* pane (see chapter 8.4.2)
- Displayed in the *Measurand Display* tab (see chapter 8.7)

Data from "Peak" and "Trough" sensors can be used as inputs to custom formulas that are used to calculate "Measurands" such as temperature or pressure using data from one or more "Sensors". Measurands are:

- Set up in the *Measurand Setup* tab (see chapter 8.6.1)
- Viewed and selected in the *Measurand Tree* pane (see chapter 8.4.3)
- Displayed in the *Measurand Display* tab (see chapter 8.7)

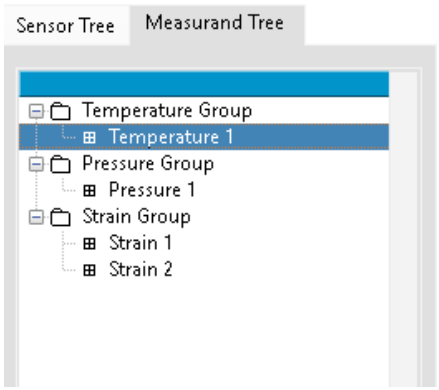
8.4.2 Sensor Tree

When sensors have been set up they can be viewed in the *Sensor Tree* pane. This pane is used to select "channels" and define "sensors" for setup. Click on a channel that has sensors attached to see the spectral response in the *Sensor Setup* pane. Click on a sensor name to see information for that particular sensor in the *Sensor Setup* pane.



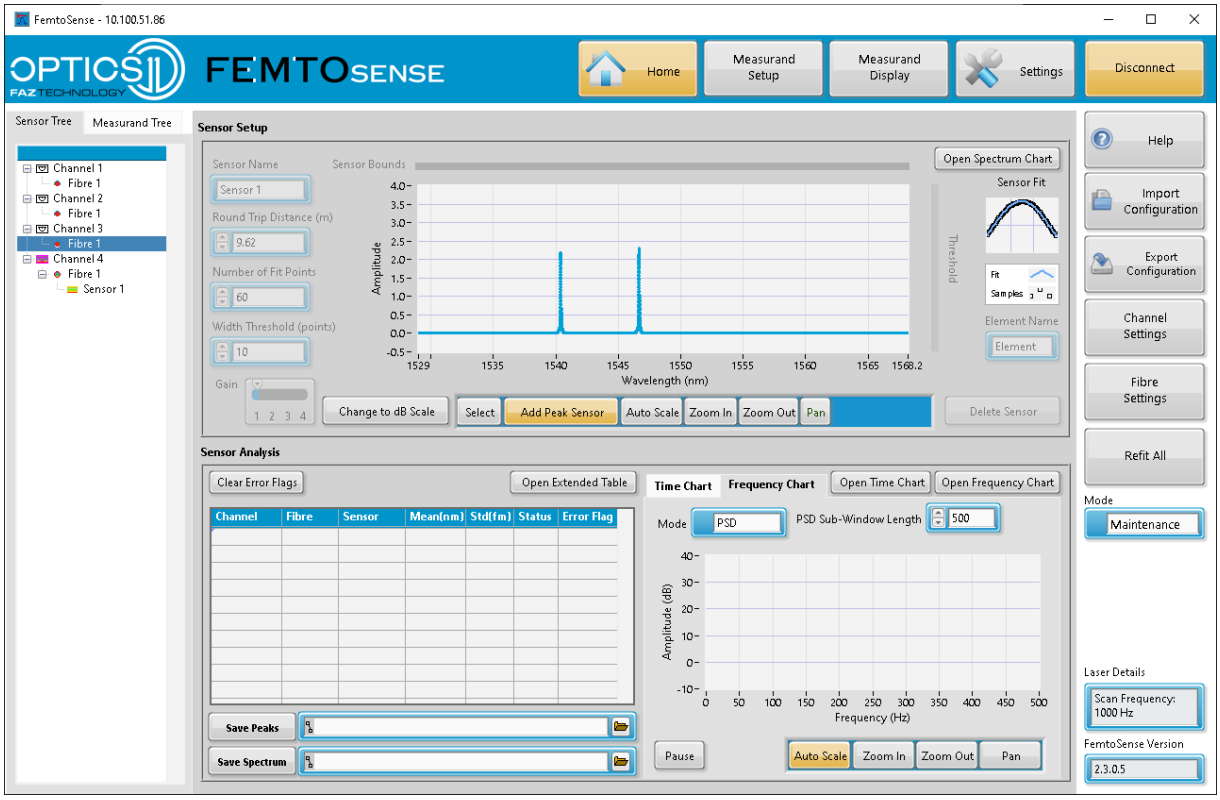
8.4.3 Measurand Tree

When measurands have been setup they can be viewed in the *Measurand Tree* tab. Click on a measurand name to see information for that particular measurand in the *Measurand Setup* tab. See chapter 8.6 for more information on measurands setup.



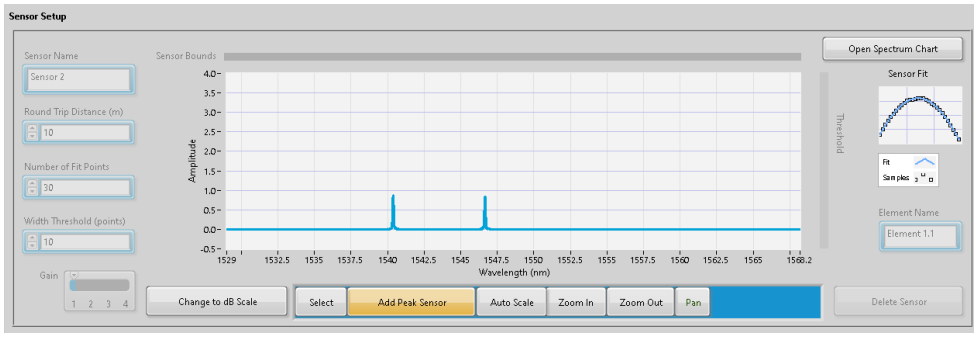
8.5 Home (Sensor) Tab

This tab of the FemtoSense application is used to add sensors to the system and to monitor peak, trough and spectral sensors of individual interrogator channels. Changes can be made by the user to channel and fibre settings.

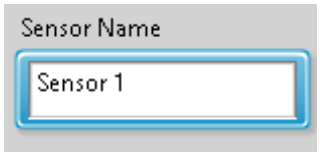


8.5.1 Sensor Setup Pane

The *Sensor Setup* pane contains a number of controls that are used to set up peak, trough and spectral sensors.

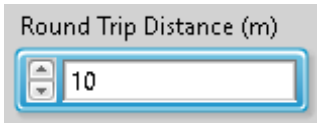


8.5.1.1 Sensor Name



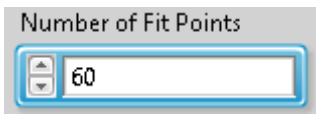
This is a unique name for the selected sensor and is stored permanently as part of the system's configuration.

8.5.1.2 Round Trip Distance (m)



The value entered should be the total roundtrip distance to the sensor that is to be detected. This is the distance the light from the laser has to travel to the sensor and back to the Interrogator (i.e. a roundtrip distance, twice the length of the fibre connecting the sensor to the Interrogator). If this distance is accurate to +/-0.25 m then the time-of flight error is less than +/-0.125 pm and interrogator performance is optimised.
The value of round-trip distance is normally limited to 6500 m. However, when *Minimum Sensor Roundtrip* in *Interrogator Settings* is set to a value of X, then the value allowed for roundtrip distance is limited to setting that are greater than X and less than X + 6500 m.

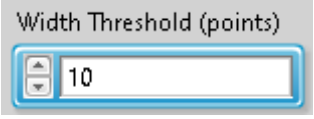
8.5.1.3 Number of Fit Points



A single fit point corresponds to ~2 pm of the sweep. The *Number of Fit Points* can be increased or decreased to optimise the fit for a specific sensor type and shape. The number of fit points is generally

optimal when the fit consistently uses as much of the peak or trough as possible but does not cover points where the curve flattens at the base of the peak or trough. This value typically lies between 1x FWHM (Full Width Half Maximum) and 2x FWHM for the peak or trough being tracked; e.g. for a 120pm FWHM FBG fit points settings in the range of 60 points to 120 points usually work well.

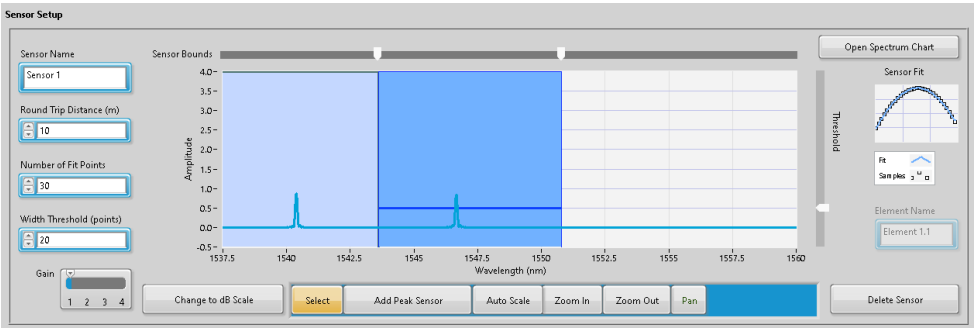
8.5.1.4 Width Threshold (fit points)



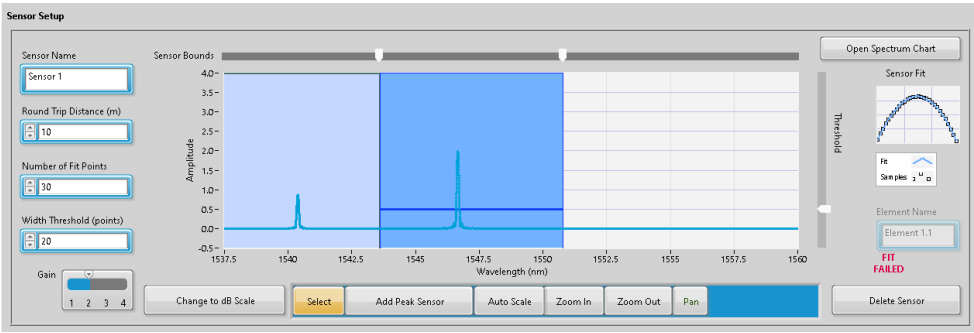
The *Width Threshold* is set for an individual sensor within a region to eliminate the possible detection of side lobes as peaks. Peaks that that have fewer than this number of fit points above the amplitude threshold are ignored by the interrogator.

8.5.1.5 Gain

Each individual region has 4 gain settings (1-4). The gain can be changed by dragging the *Gain* slider for the active region.



The change in the gain level (from 1 to 2 in this case) can be seen in the spectrum window.



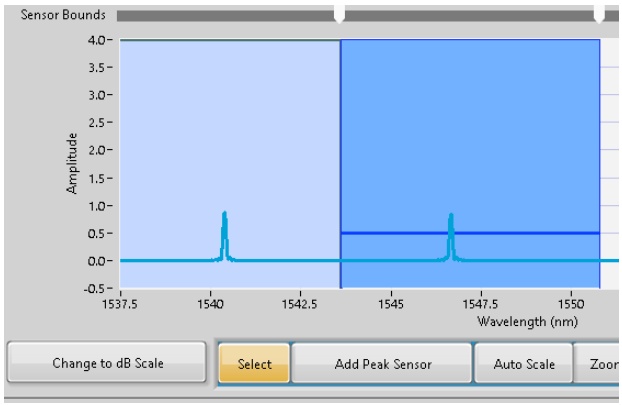
Note: Watch out for distortion of the FBG peak due to saturation when the gain is increased as it will reduce the effectiveness of peak tracking

8.5.1.6 Change to dB Scale/ Change to Linear Scale

This control changes the display from a linear scale to a dB scale. Note that conversion to dB will not produce an output for any linear values that are 0, or for negative values that appear due to the presence of small residual offsets in the data. Note also that the dB range will usually appear to compress for gain settings greater than 1 due to the fact that residual positive offsets will be amplified by the change of gain.
The received amplitude seen on each fibre is displayed in either a linear (X) or a dB scale (10*log(X)) depending on the status of this button. Note that the units used to report amplitude can be used to calculate relative power measurements but not absolute values.

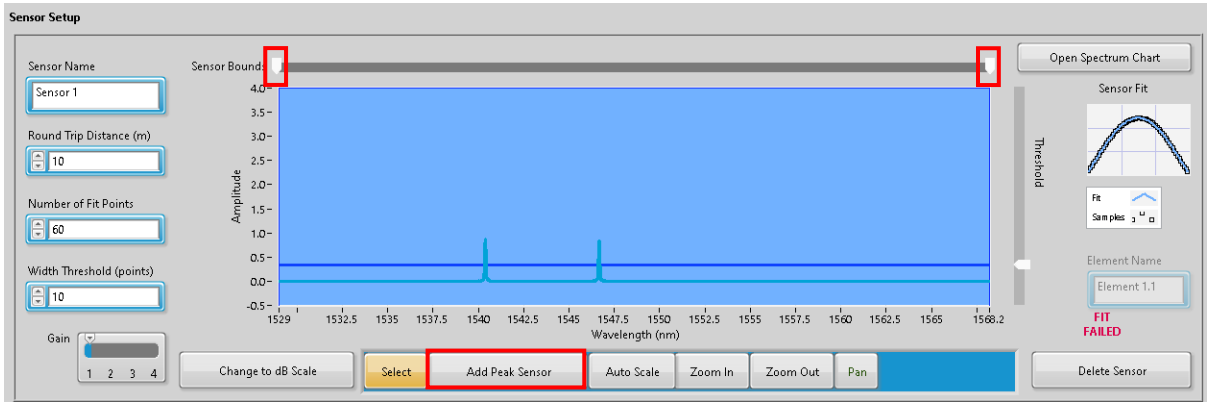
8.5.1.7 Select

Click the *Select* button, then left click on a part of the spectral display that contains a sensor to highlight it. In the example below, the area containing the right peak has been selected and is therefore highlighted in darker blue as shown below, and settings relevant to that peak are now displayed in FemtoSense.

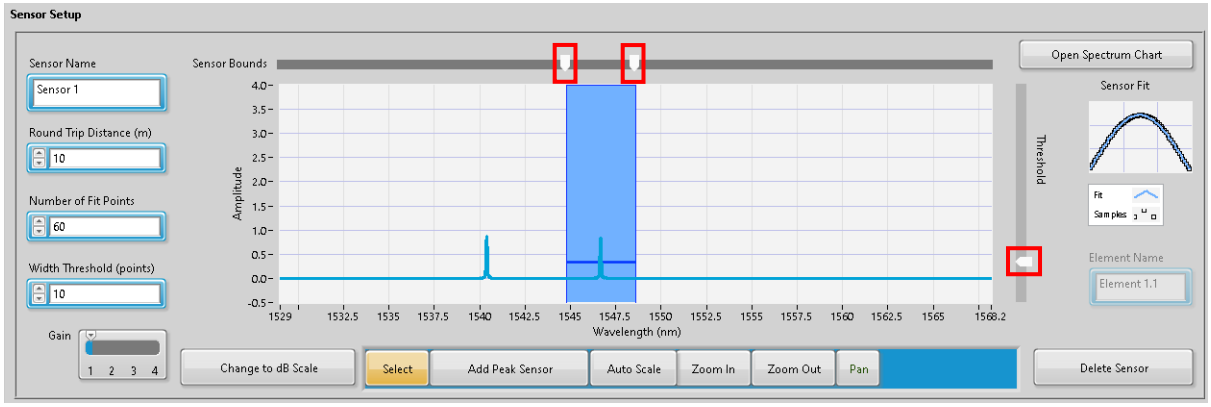


8.5.1.8 Add Peak Sensor/Add Wavelength Sensor

The *Add Peak Sensor* button is used to instruct the system to process FBG peaks at desired wavelength as a sensor. Click the *Add Peak Sensor* button, then left click on the available spectrum in the display to highlight it (shown in blue below).



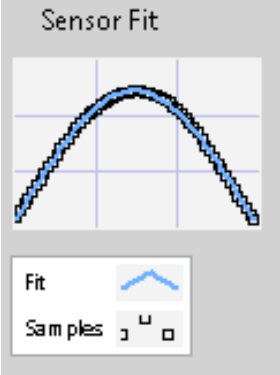
Reduce the spectrum assigned to a single sensor by moving the *Sensor Bounds* sliders (if the sliders are not visible because of the zoom level, click on the slider area).



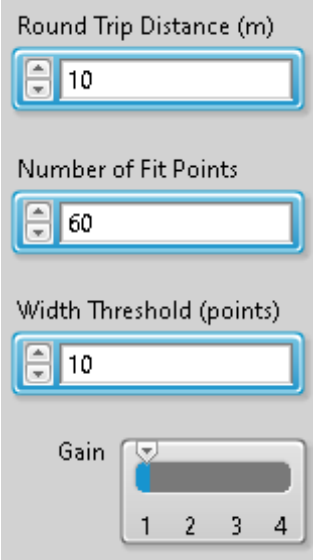
Each individual sensor can be given a unique identifier (*Sensor Name*) as it is being added – this will then be visible to the user in the *Sensor Tree* pane.

The *Threshold* slider on the right side of the spectrum (circled in red above) can now be used to adjust the detection threshold for the sensor. When the threshold is far enough below the peak amplitude for the peak to be detected, the *Sensor Analysis* pane will begin to update with samples of the centre wavelength of that peak.

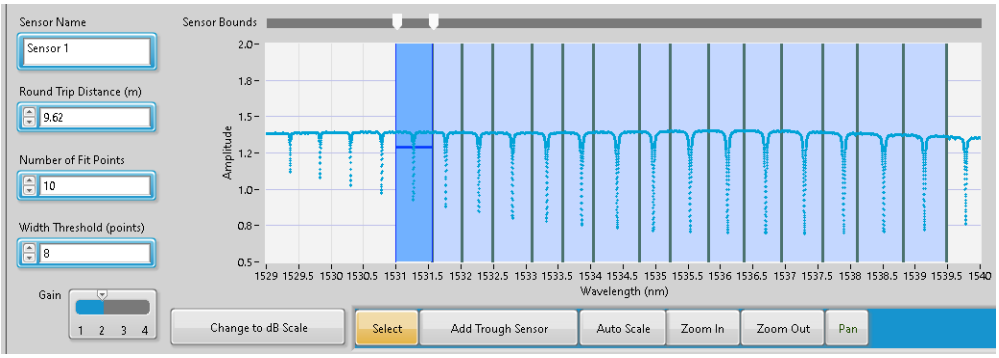
When a sensor has been successfully added, an indication of *Sensor Fit* becomes visible to the right side of the spectrum. The fit of the active sensor shows the original samples and the curve fit of the points used to detect the FBG peak location.



Modifying any of the fit related controls will force an update of the fit window.



If a "fibre" was set up to monitor "Troughs" of a gas cell instead of "Peaks" of FBGs, the spectrum and defined sensors will appear as follows (a gas cell is connected to the interrogator in this case).



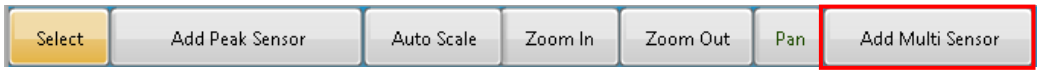
Note that the *Threshold* setting now acts to detect troughs that dip below the line, and the *Width Threshold* may be used to eliminate invalid troughs.

Add Wavelength Sensor
When "Spectral Mode" has been enabled for a "channel" in *Channel Settings*, this button becomes *Add Wavelength Sensor* because we are now enabling the delivery of the spectral values and not peaks or troughs.

8.5.1.9 Other Graph Controls

Auto Scale: Click on *Auto Scale* at any point to display the full spectrum available to the system.
Zoom In: Use this feature to activate a tool to allow magnification of any area of the plot selected by mouse left-click and drag.
Zoom Out: Use this feature to zoom out from a particular point using mouse left-click.
Pan: Use this to change the range of data visible in the window point using mouse left-click and drag.

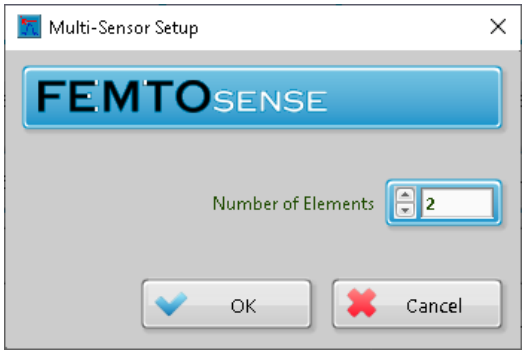
8.5.1.10 Add Multi Sensor



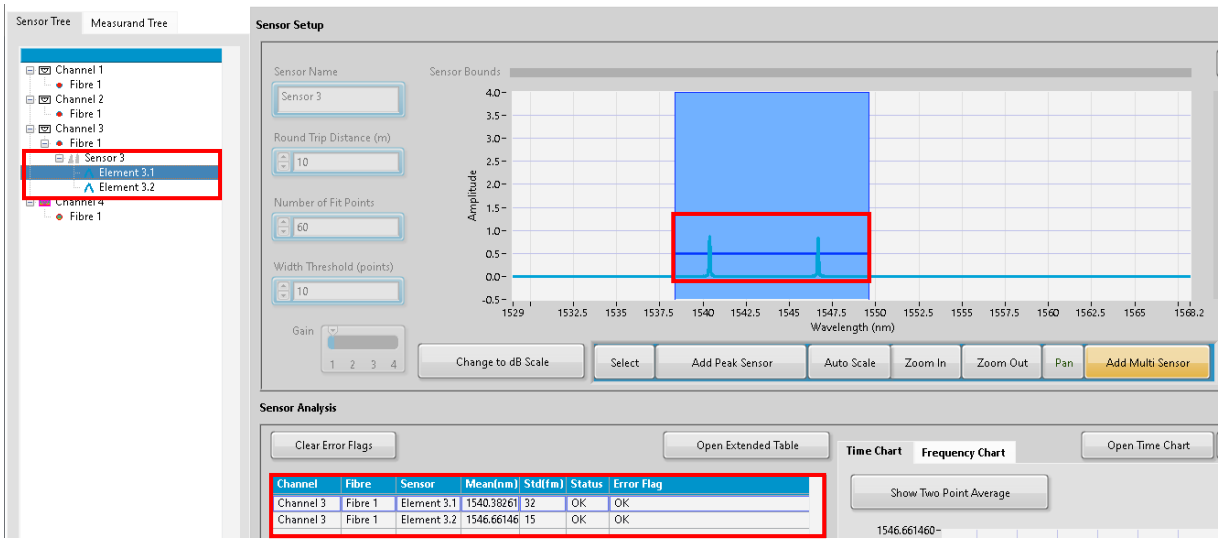
When the option in *Interrogator Settings* tab titled "Allow Multi Peak Creation" has been enabled, a button titled "Add Multi Sensor" will appear on the *Sensor Setup* pane.

This button can be used to set up regions for sensors such as birefringent FBGs that normally contain more than one peak. Note that because both peaks are in the same region, they always have the same settings for *Gain* and *Round Trip Distance*.

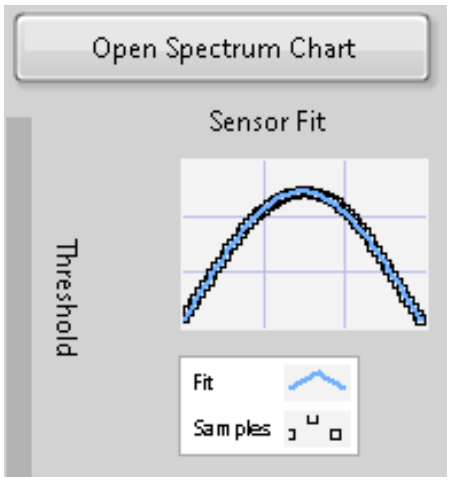
Click the *Add Multi Sensor* button, then left click on an available spectrum area to get the following:



Number of Elements at "2" means that FemtoSense will expect to see two peaks in the region that is being created, and the information will be displayed without errors in the manner highlighted below.

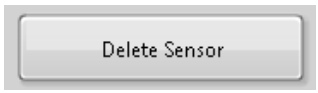


8.5.1.11 Open Spectrum Chart



Clicking on this button will open a separate window containing a larger version of the full spectrum for the selected "channel", the new window can be used to zoom into areas of the spectrum, or to add measurement cursors to the graph etc. by performing a right-click on the cursors area and then selecting "Create" followed by "Bring to Centre".

8.5.1.12 Delete Sensor

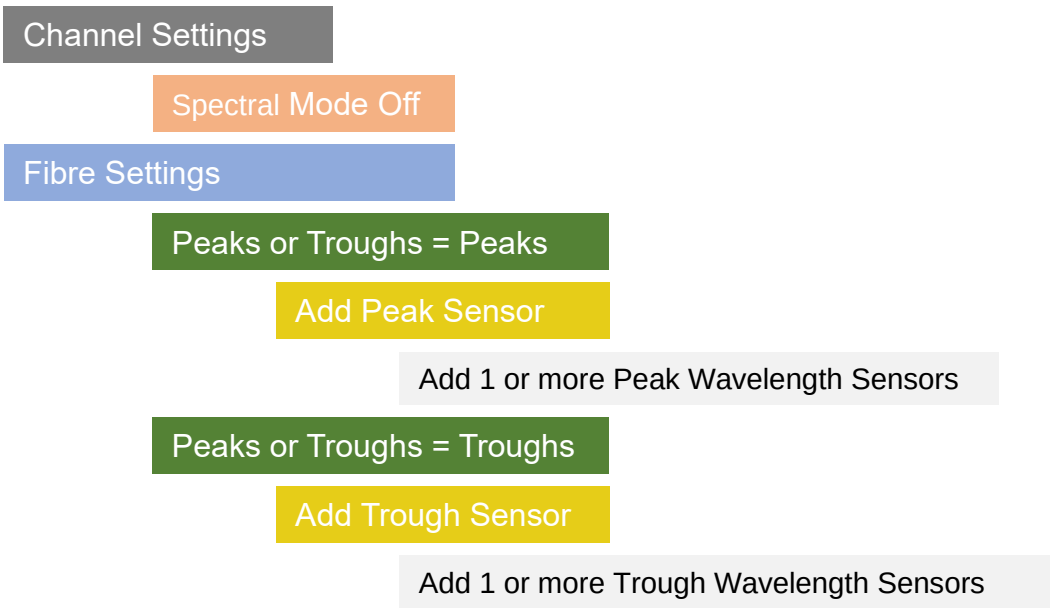


Use this button to remove the active sensor. The active sensor can be selected by left-click on the sensor names in the *Sensor Tree* pane.

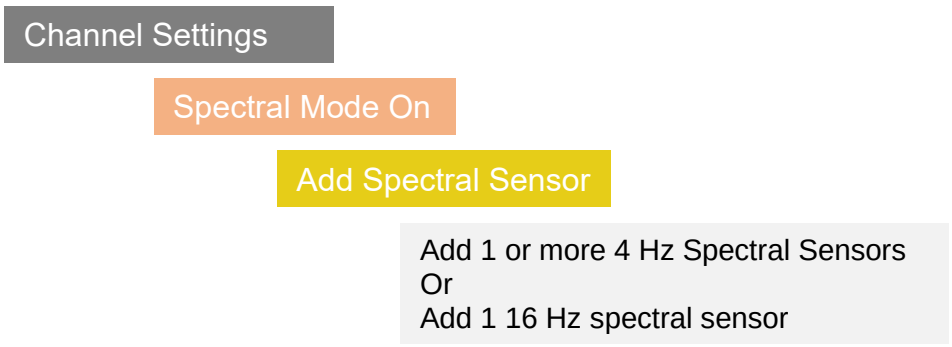
8.5.1.13 Summary: Peak/Trough/Spectral Sensor Flow Diagrams

The controls that are used to set up peak, trough and spectral sensors are summarised here for convenience.

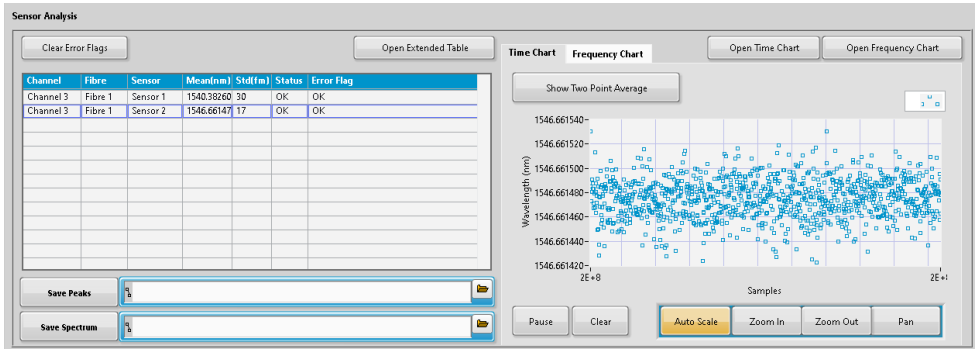
Option 1: Spectral Mode off, add peak or trough sensors:



Option 2: Spectral Mode on, add spectral sensors:

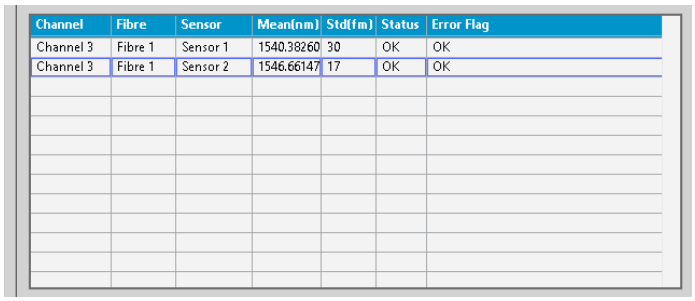


8.5.2 Sensor Analysis Pane



The *Sensor Analysis* pane of FemtoSense is used to monitor the wavelength position of the selected sensor.

8.5.2.1 Analysis Table



Channel	Fibre	Sensor	Mean(nm)	Std(fm)	Status	Error Flag
Channel 3	Fibre 1	Sensor 1	1540.38260	30	OK	OK
Channel 3	Fibre 1	Sensor 2	1546.66147	17	OK	OK

The analysis table shows the mean location (nm) of all the active sensors connected to the system as well as the standard deviation (fm) for each of the wavelengths. Both values are calculated over blocks of 2000 samples for each sensor. When using an optical multiplexer/switch, the mean and standard deviation will also be updated at the end of the period when the sensor is being read.
"Status" indicates whether there is an error currently associated with each sensor (see Appendix 2) and the "Error Flag" is set if an error has occurred related to the sensor since the last time errors were cleared.

8.5.2.2 Clear Error Flags

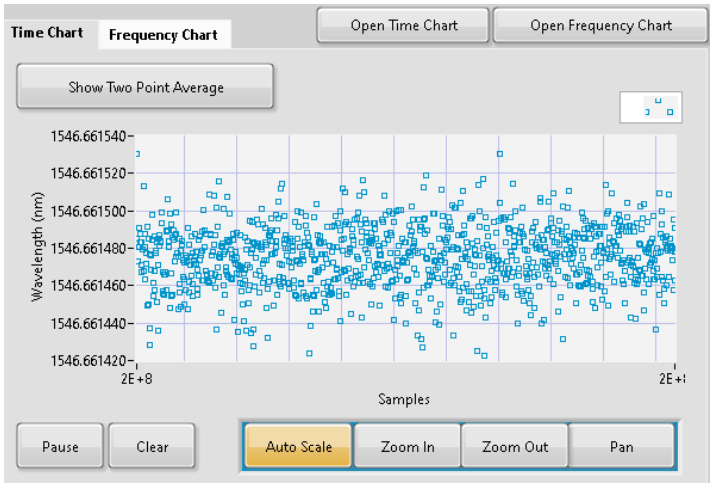
Click to reset the error flag condition for all sensors. This reset will usually be needed after the sensor setup has been modified.

8.5.2.3 Open Extended Table

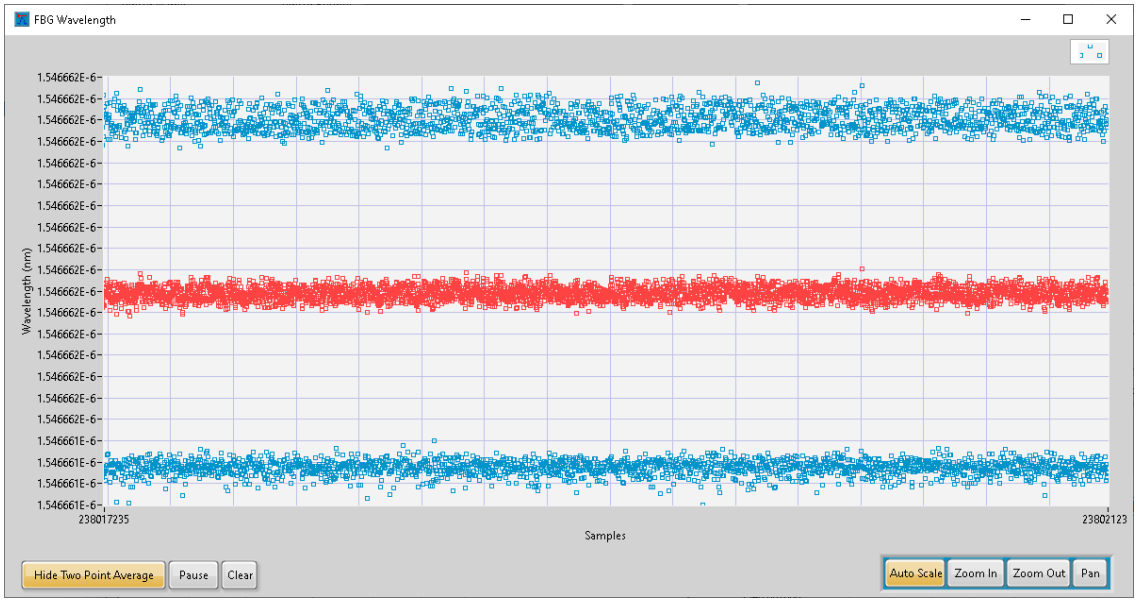
Click on the "Open Extended Table" button to open this analysis table in a separate window where additional setup information is displayed. This window can remain open while the main FemtoSense window is being used.

8.5.2.4 *Time Chart*

The *Time Chart*, shown below, shows the individual wavelength samples returned by each laser sweep. By default, the window shows 4000 wavelength samples from the selected active wavelength sensor.



8.5.2.5 *Open Time Chart*

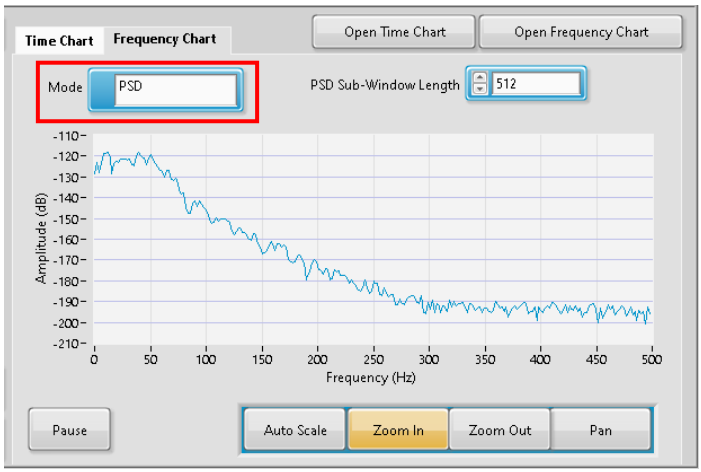


To view the behaviour of a sensor over time in greater detail, click on *Open Time Chart* button and a separate window will open.

Note that toggling the control *Show Two Point Average/Hide Two Point Average* will show/hide a red trace on screen that is calculated as the average of every pair of sequential values from the

interrogator. This can be a useful indicator of the short-term average of two orthogonal polarization states if the polarization switching is on (see chapter 8.2.4.2).

8.5.2.6 Frequency Chart



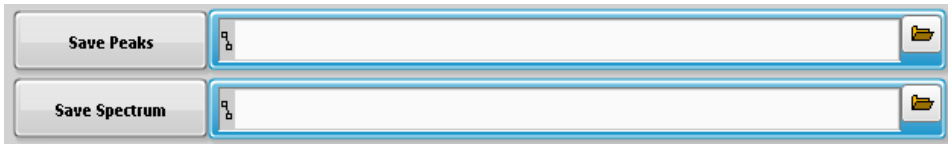
The *Frequency Chart* shows a frequency domain view of the selected sensor. Power Spectral Density (PSD) or Fast Fourier Transform (FFT) modes can be selected using the button highlighted above. By convention, in PSD mode the magnitude has been squared, the mean level has been removed and the numbers are converted by 10*log(X) so the units are dB nm^2/Hz. In FFT mode, the magnitude is not squared, the mean level is not removed from the numbers and data is converted by 10*log(X).

8.5.2.7 PSD Sub-Window Length

The *Sub-Window Length* can be changed in the range from 32 to 2000 which controls the width of the frequency bins used to display spectral power density.

Note: Basic FFT window width used to calculate *Frequency Chart* is fixed to 2048 acquisition points.

8.5.2.8 Save Peaks, Save Spectrum



When sensors have been added the peak data (all wavelength samples for all active sensors) can be saved to a text file. To save wavelength sensor data, select a desired saving folder/path and press *Save Peaks* to start recording peak data.

Peak data is saved in tables starting with columns showing timestamp information and sweep number.

Timestamp	Unformatted Timestamp (ns)	Reserved	Sweep Num.
7-Sep-2016 14:49:28.329818	3682244968329818064	0	423279881

The timestamp/sweep number columns are followed with six columns for each sensor with structure as shown below (without column headers).

Channel	Fibre	Sensor	Valid	Wavelength (m)	Time Offset from Start of Sweep (s)
Channel 1	Fibre 1	Sensor 2	1	1.535918175116E-6	5.287535000000E-4

"Timestamp" is day-month-year hour: minute: second. When NTP is on, this timestamp will track a reference clock on the network.
"Time Offset from Start of Sweep" is the time in seconds from the start of the current sweep to the instant when the peak was sampled. This value can be used with the sweep number to improve the spectral analysis of fast moving signals.
"Valid" is 1 when the interrogator has reported a valid sample for that sensor, otherwise it is 0.

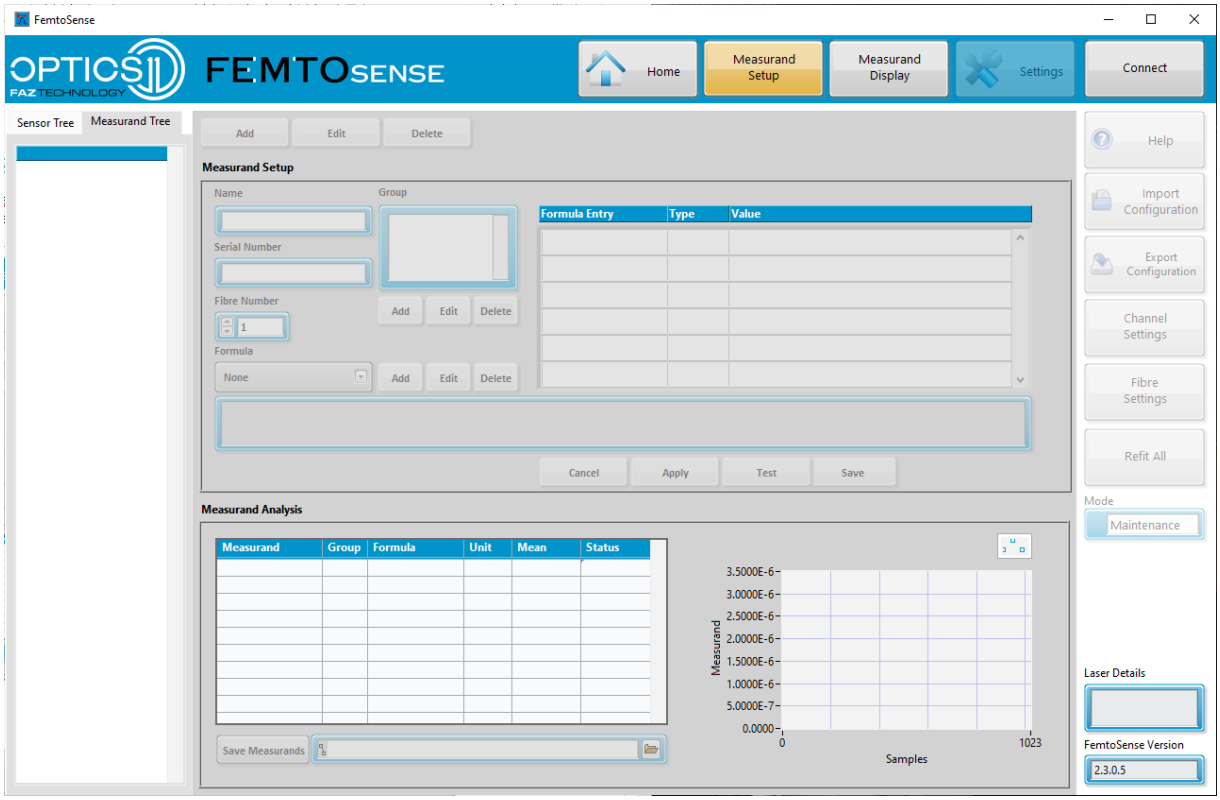
Spectral data can be saved in binary (.bin) format. To save the raw spectral data enter a path in the path box and click *Save Spectrum*.
Each Spectral data point is separated by 1 pm. FemtoSense packages each sweep for each channel of the laser into one packet. The data is saved in binary format (little endian).
The format of the spectral data packet is shown below.

1. Packet Size	(I32, 4 Bytes)	This is the number of Bytes of spectral data in a single sweep
2. Timestamp	(U64, 8 Bytes)	ns since the epoch 01/01/1900 00:00:00.00 UTC (using the Gregorian calendar and ignoring leap seconds),
3. Reserved	(I32, 4 Bytes)	
4. Channel No.	(I32, 4 Bytes)	
4. Fibre No.	(I32, 4 Bytes)	
5. Start wavelength, nm	(dBl, 8 Bytes)	
6. Stop wavelength, nm	(dBl, 8 Bytes)	
7. No. of wavelength points per sweep	(I32, 4 Bytes)	
8. Spectral data, for N points in sweep	(I16, 2 Bytes) x N	

For further clarity, the following sample Python code will read the spectral file header and then the first 3 spectral values.

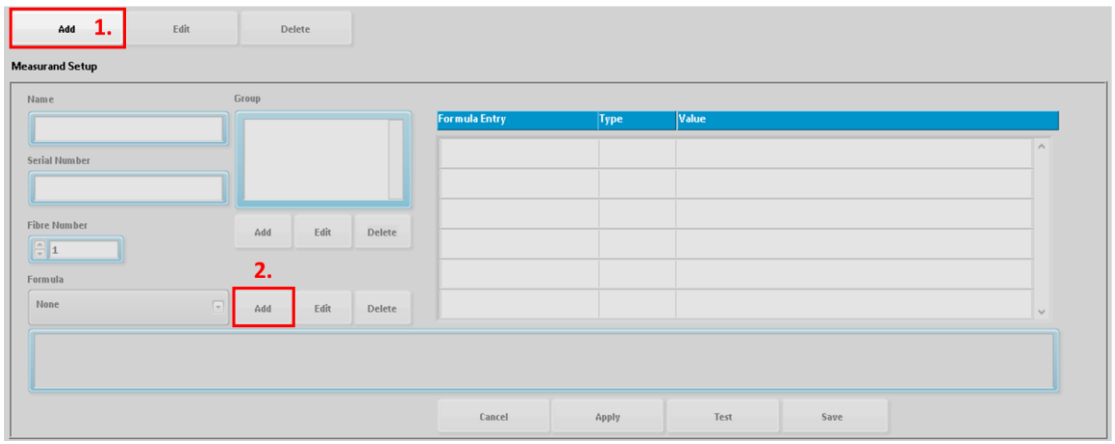
```
import struct
file = open("sample_file.bin", mode='rb')
data = file.read(44)
(PacketSize, Timestamp, Reserved, Channel, Fibre, StartWavelength,
StopWavelength, NumPoints ) = struct.unpack("<iQiiiddi", data)
data = file.read(6)
(value1, value2, value3) = struct.unpack("<hhh", data)
```

8.6 Measurand Setup Tab



This tab of the FemtoSense application is used to add and monitor measurands based on formulas that use sensor input values in wavelength.

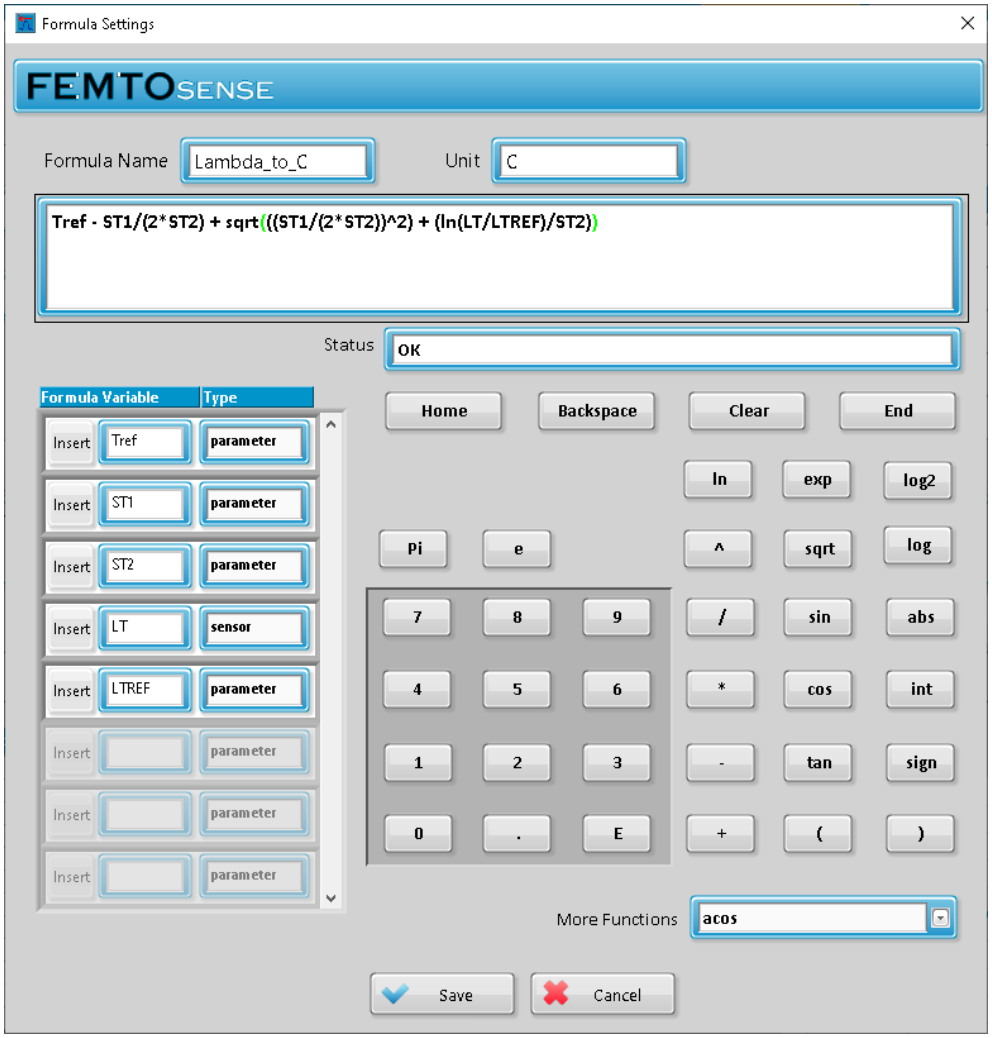
8.6.1 Measurand Setup Pane



Measurands such as temperature and pressure can be defined using this pane. Use following procedure to add measurands.

8.6.1.1 Add Formula

Click *Add* measurand (see 1. above) then *Add* formula (see 2. above) and enter the name, unit, and formula such as:



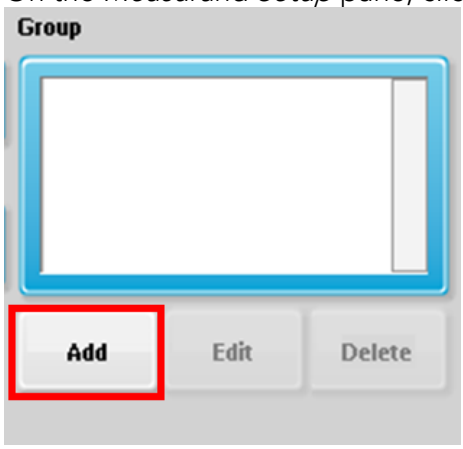
The formula variables will be automatically listed in the window and will default to "parameter" type. Click to the right of each formula variable in order to assign a variable "Type":

- "parameter" - a fixed coefficient value.
- "sensor" - an input to the formula that comes from a sensor, note that the sensor values will be wavelength in units of metres (m).
- "measurand" - an input to the formula that comes from another measurand.

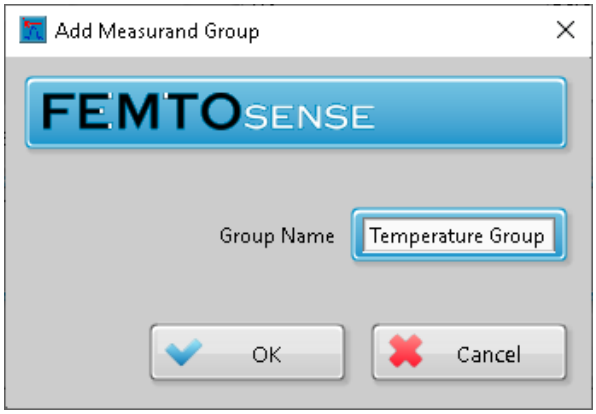
Click *Save* to save the formula.

8.6.1.2 Add Group

On the *Measurand Setup* pane, click on *Add* button under *Group* table.



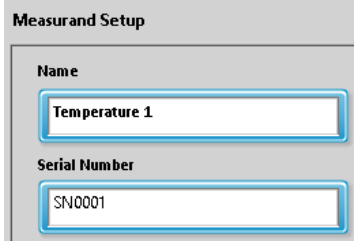
And enter a relevant group name.



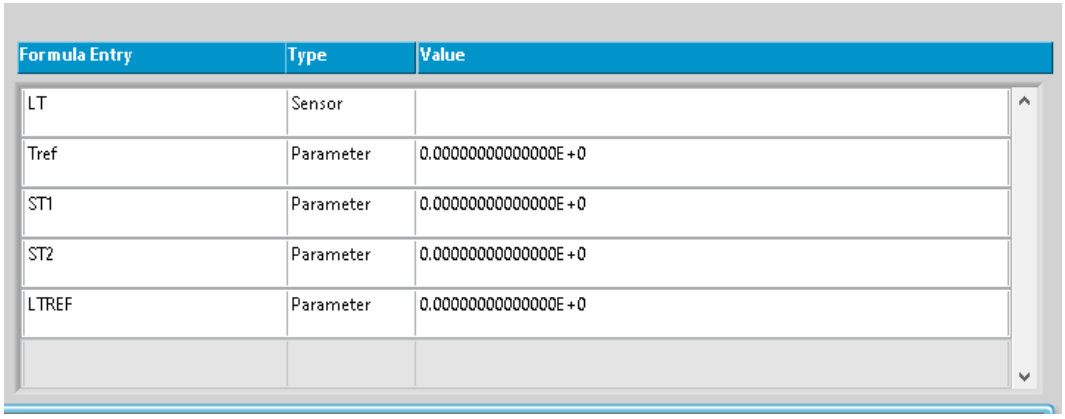
Click *OK* to return to *Measurand Setup*.

8.6.1.3 Complete Measurand

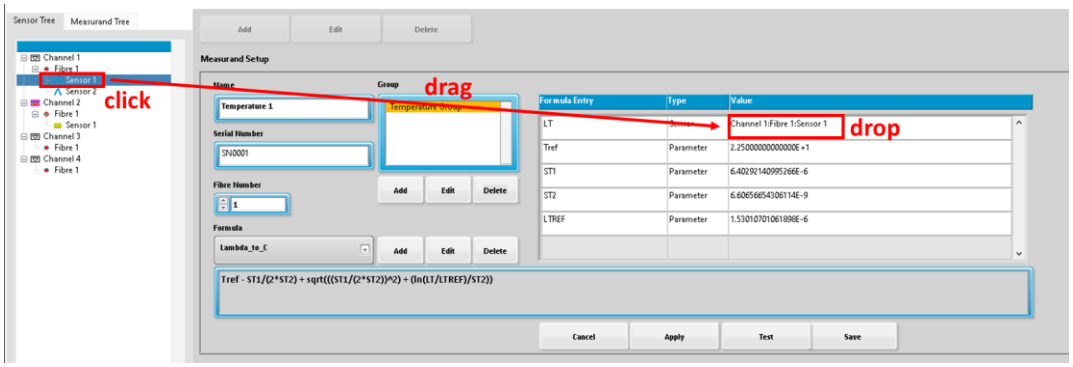
Enter the measurand *Name* and *Serial Number* if available.



Type in the values for formula parameters for this measurand.



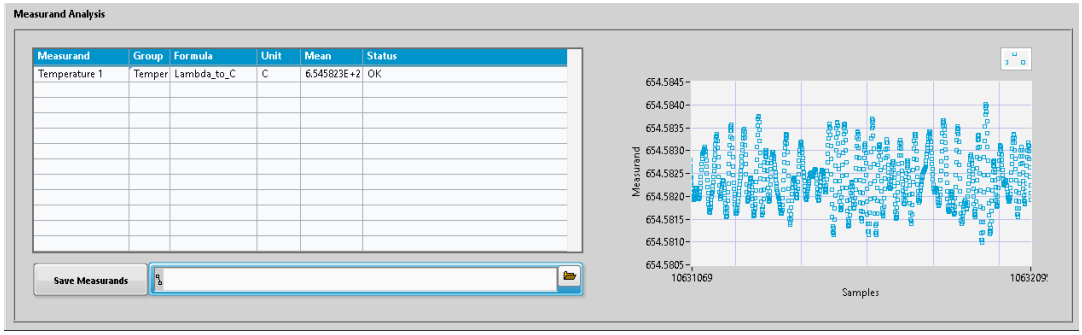
Drag and drop sensor names from the *Sensor Tree* pane to the formula inputs that have been set up as "sensors". Similarly, drag and drop names from *Measurand Tree* pane to formula inputs that have been set up as "measurands".



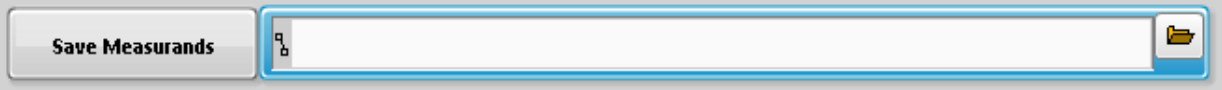
Click *Apply* and *Save*, also click *Save Measurand* if prompted.

8.6.2 Measurand Analysis Pane

If the formula has been set up correctly using valid sensors and/or measurands then valid data will now be visible in the *Measurand Analysis* pane. Basic information on all defined measurands is listed in the table on the left, while measured data for a single selected measurand can be viewed in the graph on the right.

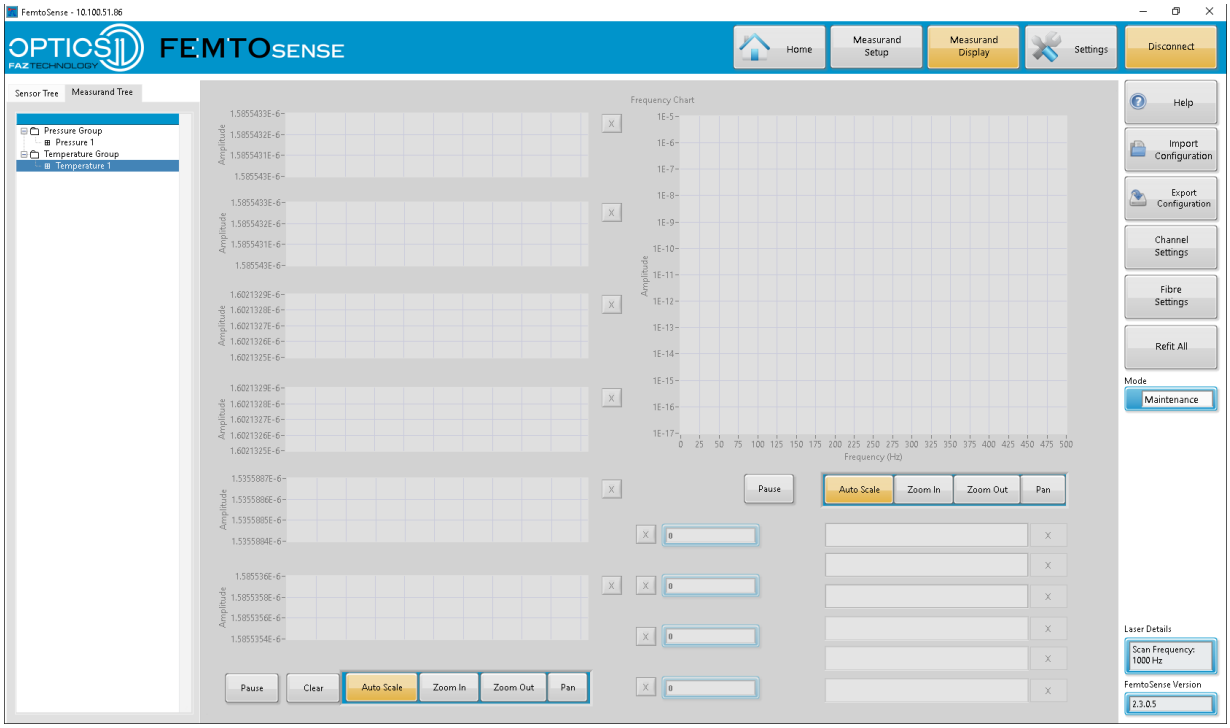


8.6.2.1 Save Measurands



All defined measurands can be save into text file for further post-processing. Define the saving directory and press *Save Measurands* button to start recording measurand values.

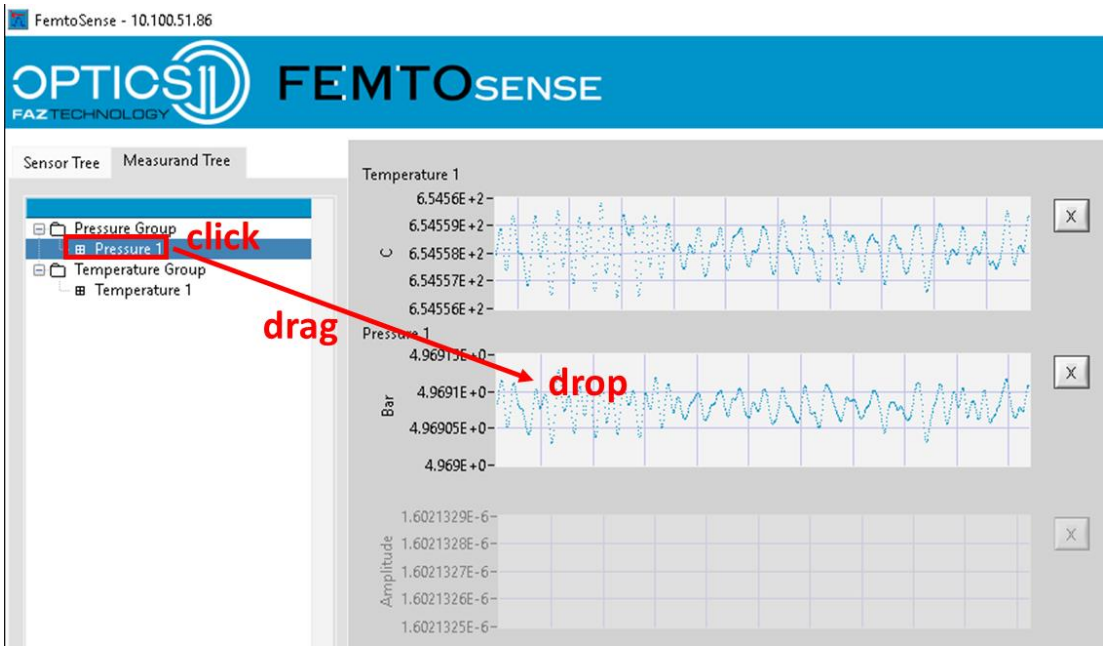
8.7 Measurand Display Tab



This tab of the FemtoSense application is used to view and monitor multiple time and frequency plots of sensor and measurand data.

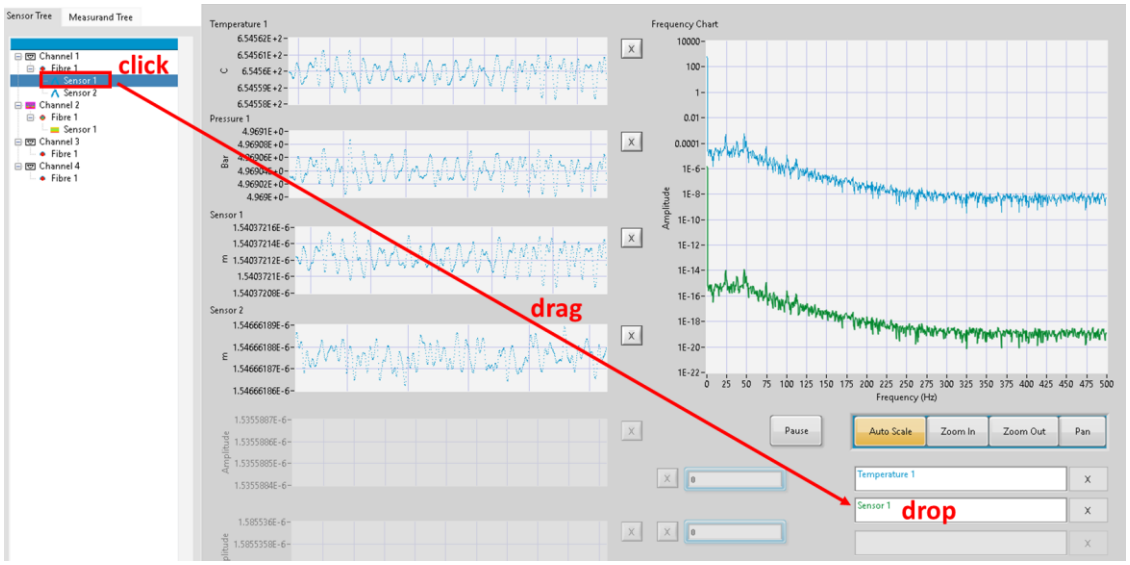
8.7.1 Time Plots

To add the desired sensor/measurand data to the time plots, drag and drop the selected measurand/sensor name from the *Measurand Tree/Sensor Tree* pane to individual graphs. Only one sensor or measurand can be plotted in each of the time plot graphs. Maximum of 6 data streams can be plotted at the same time. Use "X" buttons to the right of each plot to remove the current data stream from the time plots.



8.7.2 Frequency Chart

FFT of sensor/measurand signals can be plotted in the *Frequency Chart*. To add the desired sensor/measurand data to the *Frequency Chart*, drag and drop the selected measurand/sensor name from the *Measurand Tree/Sensor Tree* pane to individual input fields of the *Frequency Chart*. Maximum of 6 data streams can be plotted in the *Frequency Chart* at the same time. Use "X" buttons to the right of each input field to remove the current data stream from the *Frequency Chart*.



8.7.3 Graph Controls

Use graph controls below time plots and frequency chart to pause, clear, zoom or pan individual graphs.

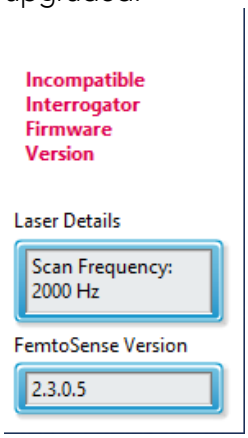
8.7.4 Sensor/Measureand Average Fields

Provide sensor/measurand value averaged over 2048 acquisition datapoints. Drag and drop desired sensor/measurand from the *Senor Tree* / *Measurand Tree* onto one of the fields to get the average value. Click *X* button on the left side of the field to remove the sensor/measurand from the field.

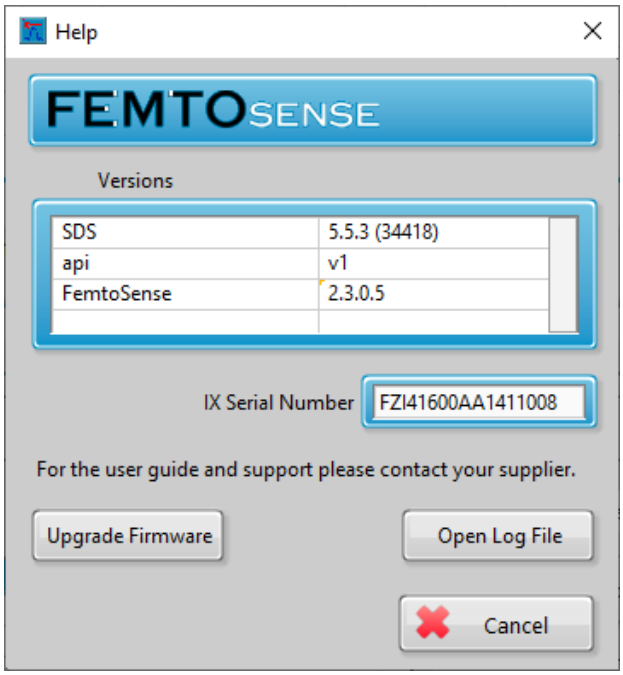
APPENDIX

Appendix 1: Firmware Upgrade

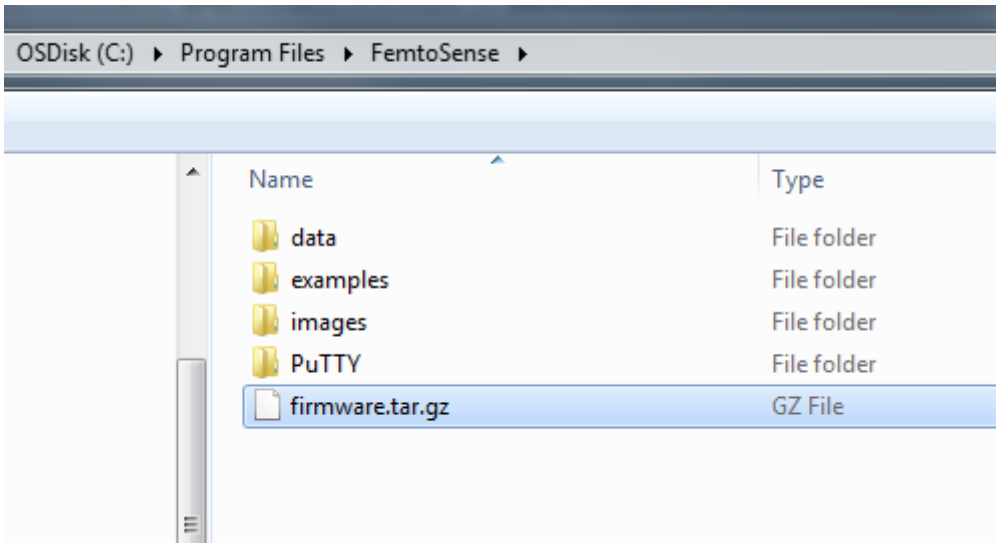
A warning message is permanently displayed on *Basic functions* pane if the interrogator firmware version is not the version that was tested with FemtoSense. It will remain displayed until the system is upgraded.



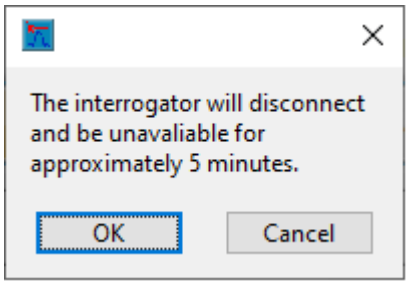
Click *Help* button on the *Basic Functions* pane to view the version of the software currently running on the I4 series interrogator.



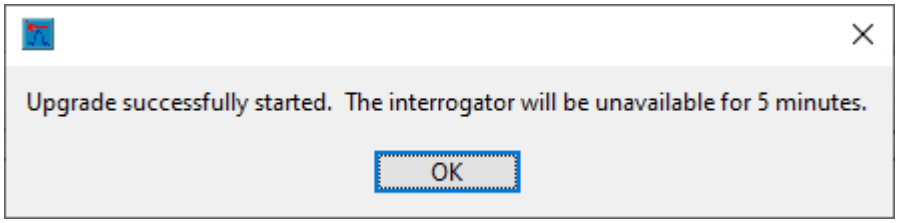
Click *Upgrade Firmware* to upgrade the system to the compatible release components. A new window will open and the default path will point to the location containing the correct components.



Select the *firmware.tar.gz* file and click *OK*. The user will be notified that the upgrade process will take ~5 minutes and the system will be unavailable during that time.



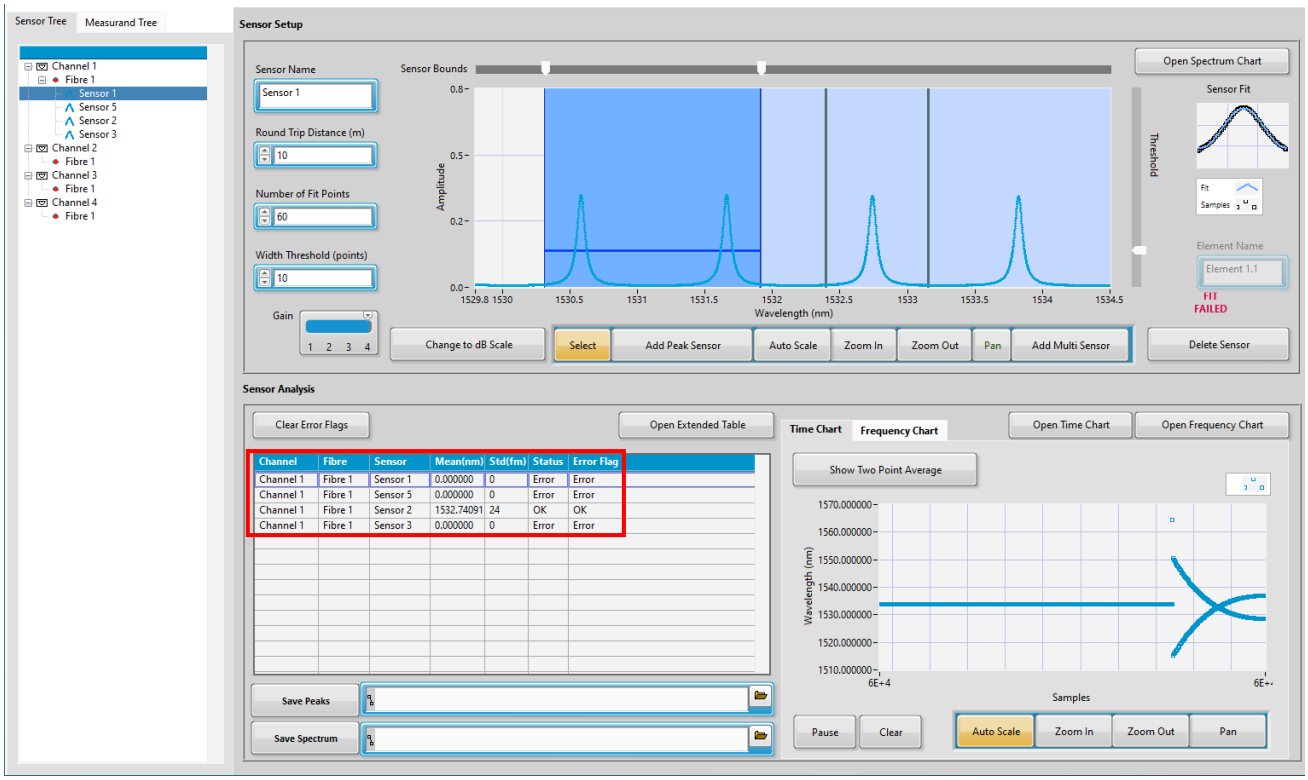
Click *OK* to begin the upgrade. After a short delay, a second dialogue box will be displayed to confirm the upgrade has started:



FemtoSense will disconnect from the interrogator and the system cannot be used for the ~5 minutes after this point.
After approximately 5 minutes, the front panel LED will return to a blue colour and the user can click *Connect* button to reconnect to the system. No warnings/dialogue boxes should be displayed after the upgrade. Click "Help" button and the new version of the system software should be displayed. The system is now ready to use.

Appendix 2: Sensor Errors and Log

A warning "Error" message is displayed in the "Status" column of the *Sensor Analysis* table if an individual sensor is currently in an error state.



There are several reasons why the sensor may be in error condition:

Missing

- The sensor may not be within the wavelength window specified.
- The sensor may not be reaching the height threshold specified.
- The sensor may not be reaching the width threshold at the height threshold.

Multiple

- More peaks than expected may have been found within the wavelength window specified.
- The height threshold may be close to the sensor lobes or noise level resulting in lobes or noise being detected as additional sensors.

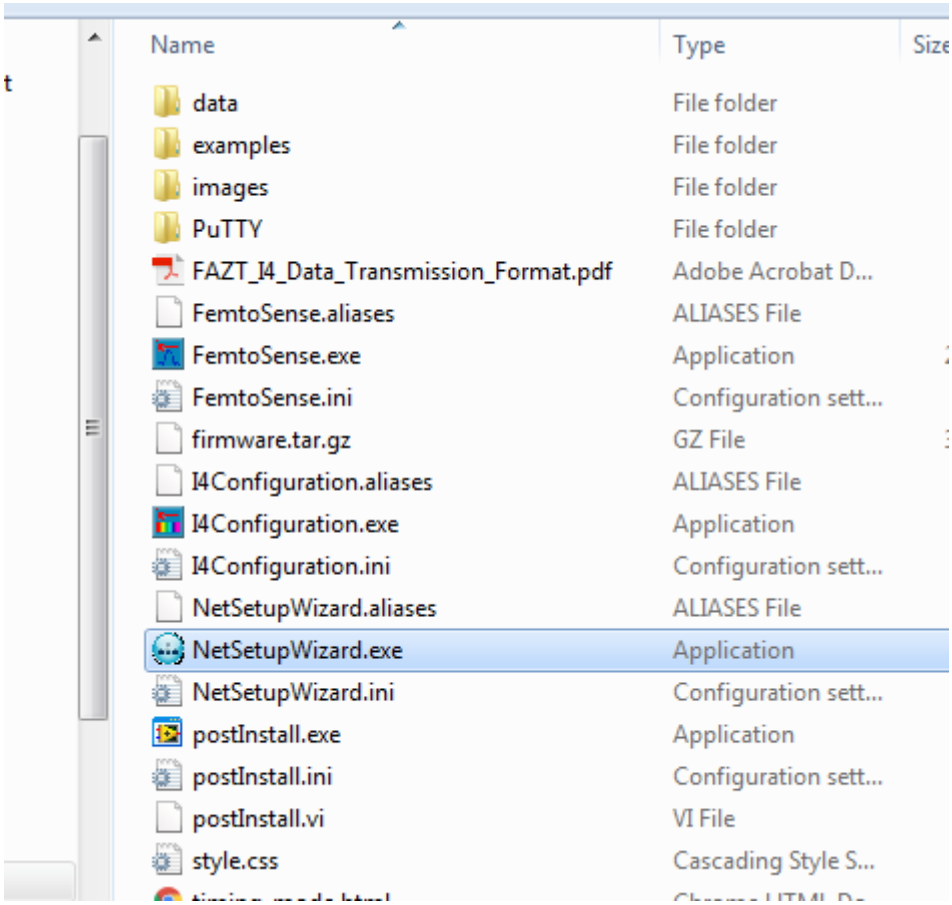
Other

- When in the "Enhanced" or "Aligned" *Timing Mode* there are additional requirements on the size of the peak being fitted that may cause error conditions if not adhered to.

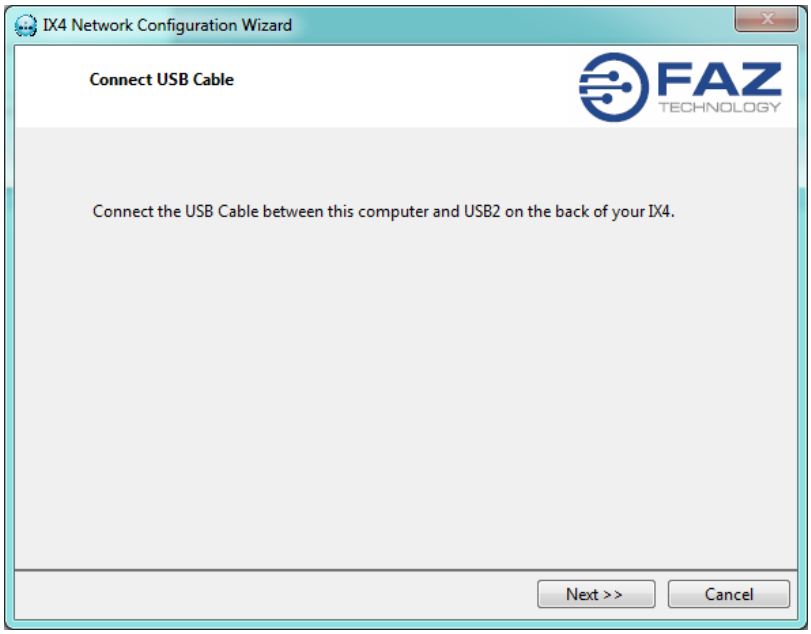
FemtoSense keeps a log file at (insert valid "current user"):
C:\Users\[current user]\AppData\Local\FemtoSense\femtosense_log.txt
(This directory location may be dependent on the PC or Laptop setup.)

Appendix 3: Changing the interrogator Network Address

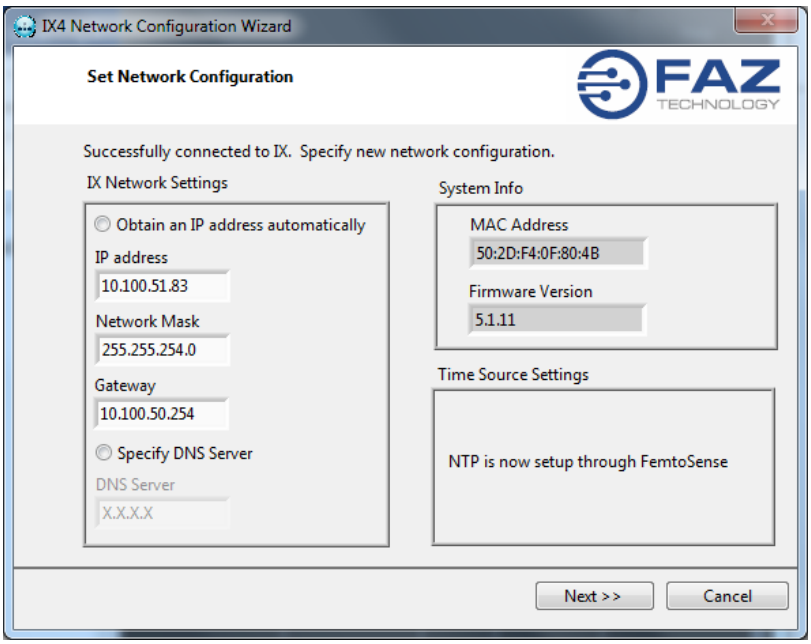
If the default IP address for the I4 series interrogator is not suitable then it can be changed with the help of the *NetSetupWizard* utility in the *C:\Program Files\FemtoSense* directory. If necessary, install the FTDI driver from http://www.ftdichip.com/Drivers/VCP.htm.



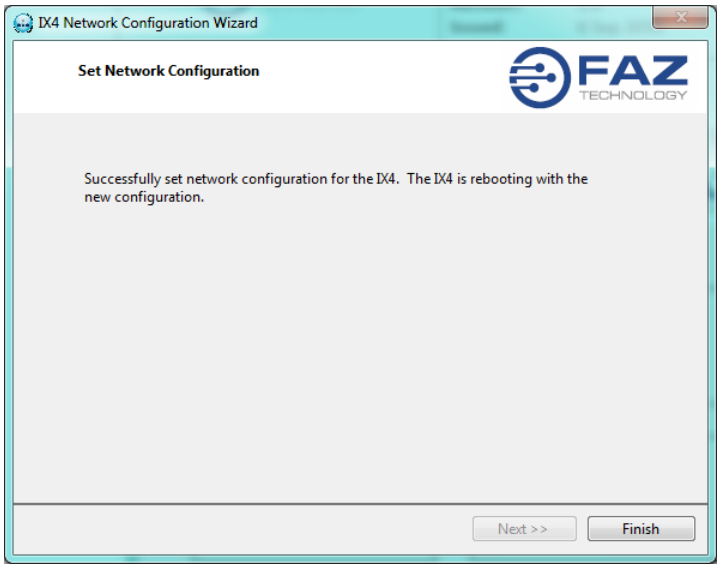
Before starting this process, ensure that the USB Cable is not connected from a PC/Laptop to the "USB2" connector on the back of the interrogator
Ensure that the Interrogator is powered on and ready for connection (Status LED is Blue) and then double-click "NetSetupWizard.exe"



Connect a USB cable from your PC/Laptop to the *USB2 m*ini-B port on the back of the I4 series interrogator.
Press *Next* and wait up to a few minutes for detection of the I4 series interrogator.



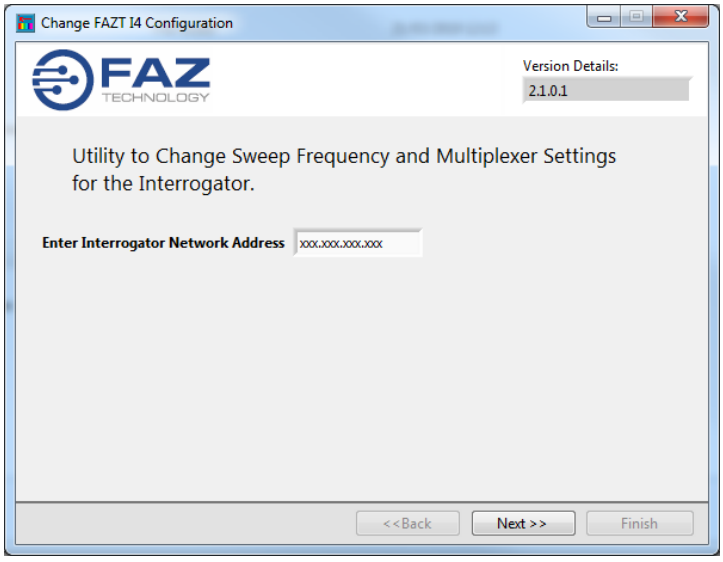
Enter your preferred network information and press Next.
After the screen below is shown, the IX will restart with the network information that has been set.



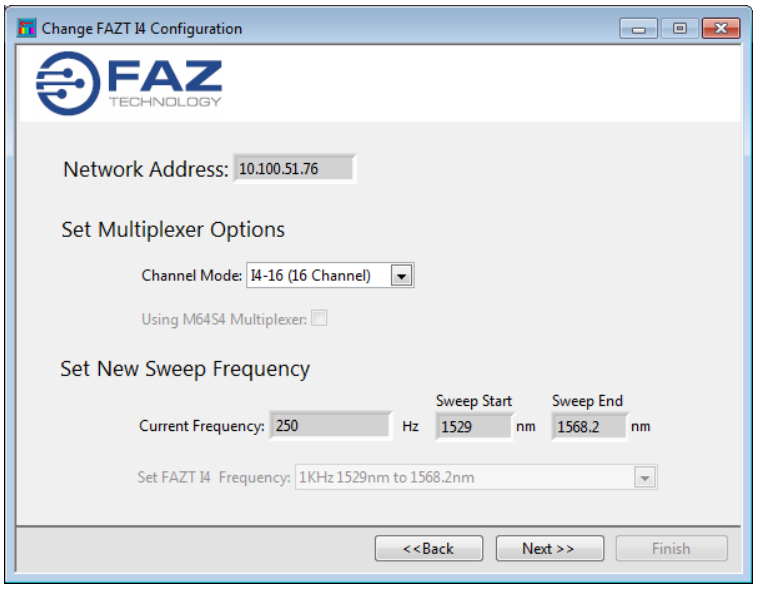
Appendix 4: Change I4 Configuration: Sweep Speed or Multiplexer Options

The I4 series interrogator supports laser tuning rates for 1 kHz, 2 kHz, 4 kHz and 8 kHz sweep frequency (ranges available are dependent on model of the I4 interrogator being used).

To change/set up sweep frequency run "I4Configuration.exe" from *C:\Program Files\FemtoSense* folder. Enter the IP address of the interrogator and click *Next*.

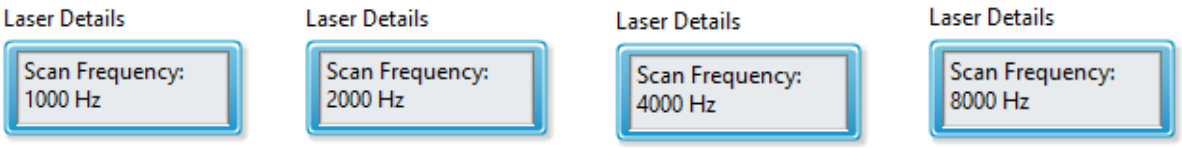


If you connect to a 16 channel interrogator then *Channel Mode* will be selectable under *Multiplexer Options* as shown below.

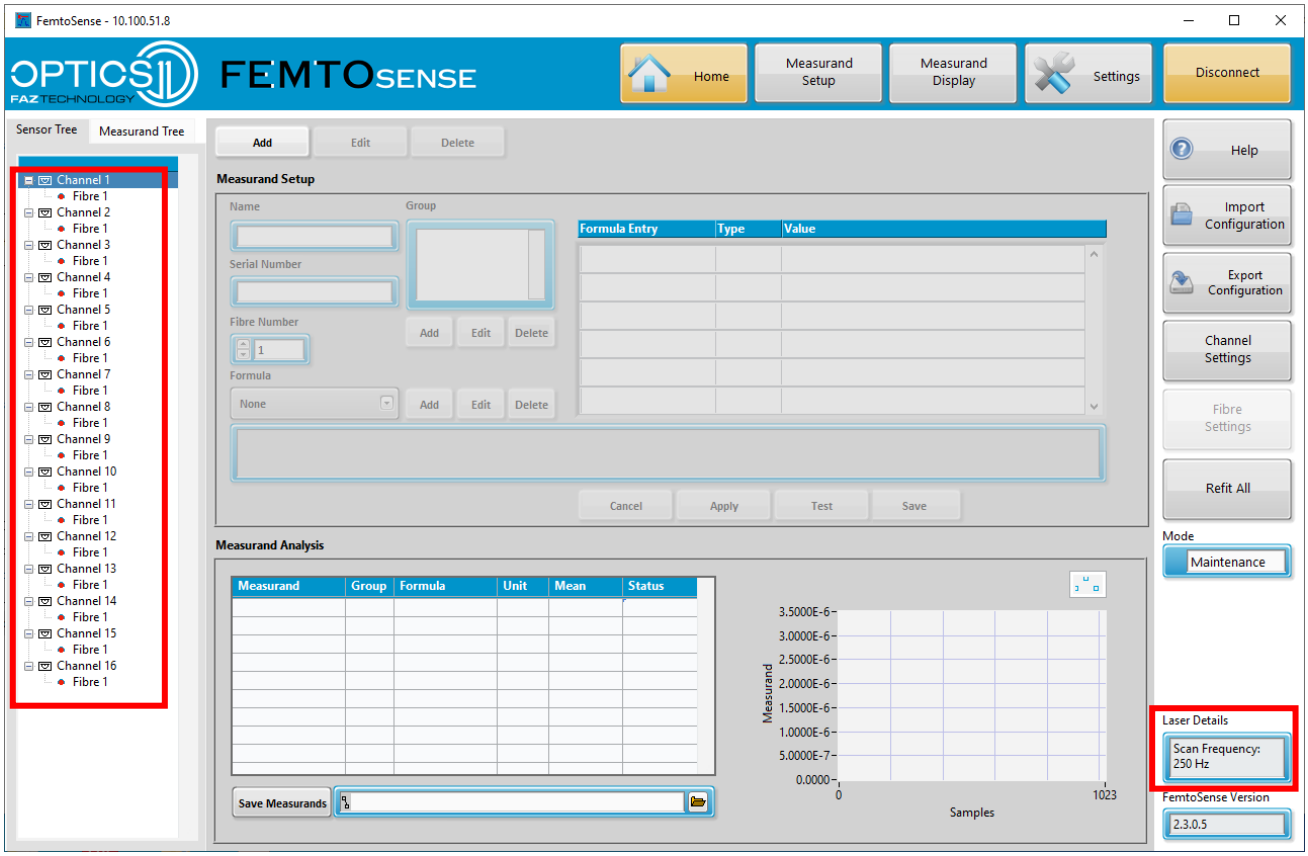


Set New Sweep Frequency

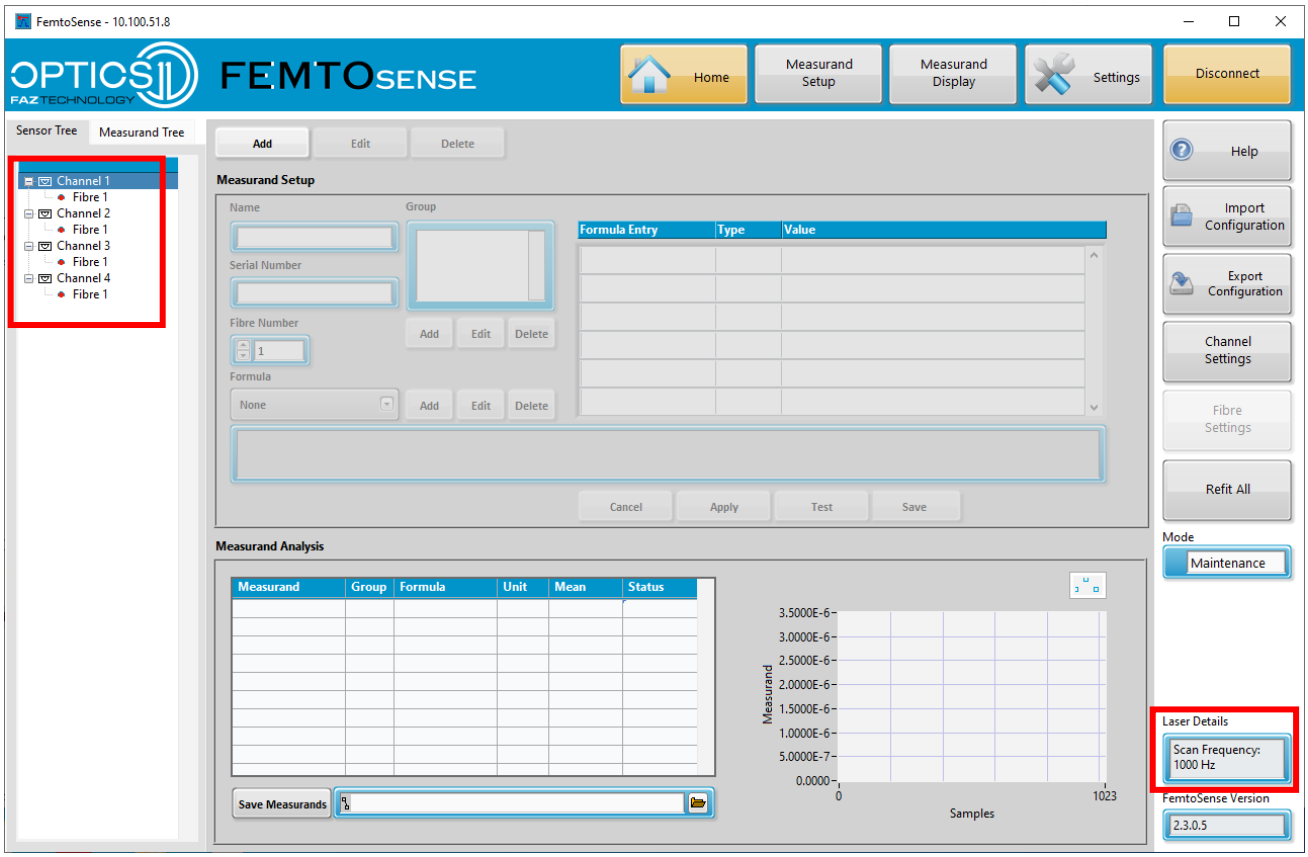
If you have used a new setting for *interrogator Frequency* the new frequency will be displayed on FemtoSense's *Basic Functions* pane as either 1000 Hz, 2000 Hz, 4000 Hz or 8000Hz as follows:



The following are examples of how the new scan frequency and number of available channels will be displayed on FemtoSense:



or

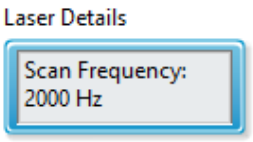

FemtoSense - 10.100.51.8
OPTICS11
FAZTECHNOLOGY
FEMTOSENSE
Home
Measurand Setup
Measurand Display
Settings
Disconnect
Sensor Tree
Measurand Tree
Channel 1
Fibre 1
Channel 2
Fibre 1
Channel 3
Fibre 1
Channel 4
Fibre 1
Add
Edit
Delete
Measurand Setup
Name
Group
Serial Number
Fibre Number
Formula
None
Formula Entry
Type
Value
Cancel
Apply
Test
Save
Measurand Analysis
Measurand
Group
Formula
Unit
Mean
Status
Save Measurands
3.5000E-6
3.0000E-6
2.5000E-6
2.0000E-6
1.5000E-6
1.0000E-6
5.0000E-7
0.0000
Measurand
0
1023
Samples
Help
Import Configuration
Export Configuration
Channel Settings
Fibre Settings
Refit All
Mode
Maintenance
Laser Details
Scan Frequency: 1000 Hz
FemtoSense Version
2.3.0.5

Appendix 5: I4G 2 kHz Sweep Mode

The I4G interrogator can be set up in a 2 kHz (39.2 nm) Sweep Mode that increases the sweep rate of the laser.

Identification of 2 kHz mode

Start FemtoSense and initiate a connection to the interrogator as usual.
When connected, if the I4G has been set up for 2 kHz sweeping then the text in the bottom right area of the main FemtoSense screen will say "Laser Frequency: 2000Hz".

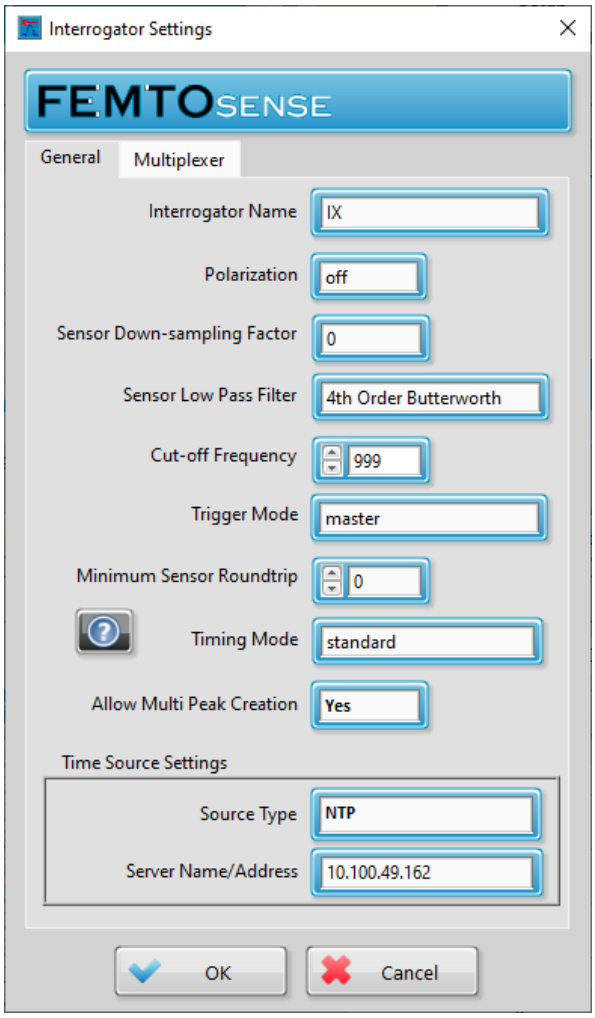


Polarization Switch – 2 kHz sweep rate

Due to switching time limitations of the optical components, the option to have a polarization switch on each sweep is not available in 2 kHz sweeping mode.

Filter Cut-off Frequency – 2 kHz sweep rate

The cut-off frequency can be set for the low-pass filter once the 'Butterworth' filter option has been chosen. The maximum cut-off frequency allowed is 999Hz.



Number of Fit Points - 2 kHz sweep rate

At the 2 kHz sweep rate, a single fit point corresponds to ~4 pm of the sweep. The number of points can be increased or decreased to optimise the fit for a specific sensor type and shape. The number of fit points is generally optimal when the fit consistently uses as much of the peak or trough as possible but does not cover points where the curve flattens at the base of the peak or trough. This value typically lies between 1 x FWHM (Full Width Half Maximum) and 2 x FWHM for the peak or trough being tracked; e.g., for a 120pm FWHM FBG fit points settings in the range of 30 points to 60 points usually work well.

Trigger Mode - 2 kHz sweep rate

Two trigger modes are supported by the I4G at 2 kHz sweeping:

- "Master" mode where the sweeps are triggered by the internal timing of the interrogator and run at a constant rate of 2 kHz
- "Slave" mode where the interrogator waits for an external signal before each sweep is triggered.

In "Slave" mode, the external clock must be applied to the *Gate In* SMA connector on the rear panel of the interrogator and has:

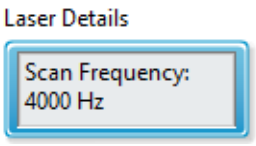
- Electrical characteristics of the trigger as described in the Specification Table in this document.
- A clock frequency greater than or equal to 1600 Hz and less than or equal to 2000 Hz.
- A high to low duty cycle of at least 45% and not more than 55%.

Appendix 6: I4G 4 kHz Sweep Mode

The I4G interrogator can be set up in a number of 4 kHz (18 nm) Sweep Modes that increases the sweep rate of the laser.

Identification of 4 kHz mode

Start FemtoSense and initiate a connection to the interrogator as usual. When connected, if the I4G has been set up for 4 kHz sweeping then the text in the bottom right area of the main FemtoSense screen will say "Laser Frequency: 4000Hz".



Polarization Switch – 4 kHz sweep rate

Due to switching time limitations of the optical components, the option to have a polarization switch on each sweep is not available in 4 kHz sweeping mode.

Filter Cut-off Frequency – 4 kHz sweep rate

The cut-off frequency can be set for the low-pass filter once the 'Butterworth' filter option has been chosen. The maximum cut-off frequency allowed is 1999Hz.

Number of Fit Points - 4 kHz sweep rate

At the 4 kHz sweep rate, a single fit point corresponds to ~4 pm of the sweep. The number of points can be increased or decreased to optimise the fit for a specific sensor type and shape. The number of fit points is generally optimal when the fit consistently uses as much of the peak or trough as possible but does not cover points where the curve flattens at the base of the peak or trough. This value typically lies between 1 x FWHM (Full Width Half Maximum) and 2 x FWHM for the peak or trough being tracked; e.g. for a 120pm FWHM FBG fit points settings in the range of 30 points to 60 points usually work well.

Trigger Mode - 4 kHz sweep rate

Two trigger modes are supported by the I4G at 4 kHz sweeping:

- "Master" mode where the sweeps are triggered by the internal timing of the interrogator and run at a constant rate of 4 kHz

- "Slave" mode where the interrogator waits for an external signal before each sweep is triggered.

In "Slave" mode, the external clock must be applied to the *Gate In* SMA connector on the rear panel of the I4G and has:

- Electrical characteristics of the trigger as described in the *Specification Table* in this document.
- A clock frequency greater than or equal to 3200 Hz and less than or equal to 4000 Hz.
- A high to low duty cycle of at least 45% and not more than 55%.

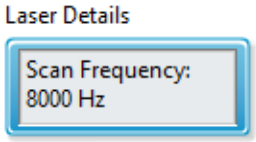
Appendix 7: I4G 8 kHz Sweep Mode

The I4G interrogator can be set up in a number of 8 kHz (8 nm) Sweep Modes that increases the sweep rate of the laser and achieves the following specification:

Parameter	Symbol	Min	TYP	MAX	UNIT	Notes
Wavelength range (8.1)	λ	1529		1537	nm	8nm range
Wavelength range (8.2)	λ	1533		1541	nm	8nm range
Wavelength range (8.3)	λ	1537		1545	nm	8nm range
Wavelength range (8.4)	λ	1541		1549	nm	8nm range
Wavelength range (8.5)	λ	1545		1553	nm	8nm range
Wavelength range (8.6)	λ	1549		1557	nm	8nm range
Wavelength range (8.7)	λ	1553		1561	nm	8nm range
Wavelength range (8.8)	λ	1557		1565	nm	8nm range
Wavelength range (8.9)	λ	1560.2		1568.2	nm	8nm range
Number of Channels	Channels		4			
Number of Sensors Per Interrogator	Sensors			20		
Sample Size/Resolution	Δλ step		1		pm	Applies to spectral mode
Scan Frequency (FBG processing/channel)	F SWEEP		8000		Hz	

Identification of 8 kHz mode

Start FemtoSense and initiate a connection to the interrogator as usual. When connected, if the I4G has been set up for 8 kHz sweeping then the text in the top right area of the main FemtoSense screen will say "Laser Frequency: 8000Hz".



Polarization Switch – 8 kHz sweep rate

Due to switching time limitations of the optical components, the option to have a polarization switch on each sweep is not available in 8 kHz sweeping mode.

Filter Cut-off Frequency – 8 kHz sweep rate

The cut-off frequency can be set for the low-pass filter once the 'Butterworth' filter option has been chosen. The maximum cut-off frequency allowed is 3999Hz.

Number of Fit Points - 8 kHz sweep rate

At the 8 kHz sweep rate, a single fit point corresponds to ~4 pm of the sweep. The number of points can be increased or decreased to optimise the fit for a specific sensor type and shape. The number of fit points is generally optimal when the fit consistently uses as much of the peak or trough as possible but does not cover points where the curve flattens at the base of the peak or trough. This

value typically lies between 1 x FWHM (Full Width Half Maximum) and 2 x FWHM for the peak or trough being tracked; e.g. for a 120pm FWHM FBG fit points settings in the range of 30 points to 60 points usually work well.

Trigger Mode - 8 kHz sweep rate

Two trigger modes are supported by the I4G at 8 kHz sweeping:

- "Master" mode where the sweeps are triggered by the internal timing of the interrogator and run at a constant rate of 8 kHz
- "Slave" mode where the interrogator waits for an external signal before each sweep is triggered.

In "Slave" mode, the external clock must be applied to the *Gate In* SMA connector on the rear panel of the I4G and has:

- Electrical characteristics of the trigger as described in the *Specification Table* in this document.
- A clock frequency greater than or equal to 6400 Hz and less than or equal to 8000 Hz.
- A high to low duty cycle of at least 45% and not more than 55%