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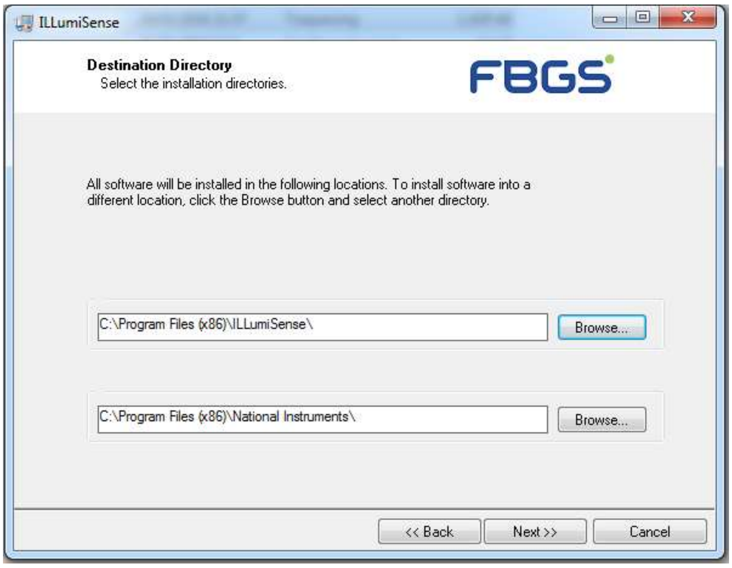
This document describes the use and functionality of the FBGS 'ILLumiSense' software version 3.1. This software has been developed to perform real time measurements using the FBG-Scan interrogator series of FBGS. It supports both the 80X as well as the 90X series and also supports the EP-versions of those systems (Embedded Processing). The software allows sensor configuration, data acquisition, processing and visualization. It works with a modular approach, of which the functionality can be extended by adding extra plugin windows for customer specific applications. In addition, the ILLumiSense can be controlled remotely over a Web Service using an API.

The 'ILLumiSense' software should be installed by following the next steps:

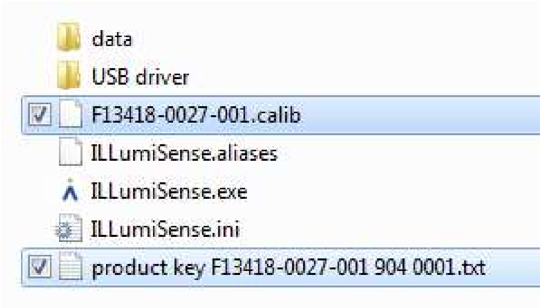
1. Run the 'setup.exe' file from the installation USB-drive, delivered with the FBG-Scan interrogator. The installer does the following steps:

    - Install the 'ILLumiSense' software.



    - Install the USB-device drivers.
    - Installs the 'ILLWS' Web Service

2. Copy the calibration file and product key from the installation USB-drive to the 'ILLumiSense' program folder. The calibration file and product key are device specific files. Therefore, their name contains the serial number of the device. The text file that contains the product key always starts with the serial number of the device. Then it specifies the model for which it is intended, for example '904' and to which user specific windows the key gives access, for example '0001'. An example product key filename is 'F13418-0027-001 904 0001.txt'. The calibration file name for the 90X models also start with the same serial number and it has the extension 'calib', for example 'F13418-0027-001.calib'. The calibration file for the 80X series has a different format. It contains a different F-number and has the extension 'dat', for example 'Calib_LT_F1931444.dat'. The files can be found on the installation USB-drive and it is recommended to copy them to the 'ILLumiSense' program folder that is located on the path as specified during installation. The default location is 'C:\Program Files (x86)\ILLumiSense'.



3. After completion of the previous steps, connect the USB2.0 cable from the FBG-Scan interrogator to the computer. The interrogator should now be recognized by the PC.

4. Launch the ‘ILLumiSense’ software. The first time the software is started, it asks for the product key. Open the product key text file, copy the key in the Product Key popup window and click OK.

The product key will be written to the initialization file from where it can be retrieved at any later point in time.

5. A similar procedure needs to be done with the calibration file. The first time the software is started, it asks also for the calibration file. A browse window will open and the calibration file should be selected. Go to the ILLumiSense program folder and select the calibration file.

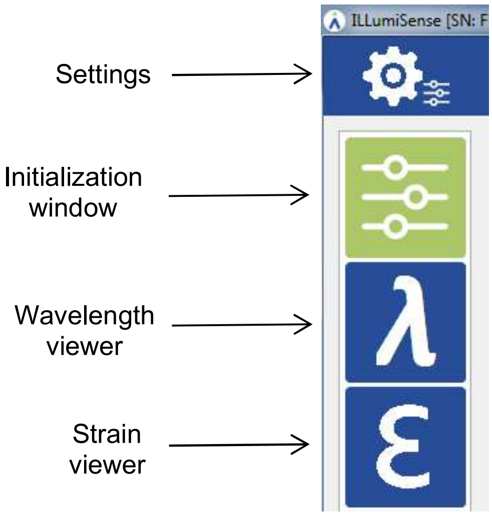
The calibration file path will be written to the initialization file from where it can be retrieved at any later point in time.

The ‘ILLumiSense’ software is compatible with the following models of FBG-Scan interrogators:

800	1510-1590	1
804		4
808		8
904		4
908		8

It also supports the models with Embedded Processing (the ‘EP’ units). Its main functionality is to interface with the FBG-Scan for sensor configuration and data acquisition and to interface with the user for data visualization by means of several ‘viewer’ windows. Standard viewer windows are for wavelength visualization (‘λ') and for strain and temperature compensated strain (‘ε'). More advanced viewer windows like e.g. for curvature and shape need to be activated with a suitable product key and this enables an additional viewer window and button in the User Interface. The software can therefore be thought of like a main data acquisition engine on which several plugins can be added for visualization of customer specific measurement data. The main engine generates wavelength data and this data is transferred to one of the viewers which converts the wavelength data into application specific engineered data that can then also be visualized. Also customized viewers can be made by FBGS on request of the customer so that they can be combined within the main User Interface based on the same working principle. Next to online data processing and visualization, the software can also be used to stream data out over TCP or to save the data into file. The general settings of the ILLumiSense can also be controlled remotely via a Web Service via a set of commands; the so-called ‘Application Programming Interface’ or ‘API’ in short. A description of the commands can also be found in this manual.

The main menu to browse to the different windows can be found on the left-hand side of the User Interface (UI), like shown below. Standard windows are (1) the initialization window, (2) the wavelength viewer window (‘λ') and (3) the strain viewer window (‘ε'), see picture below.

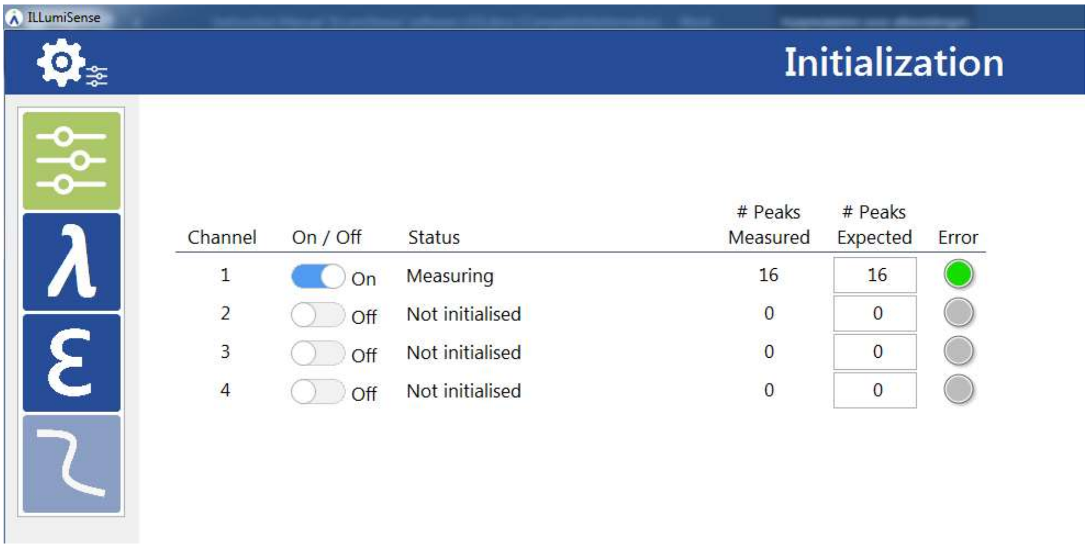


Clicking on a button will show the corresponding window on the right-hand side of the User Interface. Each window is conceived to work intuitively for non-expert users. More advanced settings can be adjusted on each window by clicking on the ‘Settings’ button on the top left, that will make appear the corresponding settings window: one settings window for each main window. The Settings windows are intended for the more advanced users, which are already familiar with fiber sensing technology.

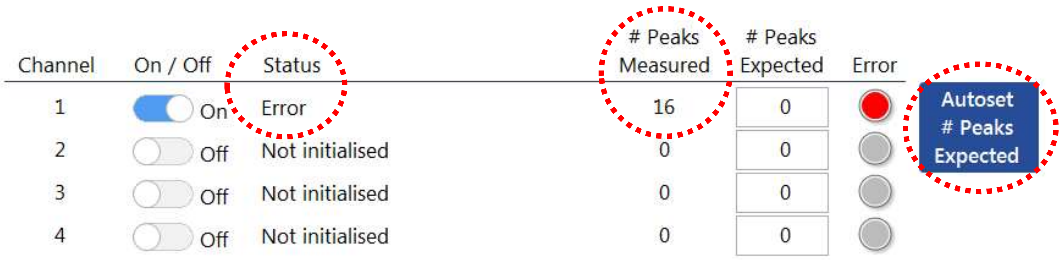
In this section, we give a quick description of the main windows of the User Interface, without going into the details of the settings that can be adjusted in the corresponding ‘Settings’ windows. These details are treated in the next section, see section 5.

The Initialization window is the first button from the top:

This is the first window to start with. It is shown below.



The initialization window needs to be used for initialization of the different optical channels. By default, all channels are disabled. Enabling a particular channel will initiate automatic initialization of this channel: the unit will adjust its settings to optimize detection of the sensors that are present in this channel. After initialization, the number of detected peaks will be displayed in the ‘# Peaks Measured’ column and the ‘Error’ status will indicate red.

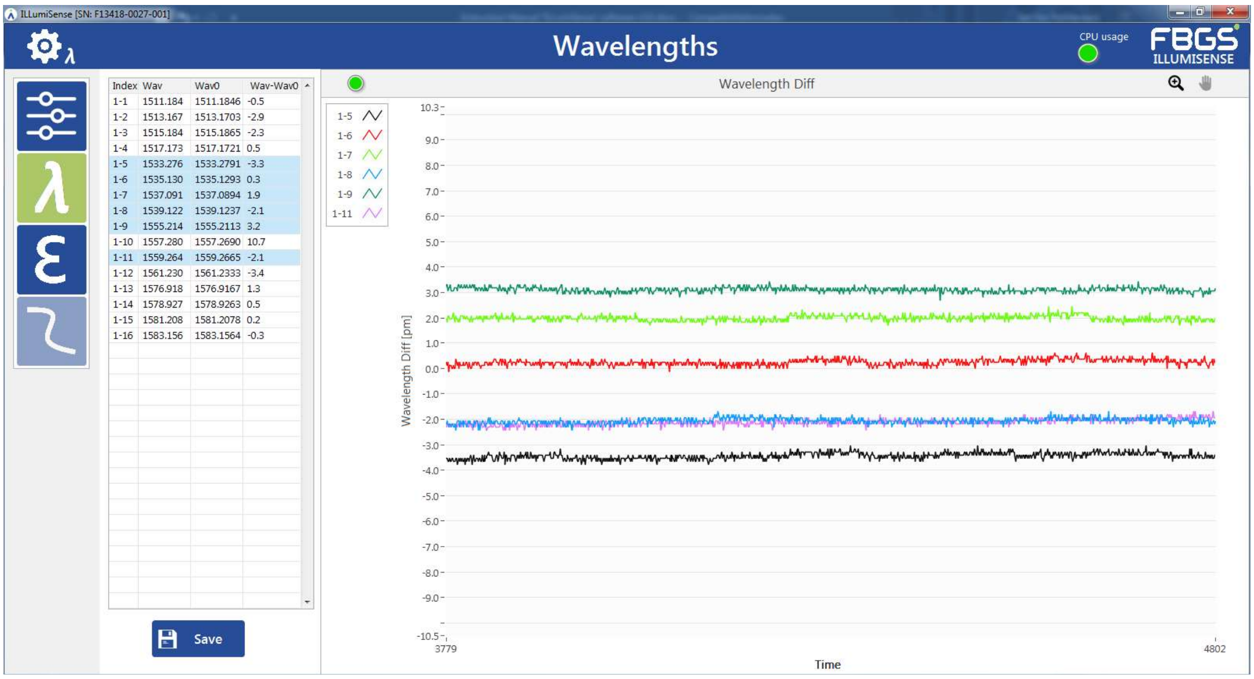


If this number corresponds to the expected number of sensors, the user needs to confirm this by pressing the ‘Auto set # of peaks expected’ button that appears on the right after initialization. Pressing the button confirms the number of sensors and it will set the ‘Error’ status to green. In case the number is different, the user is referred to the ‘Initialization settings’ window, see section 5. When the error status is green, the unit is ready for measurement. The status is indicating ‘Measuring’.

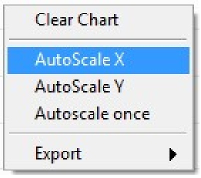
When the sensors from an enabled channel are changed, the channel needs to be initialized again. Therefore, the channel needs to be switched off first and then it needs to be turned on again.

The wavelength window can be accessed by pressing the ‘λ’ button:

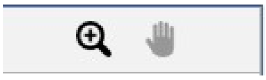
The Wavelength Viewer window is shown below. When the error status is green, the window displays all detected wavelengths of all active channels in table format. For each row, the table presents the sensor ID (given by the channel number and the index of the sensor within this channel), the current wavelength (‘wav’), the reference wavelength (‘wav0’) and the absolute wavelength difference between current and reference wavelength (wav – wav0). The reference wavelengths are defined from the moment when the channel is activated. Clicking on a particular row in the table will plot the wavelength difference in the graph. Multiple sensors can be displayed together in the graph by selecting multiple sensors, while pressing the ‘control’ or ‘shift’ buttons. Up to 10 different sensors can be displayed simultaneously.



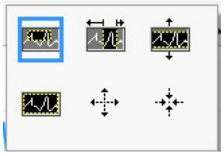
The default settings for the chart is with ‘Auto Scale’ switched off for both axes. Auto Scale for the x- or y-axis can be switched on by right clicking on a particular axis. This will show the Auto Scale selector window:



Zooming in the graph can be done when Auto Scale is off and then by selecting the zoom button on the top right:



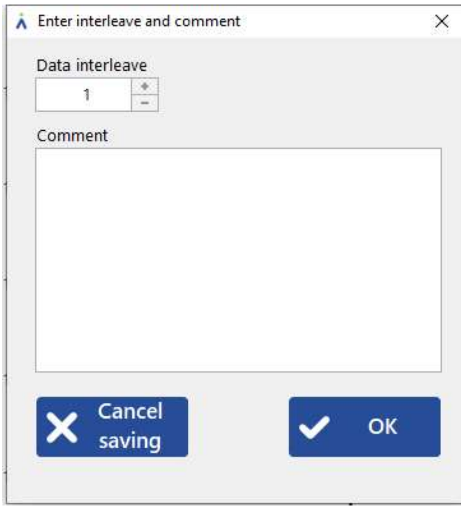
This will show the zoom selector window:



The user can then select to zoom in (top row) or zoom out (bottom row). Panning can be done by selecting the hand button.

If needed, the data can also be logged into file by pressing the ‘Save’ button. The default save folder is ‘C:\My Documents\ILLumiSense\Data’ and the default filename suffix is ‘ILLumiSense’ with the reversed date and time as prefix and the type of data (‘Wav’) and channel number as postfixes. Example for a wavelength data file recorded for channel 1 is ‘20190122 115543-ILLumiSense-Wav-CH1.txt’. The used file format is explained in *Annex 2*.

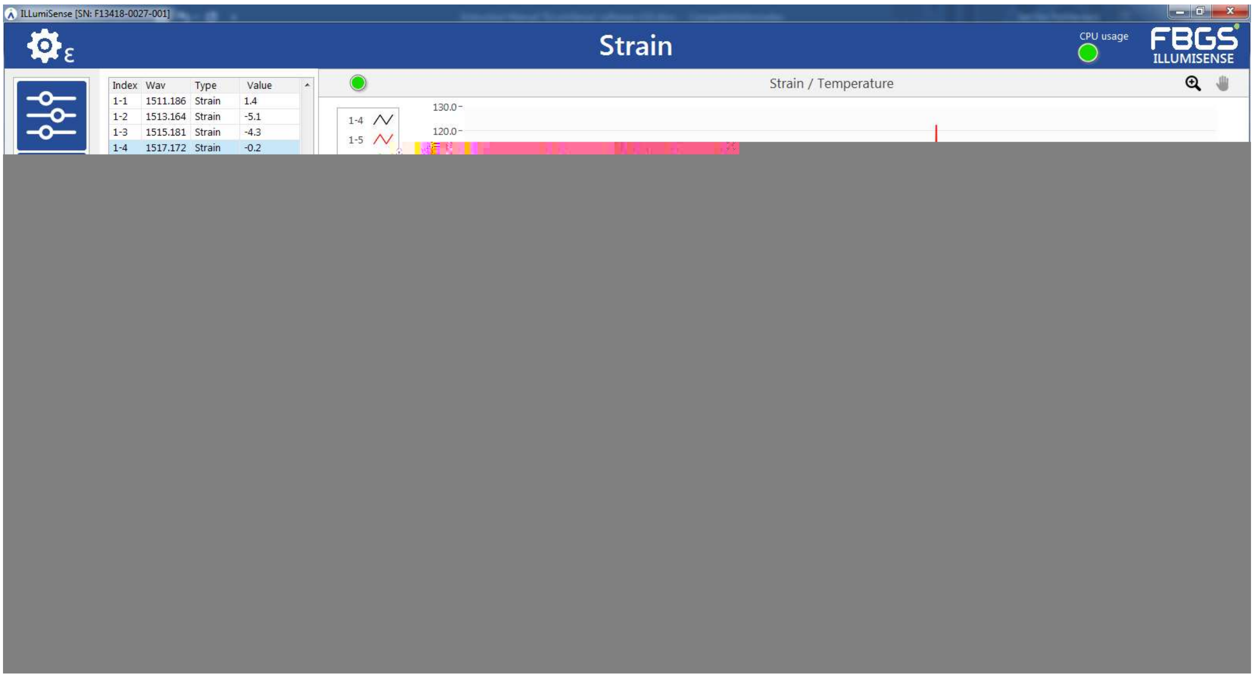
When the Save button is pressed, the following window will appear:



The window allows the user to adjust the ‘Data interleave’ and to enter a comment that will be placed in the header of the save file. The comment can be used to describe the experimental conditions of the current recording. The ‘Data interleave’ is intended to reduce the amount of data stored into file. When the value is 1 (default), all data will be written to file. When the value is larger than one, only samples having a sample number that equals an integer multiple of this value will be written to file. For example, if the data interleave is 10, only the samples with sample number 10, 20, 30 and so on will be written to file. Hence the save data rate equals the scan rate divided by the data interleave.

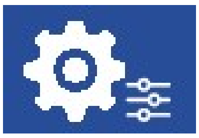
The Strain Viewer window can be accessed by pressing the ‘ε’ button:

In similarity, the Strain Viewer window visualizes the strain in table format and, when selected, also in chart format. It assumes that each sensor is a strain sensor and it uses the same reference wavelengths as in the Wavelength Viewer. A default strain sensitivity factor (or the most recently entered value) is used for conversion of wavelength difference to strain. Selecting the sensors to be plotted in the chart is done similar like for the wavelengths. Also zooming and setting the Auto Scale is done similarly. If needed, the data can also be logged into file by pressing the 'Save' button. The default save file path is 'C:\My Documents\ILLumiSense\Data' and the default filename suffix is 'ILLumiSense'. The prefix is the reversed date and time and the postfix contains the data type ('strain') and the channel number. Example: '20190122 124330-ILLumiSense-Strain-CH1.txt'. The used file format is explained in *Annex 3*. Also, a similar popup window will appear when pressing the Save button that allows the user to adjust the Data interleave and to add Comments in the save file. More advanced settings can be adjusted in the 'Strain Settings' window, see section 5.

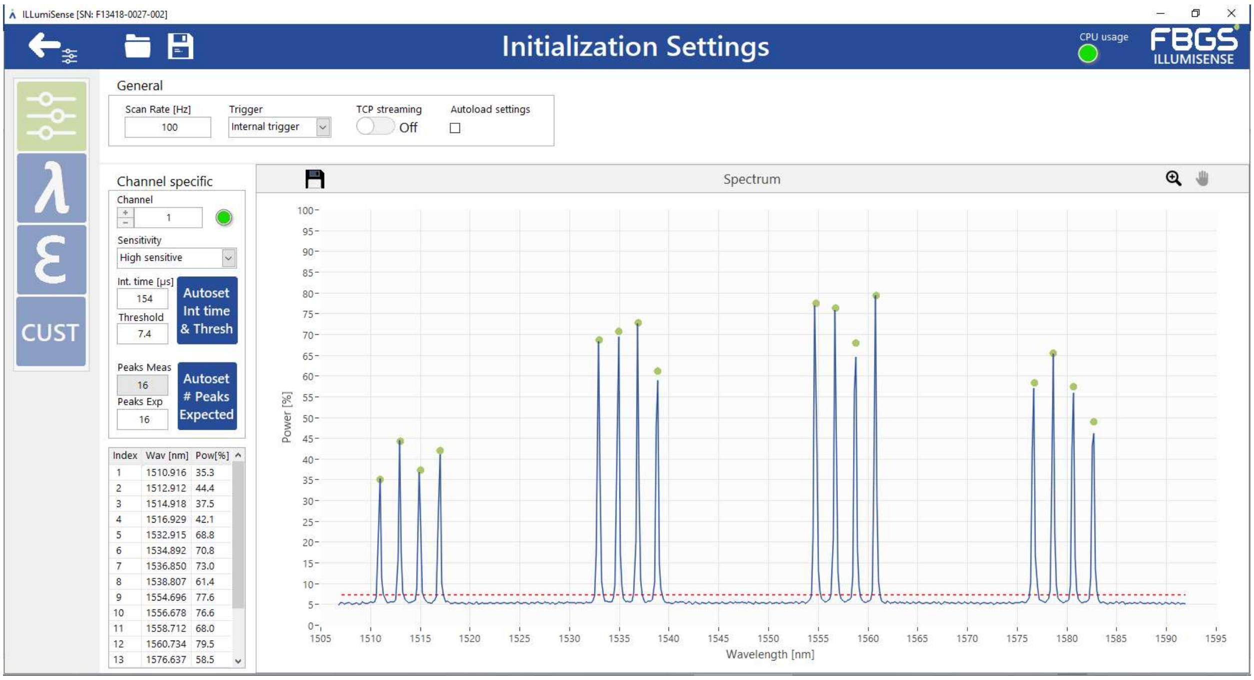


In this section, we will give a more detailed description of the different settings windows, intended for the more advanced users.

For more advanced settings during the initialization step, the 'Initialization Settings' window can be called by pressing the 'Settings' button:

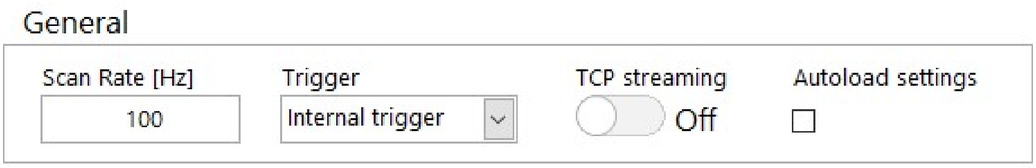


The Initialization Settings window is shown below.

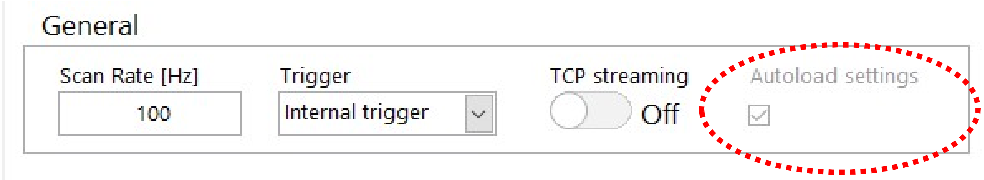


In this window, the optical spectra of the active channels can be visualized and hence allows a visual inspection of their quality. The x-axis shows the wavelength (in nm) whereas the y-axis shows the power (in % of the saturation level of the photo diodes). The active spectrum can be saved by pressing the save button above the spectrum chart. The data file format is explained in *Annex 1*. Ideally, peak powers are near 80 % and the noise level is below 10%. The Threshold is the horizontal line used to discriminate noise from true peaks. The threshold level should be above the noise but apart from that it should be as low as possible. A bullet is shown above all detected peaks. The following settings can be adjusted by the user:

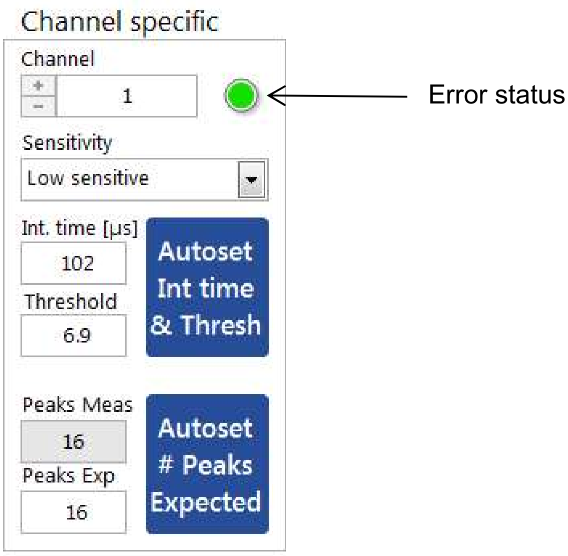
- General settings:



  - The   of the device (in Hz): default value is 100 Hz but can be adjusted from 1 to 5000 Hz, depending on the interrogator model, number of active channels and on the used integration times for the channels.
  - The ‘   ’ mode: indicates which ‘clock’ is used for sampling. Sampling can be done either with the internal clock of the spectrometer (‘Internal trigger’) or either using an external trigger signal (‘External trigger’). The external trigger needs to be delivered on the rear panel of the interrogator via an SMA connector and requires a 3.3 V TTL signal. Several external triggers need to be given for each sample: number of active channels for the 80X models and number of active channels + 1 for the 90X models. For example, if 3 channels are active on the 904, 4 external trigger signals need to be supplied for each sample. Note that the external trigger will only become activated with the software running in a viewer window other than the Initialization window. Switching back to the Initialization window will de-activate the external trigger again.
  - : can be used to enable or disable data streaming over TCP. More info on this can be found in section 6. The default setting is Off. It is recommended to leave this option switched off in case it is not used in order to spare CPU time.
  - : checking this box will enable the software to automatically load the previously saved settings file after having restarted the software. Note that for the EP-units (Embedded Processing), the Autoload settings box is always checked and the control will be disabled and greyed out, like shown below. See section 8 for more info.



- Channel specific settings:



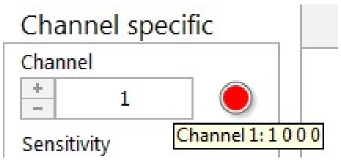
  - : select the channel to be displayed and / or edited.
  - or integration time (in micro seconds): is the time that the photo diodes from the spectrometer detector array collect the light. Longer integration times will increase the peak power in the optical spectrum and vice versa. The integration time needs to be adjusted so that the peak powers are approximately 80 % of the saturation level. Higher peak powers may lead to saturation of the photo detector, which should be avoided. Lower powers increase the risk for the peaks to become cut off by the detection threshold. Notice however that the integration time may put restrictions on the scan rate.
  - mode of the detector array: for each channel, the sensitivity mode can be adjusted between ‘low sensitive’ or ‘high sensitive’. The former can be used for high reflective gratings whereas the latter can be used for low reflective gratings. The sensitivity mode goes together with the ‘Integration time’, see previous bullet. If a spectrum can be measured in high sensitivity mode with all the peaks at or below 80 % of the saturation level, this is the preferred mode. However, when the peak powers are higher than 80 % or saturated, the ‘low sensitivity’ mode needs to be used.
  - level: this is the horizontal line that discriminates noise from true signals. The threshold should be set above the noise but below the peaks. Only signals higher than the threshold can be regarded as true peaks. Therefore, it is recommended to set the threshold above the noise but as low as possible.
  - automatic adjustment of the integration time and threshold.
  - the number of sensors expected in the spectrum can be entered.
  - assumes that the number of detected peaks corresponds to the number of expected peaks and takes this value as the number of expected peaks for a particular channel.

> NOTE
> The integration time may affect the maximum sampling rate of the unit. The longer the integration time, the lower the maximum sampling rate can be. The software will automatically calculate the maximum allowed sampling rate depending on the set integration time(s).

All the above settings can be stored into file by pressing the save button. The save file name (‘ILLimiSense.ini’) and path (‘C:\My Documents\ILLumiSense’) will be displayed after a successful save operation. Saved settings can be loaded again by pressing the browse button. After confirmation, this will load the ‘ILLumiSense.ini’ file back into the software.

Note that the save and load settings buttons write all settings from all the windows to the settings file and so not only for the initialization window but also for the wavelength and strain windows. Note also that for the ‘Autoload settings’ button to work, the settings need to be explicitly saved by pressing this button prior to closing the software.

For each channel, the error status will be displayed. The error is green if no errors are detected and red when one or more errors are detected. Errors are divided into 4 different categories: A, B, C and D. The error status can therefore be represented by 4 individual numbers that are 0 when no error is present and ≠ 0 when there are errors. The error status A B C D can be seen in the tip strip when pointing the mouse arrow over the error status indicator:



The meaning of the values are as follows:

- When different from 0, it means that there is a conflict between the number of peaks detected and the number of peaks expected. The specified value for A is the difference in number of peaks. There can be several reasons for this error to occur like e.g. a drop of the peak powers, a ‘noise peak’ suddenly appearing above the noise threshold, a broken sensor, …

- Indicates that there are peaks with an intensity larger than 90% of the saturation intensity. If this is the case, the integration time needs to be lowered or the sensitivity mode needs to be adapted from high sensitivity to low.

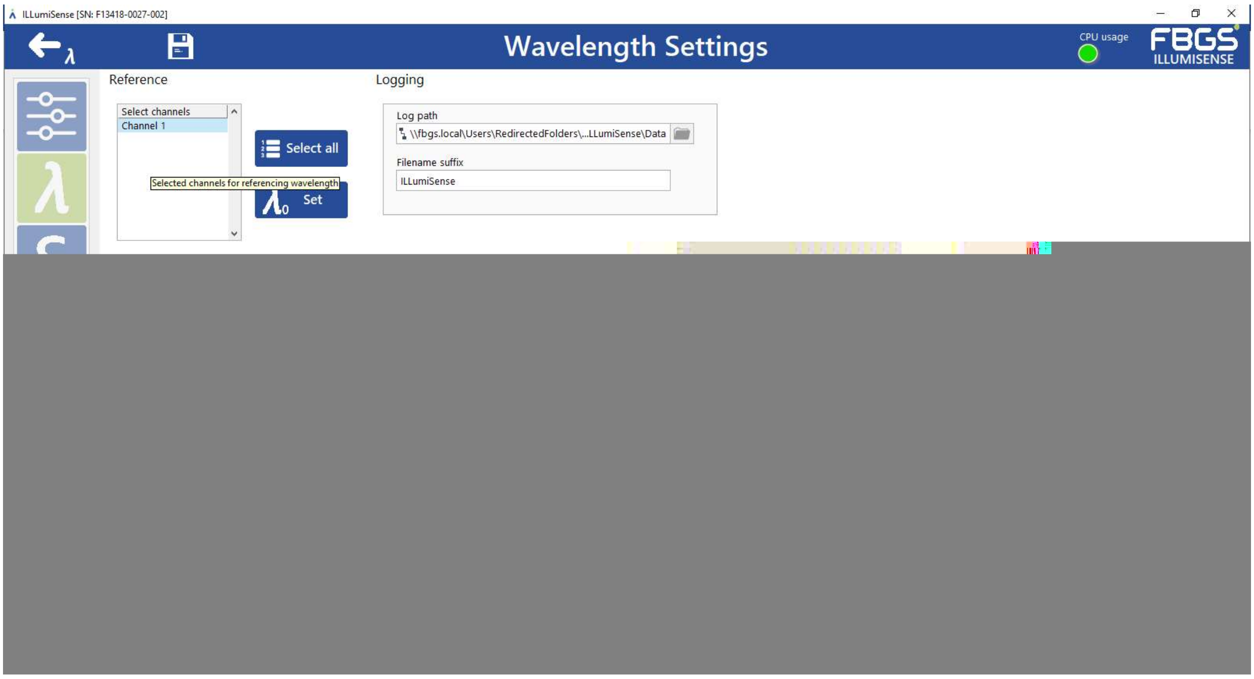
- Indicates that there are peaks that have an intensity smaller then 4/3 of the noise threshold. This could be due to e.g. connectors getting dirty or from sharp bends in the optical path. In this case, clean the connectors and check the lead fibers for sharp bends. If this does not resolve the issue, the integration time needs to be increased or the noise threshold should be lowered.

- Indicates that there are peaks for which the minimum separation with the adjacent peaks is lower than 0.8 nm. When two peaks are less than 0.8 nm from each other, they risk to overlap and hence this may result into faulty measurements. This can occur if the sensor spacing (in wavelength domain) is insufficient or in case some sensors exceed their targeted wavelength range.

> NOTE
> Always be sure that all the optical connectors are properly cleaned, using a ferrule cleaner. Dirty connectors may cause power drops that can in turns cause errors to appear in the sensing network.

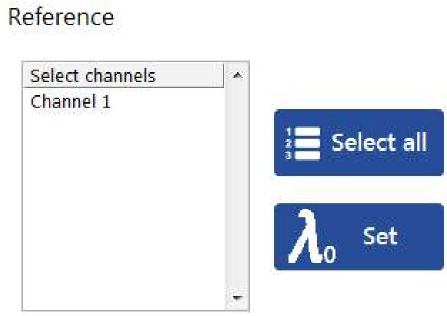
For more advanced settings when in the wavelength viewer window, the ‘Wavelength Settings’ window can be called by pressing the ‘Settings’ button.

The Wavelength Settings window is shown below.

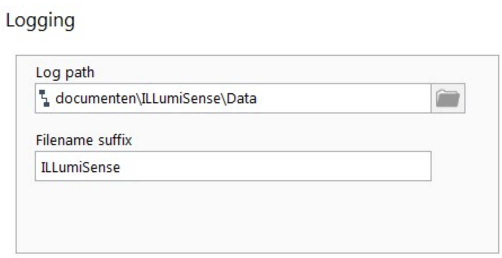


The following settings can be adjusted:

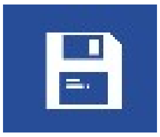
- Update the (‘wav0’ or ‘λ_0’): the reference wavelengths are recorded when the channel is being initialized and from then on, the absolute wavelength difference with respect to this reference (wav – wav0) can be visualized. Updating the reference wavelengths can be done at any other moment in time by pressing the ‘λ_0 set’ button and this for the selected channels from the selection box. Multiple channels can be selected by holding the ‘control’ or ‘shift’ button while selecting the channels. All channels can be selected by pressing the ‘Select all’ button. After successful referencing, a message will appear that referencing has succeeded.



- settings: define the save file path and name. The wavelength data can be logged into file in the Wavelength Viewer window. The default file path is ‘C:\My Documents\ILLumiSense\Data’ and the default suffix is ‘ILLumiSense’. Other log file names and / or paths can be specified in the ‘Logging’ section of the Wavelength Settings window. The log path can be specified or selected from the browse button and another filename suffix can be entered. When logging is started, the time and date are added as prefix and the data type ‘Wav’ and channel number are added as postfix. This way, the filename is uniquely defined each time the ‘Save’ button is pressed.

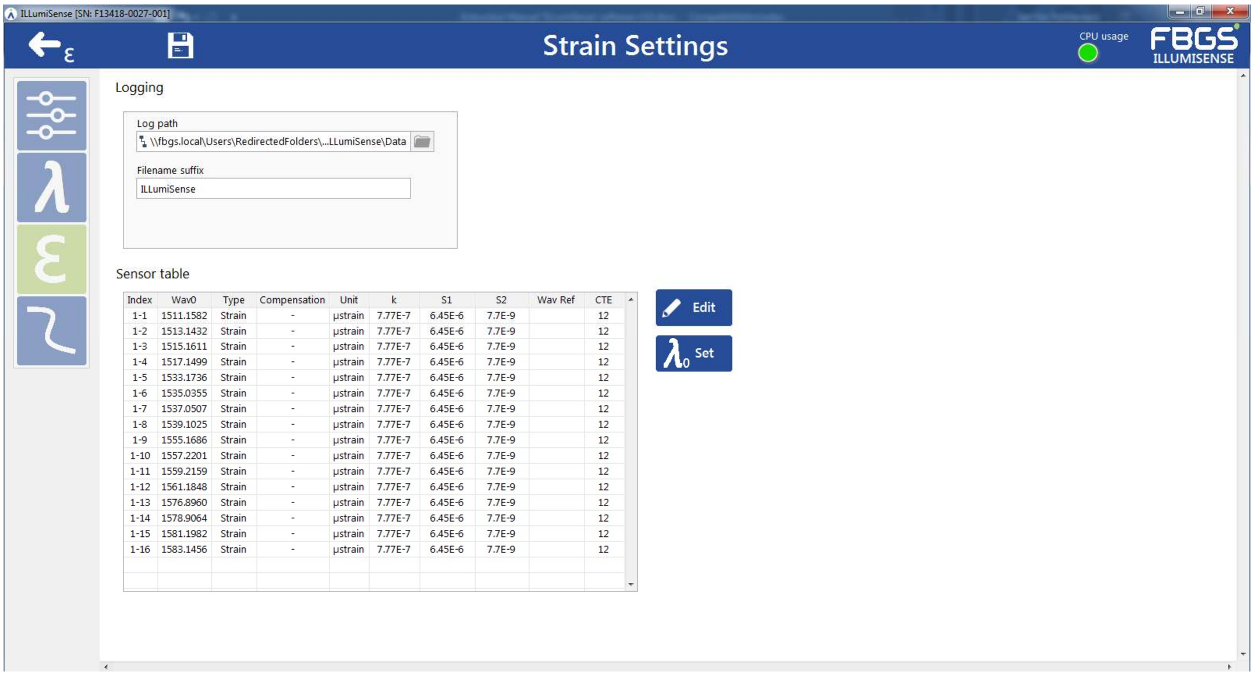


Adapted save file settings together with the updated reference wavelengths can be written to the settings file (‘ILLumiSense.ini’) by pressing the ‘save’ button.



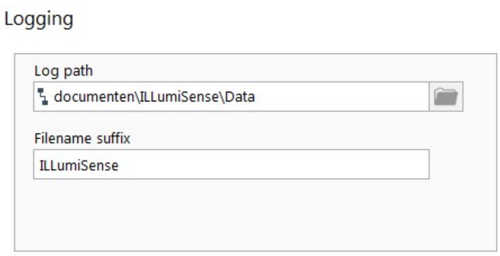
For more advanced settings when in the strain viewer window, the ‘Strain Settings’ window can be called by pressing the ‘Settings’ button.

The Strain Settings window is shown below.

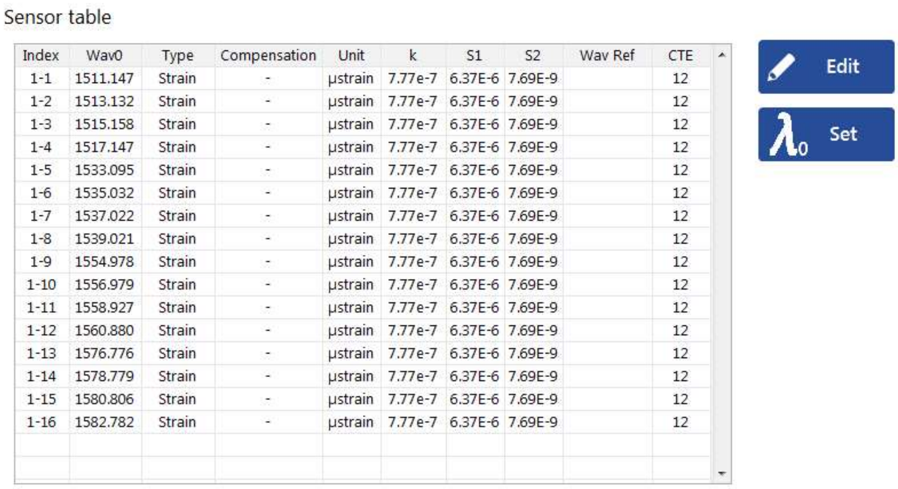


The following settings can be adjusted:

- settings: define the save file path and name. The strain data can be logged into file in the Strain Viewer window. The default file path is 'C:\My Documents\ILLumiSense\Data' and the default suffix is 'ILLumiSense'. Other log file names and / or paths can be specified in the 'Logging' section of the Strain Settings window. The log path can be specified or selected from the browse button and another filename suffix can be entered. When logging is started, the time and date are added as prefix and the data type 'Strain' and channel number are added as postfix. This way, the filename is uniquely defined each time the 'Save' button is pressed.

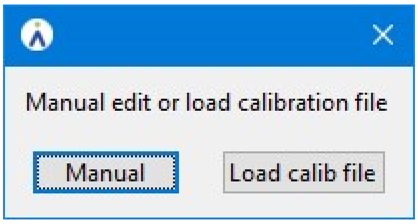


- Enter the calibration parameters in the : by default, all sensors are assumed to be strain sensors.



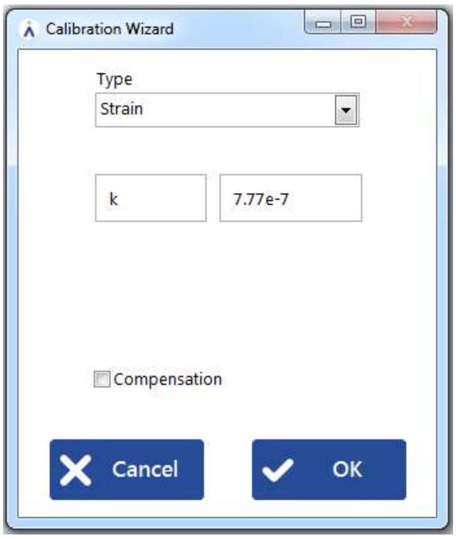
Index	Wav0	Type	Compensation	Unit	k	S1	S2	Wav Ref	CTE
1-1	1511.147	Strain	-	µstrain	7.77e-7	6.37E-6	7.69E-9		12
1-2	1513.132	Strain	-	µstrain	7.77e-7	6.37E-6	7.69E-9		12
1-3	1515.158	Strain	-	µstrain	7.77e-7	6.37E-6	7.69E-9		12
1-4	1517.147	Strain	-	µstrain	7.77e-7	6.37E-6	7.69E-9		12
1-5	1533.095	Strain	-	µstrain	7.77e-7	6.37E-6	7.69E-9		12
1-6	1535.032	Strain	-	µstrain	7.77e-7	6.37E-6	7.69E-9		12
1-7	1537.022	Strain	-	µstrain	7.77e-7	6.37E-6	7.69E-9		12
1-8	1539.021	Strain	-	µstrain	7.77e-7	6.37E-6	7.69E-9		12
1-9	1554.978	Strain	-	µstrain	7.77e-7	6.37E-6	7.69E-9		12
1-10	1556.979	Strain	-	µstrain	7.77e-7	6.37E-6	7.69E-9		12
1-11	1558.927	Strain	-	µstrain	7.77e-7	6.37E-6	7.69E-9		12
1-12	1560.880	Strain	-	µstrain	7.77e-7	6.37E-6	7.69E-9		12
1-13	1576.776	Strain	-	µstrain	7.77e-7	6.37E-6	7.69E-9		12
1-14	1578.779	Strain	-	µstrain	7.77e-7	6.37E-6	7.69E-9		12
1-15	1580.806	Strain	-	µstrain	7.77e-7	6.37E-6	7.69E-9		12
1-16	1582.782	Strain	-	µstrain	7.77e-7	6.37E-6	7.69E-9		12

The type of sensor can be modified by selecting the sensor(s) in the table and by pressing the 'Edit' button. Multiple sensors can be converted simultaneously by selecting multiple sensor from the table using the 'control' or 'shift' buttons before pushing the 'Edit' button. A dialog for selecting the type of editing will be shown: upload a calibration file or manual editing.



- select the calibration file of the selected sensor(s). Note: the number of selected sensors and sensors in the calibration file must be equal. The used file format of the calibration file is outlined in *Annex 5*.

- This will show the 'Calibration Wizard', where the type ('Strain' or 'Temperature') can be selected from the drop down box:



In case a strain sensor needs to be compensated by another sensor, the 'Compensation' check box needs to be checked. This will update the calibration parameters together with a sensor selection box, where the sensor ID of the compensating sensor can be selected. The compensating sensor can be either a temperature sensor or another strain sensor, assuming that this sensor is mounted on a so-called ‘compensating plate’.

The formulas for strain and temperature calibration and temperature compensated strain are all implemented in the software and do not need to be entered. The used formula depends on the type of sensor that is defined (strain sensor, temperature sensor or compensated strain sensor), see table below.

S		
Strain (ε)	$\varepsilon = \frac{1}{k} ln\left(\frac{\lambda}{\lambda_0}\right)$	k = gage factor λ = actual wavelength λ_0 = reference wavelength
Temperature (T)	$T = 22.5 - \frac{S_1}{2S_2} + \frac{S_2}{\lvert S_2\rvert} \cdot \sqrt{\left(\frac{S_1}{2S_2}\right)^2 + \frac{1}{S_2} ln\left(\frac{\lambda}{\lambda_{ref}}\right)}$	S_1= linear T-sensitivity S_2 = quadratic T-sensitivity λ_{ref} = wavelength at 22.5°C
Temperature Compensated strain (ε)	$\varepsilon = \frac{1}{k}\left[ln\left(\frac{\lambda}{\lambda_0}\right) - S_1(\Delta T - \Delta T_0) - S_2\left(\Delta T^2 - \Delta {T_0}^2\right)\right] - \left(\alpha_s - \alpha_f\right).(\Delta T - \Delta T_0)$	S_1= linear T-sensitivity S_2 = quadratic T-sensitivity ΔT = T - 22.5°C $\Delta T_0 = T_0 - 22.5$°C; T_0 the temperature at referencing α_s = CTE of host material α_f = CTE of optical fiber (0.5 με / °C)
Compensated strain via compensating plate (ε)	$\varepsilon = \frac{1}{k}\left[ln\left(\frac{\lambda}{\lambda_0}\right) - ln\left(\frac{\lambda_C}{\lambda_{0C}}\right)\right]$	λ_C = wavelength of compensating gage λ_{0C} = reference wavelength of compensating gage

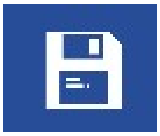
For a more detailed explanation of the different compensation principles, the user is referred to the Fibre Optic Strain Gages Installation Manual. The calibration parameters need to be specified in the calibration wizard and they are stored and shown in the sensor table from the Strain Settings Window.

Depending on the type of sensor, the following calibration parameters need to be specified:

Strain	k	Gage factor or strain sensitivity parameter. The value is typically 7.77 10^{-7} but might vary slightly depending on the production batch.
Temperature	S1	Linear temperature sensitivity factor.
	S2	Quadratic temperature sensitivity factor.
	WavRef	Reference wavelength at 22.5°C. Determined for each sensor individually.
T-compensated strain	k	Gage factor or strain sensitivity factor.
	S1	Linear temperature sensitivity factor.
	S2	Quadratic temperature sensitivity factor.
	CTE	Coefficient of Thermal Expansion of the material to which the strain sensor is attached. Needs to be looked up in literature or checked with material supplier.
	Compensation ID	ID (channel – index) of the temperature compensating sensor.

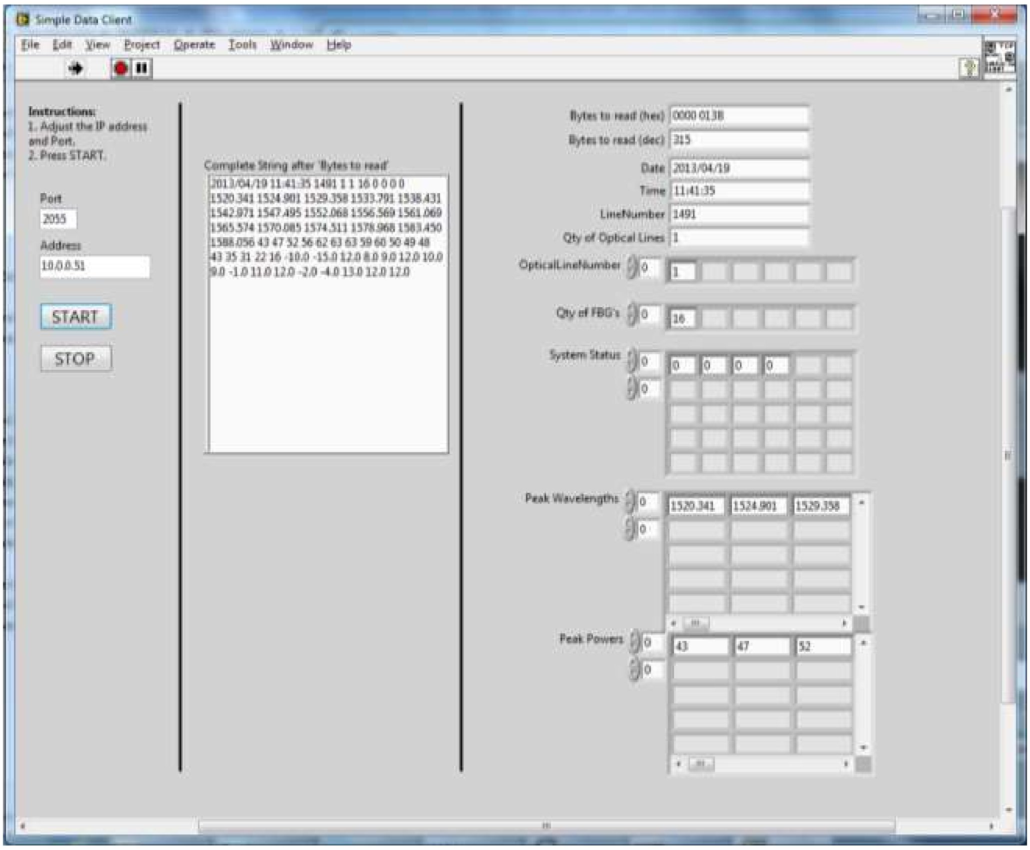
- Update the reference wavelength(s) and reference temperature of one or multiple sensors: the reference wavelengths (‘Wav0’ or ‘λ_0’) of one or several sensors can be updated in the sensor table by selecting the sensor(s) and by pressing the ‘λ_0’ set’ button. The reference wavelengths of the selected sensors will then be updated with the currently measured wavelengths.

Adapted save file settings together with the updated sensor table can be written to the settings file (‘ILLumiSense.ini’) by pressing the ‘save’ button.



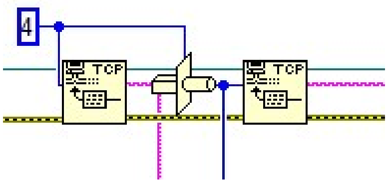
Data streaming over TCP can be enabled in the Initialization Settings window. When enabled, the software will always send out the wavelength and strain data over a TCP link via the Ethernet port from the measurement PC. In this way, the data can be collected by another network computer or by another software application for visualization, storage or further data processing. This allows users to develop customized programs, running in parallel with the ILLumiSense.

A LabVIEW example file of a data receiver program that can be used on the receiving computer is contained on the installation USB-drive in the folder ‘Example TCP Data Receiver’. The used version of LabVIEW is 2016. The User Interface is shown in the figure below.



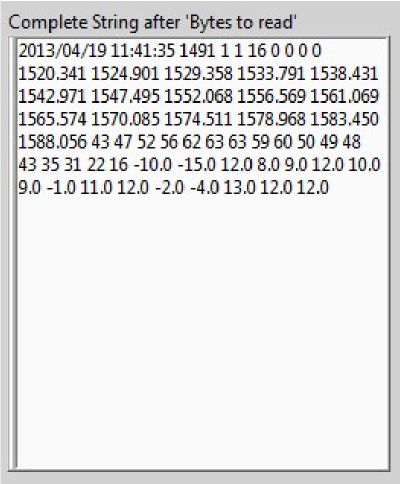
The program needs the IP-address of the measurement computer as input and the used TCP port number. The latter is 2055. The data receiver program can also run on the same computer as where the ILLumiSense is running. In this case, the IP address to be used is 127.0.0.1. Both the ILLumiSense and the data receiver program are running then in parallel on the same computer.

The example receiver program is made in LabVIEW but this can in principle be any software platform that is capable to receive the TCP data stream. The main flow that the receiver program should have is as follows. A TCP connection is opened and a first read operation is executed. This read operation gives as a result the total length in bytes of the string that follows. During a second read operation, the rest of the string is read with the length of the first read operation. In LabVIEW, this can be done with the following piece of code:



The first read operation has a length of 4 bytes because the first value from each data string is a 4 byte (or 32 bit) signed integer that represents the length in bytes of the string to follow. The result of this read operation is a string that can be type casted into a signed 32 bit integer. This value is subsequently used as the input for a second read operation, which yields a string in ASCII characters of which the different fields are TAB separated. The used format of this data string is presented in *Annex 4*.

With the example receiver program running, it will show the real time data string in the middle of the panel. On the right-hand side of the panel, the data string is further disentangled into the various TAB separated items such as wavelengths, powers, error codes etc. for the different active channels.



The web based API is particularly useful for the EP-versions in order to control the ILLumiSense remotely. In this section, the commands that can be used from the API will be detailed.

General information:

- The commands start with http://*IP-address*:*port*/ILLWS/
- If the API commands are send out from the same PC as the one that is running the ILLumiSense, the IP-address should be 127.0.0.1. If ILLumiSense is running on a different machine, the IP-address of this particular machine needs to be used.
- The port to be used is 8002 (unsecured link).
- The results are returned in JSON format.
- The channel numbering starts at index 0:
    - channel 1 = 0
    - channel 2 = 1
    - …
- The 'Error' has the following possible returns:
    - 0: No error
    - 1: Error during execution of the command
    - 2: Accept command timeout (30 s)
    - 3: System ready timeout (5 s)
- Fields indicated between curly brackets like for example {value} should be replaced with the actual value and the curly brackets should be omitted.
- Example:
    - Command: http://127.0.0.1:8002/ILLWS/EnableChannel?Enable=1&Channel=1
    - This command enables channel 2
    - Exemplary return: {"Error":0,"Peaks":16}

	/GetHWInformation
	-
	• Error • TypeHW: Name of interrogator • NumberOfChannels: Maximum number of channels • ScanRates: Array with maximum possible scan rate (in Hz) depending on the number of enabled channels. First element is maximum scan rate when 1 channel is

	enabled, second element is maximum scan rate when 2 channels are enabled, …
	{"Error":0,"TypeHW":"FBG-scan 904","NumberOfChannels":4,"ScanRates":[1000,667,500,400]}

	/GetSWVersion
	-
	• Error • SWVersion: Version of the webservice software
	{"Error":0,"SWVersion":"ILLumiSense v3.1.0"}

	/GetFWVersion
	-
	• Error • FWVersion: Version of firmware spectrometer
	{"Error":0,"FWVersion":"20190516"}

	/GetSerialNumber
	-
	• Error • SN: Serial number of the interrogator
	{"Error":0,"SN":"F13418-0027-001"}

	/EnableChannel?Enable={value}&Channel={value}
	• Enable: 0 / 1 to disable / enable the channel • Channel: the channel number to be enabled / disabled (channel numbering starts with 0).
	• Error • Peaks: Number of peaks detected
	{"Error":0,"Peaks":1}

	/AutoSetChannel?Channel={value}
	• Channel: the channel number for which the settings should be adjusted automatically (channel numbering starts with 0).
	• Error • SensitivityMode: 0 or 1 for 'Low sensitive' or 'High sensitive' mode respectively • IntegrationTime: the set integration time (value in microseconds) • ThresholdLevel: the set threshold level (value in % of saturation value)
	{"Error":0,"SensitivityMode":0,"IntegrationTime":260, "ThresholdLevel":7.8}

	/AutoSetExpectedPeaks?Channel={value}
	• Channel: the channel for which the number of expected peaks has to be set (channel

	numbering starts with 0).
	• Error • ExpectedPeaks: Number of peaks set as expected peaks
	{"Error":0,"ExpectedPeaks":1}

	/GetChannelStatus?Channel={value}
	• Channel: the channel number for which the error status is requested (channel numbering starts with 0).

	• Error
	• ErrorStatus: 1D-array representing the channel error status:
	  ○ A-error status
	  ○ B-error status
	  ○ C-error status
	  ○ D-error status

	{"Error":0,"ErrorStatus":[0,0,0,0]}

	/GetActiveChannels
	-
	• Error • ActiveChannels: 1D-array representing a list of all enabled channel numbers
	{"Error":0","ActiveChannels":[0,1]}

	/GetChannelSettings?Channel={value}
	• Channel: the channel number for which the settings are asked (channel numbering starts with 0).
	• Error • SensitivityMode: 0 or 1 for 'Low sensitive' or 'High sensitive' mode respectively • IntegrationTime: the set integration time (value in microseconds) • ThresholdLevel: the set threshold level (value in % of saturation value)
	{"Error":0,"SensitivityMode":0,"IntegrationTme":260, "ThresholdLevel":7.82351684570312}

	/SetChannelSettings?ThresholdLevel={value}&IntegrationTime={value}&SensitivityMode={value}&Channel={value}
	• ThresholdLevel: threshold level in % of the saturation line • IntegrationTime: value for the integration time in microseconds • SensitivityMode: 0 or 1 for 'Low sensitive' or 'High sensitive' mode respectively • Channel: the channel number for which the settings are updated (channel numbering starts with 0).
	• Error
	{"Error":0}

	/GetScanRate

	-
	• Error • ScanRate: the actual scan rate (value in Hz).
	{"Error":0,"ScanRate":100}

	/SetScanRate?SetScanRate={value}
	• SetScanRate: the scan rate to be set (in Hz)
	• Error • ScanRate: The set scan rate (in Hz)
	{"Error":0,"ScanRate":50}

	/EnableTCP?Enable={value}
	• Enable: 0 or 1 to disable or enable the TCP-streaming respectively
	• Error • Status: value representing the actual TCP-streaming status (0 or 1)
	{"Error":0,"Status":1}

	/GetPeaks?Channel={value}
	• Channel: the channel number for which the peak wavelengths are asked (channel numbering starts with 0).
	• Error • PeakWavelengths: 1D-array of the peak wavelengths (in nm) in ascending order • PeakPowers: 1D-array of the peak powers (in % of saturation)
	{"Error":0,"PeakWavelengths":[1511.098876953125,… ,1583.114379882813], ”PeakPowers”:[36.29401779174805,48.53025436401367,…, 60.40765380859375],}

	/GetSpectrumBasic?Channel={value}
	• Channel: the channel number for which the spectrum is asked (channel numbering starts with 0).
	• Error • SpecPow: 512 spectrum powers (in % of saturation)
	{"Error":0,"SpecPow":[5.0689697265625,5.76171875,5.5938720703125,5.3497314453125,5.3192138,… , 5.54351806640625]}

	/GetSpectrum?Channel={value}
	• Channel: the channel number for which the spectrum is asked (channel numbering starts with 0).
	• Error • SpecWav: 512 spectrum wavelengths (in nm) in ascending order • SpecPow: 512 spectrum powers (in % of saturation)
	{"Error":0, "SpecWav":[1506.806518554688,1506.986206054688,…, 1592.01318359375],"SpecPow":[5.0689697265625,5.76171875,5.5938720703125,5.3497314453125,5.3192138,… , 5.54351806640625]}

	/SaveSettings
	-
	• Error
	{"Error":0}

	/LoadSettings
	-
	• Error
	{"Error":0}

	/Reboot
	-
	• Error
	{"Error":0}

The ILLumiSense is also equipped with a ‘Watch Dog Timer’ or ‘WDT’, which is intended for usage on the EP-versions. On these systems it is standardly enabled. It can be particularly useful in case continuous monitoring is required over extended periods of time. When enabled, the WDT will restart the embedded PC when ILLumiSense becomes inactive or when the Operating System of the embedded PC crashes. After one minute of inactivity, the WDT will issue a system reboot. When it is used on any other PC (other than the one from the EP-versions), the WDT from ILLumiSense is disabled.

> NOTE
> The WDT is only enabled for the EP-versions of the FBG-Scan interrogators.

When a reboot is forced by the WDT, the ILLumiSense should reload its settings from the settings file. On the EP-versions, the ‘Autoload settings’ check box is standardly enabled and the control is disabled and greyed out. This way, the software will always continue measuring like it was doing before the reboot. In addition, the following points need to be respected as well:

- ILLumiSense should be launched after reboot. Therefore, it should be present in the ‘Start up’ menu. This is standardly configured on the EP-versions.
- The measurement computer should have auto logon so that it does not need intervention from the user to login after restart. This is standardly configured on the EP-versions.
- The settings need to be stored in the setting file.

The Spectrum data text file contains a header, that contains the system settings for the selected active channel and the spectrum data, that consists of a column with wavelength values and a column with power values. The delimiter between 2 values in the same row is a TAB character. An example of (part of) a spectrum data file is presented below.

```
Date Time: 15:55:54.255 23/01/2019
Type interrogator:      FBG-scan 904
ID number:      F13418-0027-001
Software version: v3.0.0
Active channel: 1
Integration Time [µs]: 107
High Sensitivity: FALSE
Noise Threshold: 6.965973

Wavelength[nm]  Ch1[%]
1507.5947       4.8
1507.7728       5.5
1507.9509       5.3
1508.1290       4.9
1508.3070       5.0
1508.4850       5.1
1508.6628       5.2
1508.8407       4.9
1509.0186       4.8
1509.1963       5.2
1509.3740       5.3
1509.5516       4.9
1509.7292       5.1
1509.9069       5.2
1510.0844       5.2
1510.2617       5.2
1510.4392       5.1
1510.6166       5.8
1510.7938       6.9
1510.9711       10.7
1511.1483       44.0
1511.3254       29.3
1511.5026       8.8
1511.6797       6.6
1511.8567       5.4
1512.0336       5.4
1512.2104       5.6
1512.3873       5.2
1512.5642       5.5
1512.7410       6.8
1512.9176       10.4
```

For each active channel, a separate save file will be created. Each save file has the following structure: (1) a header that contains general system settings, (2) the reference wavelengths table (wav0) for the particular channel and (3) the actual wavelength data: 1 row per sample. For each sample, there is a timestamp (date and time), a line number, the error status, the peak wavelengths and the peak powers for all the sensors from this particular channel. An example of a data file is presented below for a fiber containing 3 sensors.


Date Time: 15:56:09.383 23/01/2019
Type

> NOTE
> The time stamp and the line number are generated by 2 different clocks. The time stamp is generated by the clock of the measurement PC whereas the line number comes from the internal clock of the interrogator (no triggering) or from the external trigger source, which ticks at the set sampling rate. For fast sample speeds, there might be a synchronization mismatch between both clocks and this may give the wrong impression that the sampling is not performed regularly. In this case, the line number should be used as the most accurate clock and the time stamp should be used only for indicative purposes. It is for this reason that the time stamp is only specified with an accuracy of 1 second.

For each active channel, a separate save file will be created. Each save file has the following structure: (1) a header that contains general system settings, (2) the sensor calibration table for the particular channel and (3) the actual strain data: 1 row per sample. For each sample, there is a timestamp (date and time), a line number, the error status and the strain values per sensor from this particular channel. An example of a data file is presented below for a fiber containing 3 sensors.

```
Date Time: 15:56:20.839 23/01/2019
Type interrogator: FBG-scan 904
ID number: F13418-0027-001
Software version: v3.0.0
Active channel: 1
Integration Time [µs]: 107
High Sensitivity: FALSE
Sample Speed [Hz]: 100
Data interleave: 1
Noise Threshold: 6.965973
Comment:

Index   Type    Comp    Unit    k       S1      S2      Wav Ref
1-1     Strain  -       µstrain 7.77E-7 6.45E-6 7.7E-9
1-2     Strain  -       µstrain 7.77E-7 6.45E-6 7.7E-9
1-3     Strain  -       µstrain 7.77E-7 6.45E-6 7.7E-9

Date            Time            LineNumber      System status   1-1     1-2     1-3
2019/01/23      15:56:20        4019            0 0 0 0         0.0     -0.1    0.3
2019/01/23      15:56:20        4020            0 0 0 0         -0.1    -0.3    0.2
2019/01/23      15:56:20        4021            0 0 0 0         0.2     -0.3    0.3
2019/01/23      15:56:20        4022            0 0 0 0         -0.2    -0.2    0.3
2019/01/23      15:56:20        4023            0 0 0 0         -0.1    -0.2    0.0
2019/01/23      15:56:20        4024            0 0 0 0         -0.1    -0.2    0.2
2019/01/23      15:56:20        4025            0 0 0 0         -0.2    -0.3    0.2
2019/01/23      15:56:20        4026            0 0 0 0         0.0     -0.1    0.2
2019/01/23      15:56:20        4027            0 0 0 0         -0.2    0.0     0.5
2019/01/23      15:56:20        4028            0 0 0 0         -0.1    -0.3    0.0
2019/01/23      15:56:20        4029            0 0 0 0         -0.2    -0.2    0.2
2019/01/23      15:56:20        4030            0 0 0 0         -0.2    -0.2    0.3
2019/01/23      15:56:20        4031            0 0 0 0         -0.3    -0.2    0.5
2019/01/23      15:56:20        4032            0 0 0 0         -0.1    -0.3    0.3
2019/01/23      15:56:20        4033            0 0 0 0         -0.3    -0.1    0.3
2019/01/23      15:56:20        4034            0 0 0 0         -0.1    -0.2    0.3
2019/01/23      15:56:21        4035            0 0 0 0         0.0     -0.3    0.5
2019/01/23      15:56:21        4036            0 0 0 0         -0.3    -0.1    0.3
2019/01/23      15:56:21        4037            0 0 0 0         -0.2    -0.1    0.5
2019/01/23      15:56:21        4038            0 0 0 0         -0.2    -0.2    0.3
```

NOTE

The time stamp and the line number are generated by 2 different clocks. The time stamp is generated by the clock of the measurement PC whereas the line number comes from the internal clock of the interrogator (no triggering) or from the external trigger source, which ticks at the set sampling rate. For fast sample speeds, there might be a synchronization mismatch between both clocks and this may give the wrong impression that the sampling is not performed regularly. In this case, the line number should be used as the most accurate clock and the time stamp should be used only for indicative purposes. It is for this reason that the time stamp is only specified with an accuracy of 1 second.

In this operating mode, the data is transmitted in blocks and each block contains the data from a single sample i.e. the measurement of all sensors from the active channels. The rate of sending the data blocks thus corresponds to the sampling rate. Each data block starts with a 4 byte (or 32 bit) signed integer that represents the length in bytes of the string to follow. The rest of the block is ASCII string data of which the different items are TAB delimited. Each data block has the following format:

The total length of the string to follow in bytes. This value is a 4 byte (or 32 bit) integer.

DD/MM/YYYY where

a. DD = day of month
b. MM = month of year
c. YYYY = year (with century)

hh:mm:ss where

a. hh = hours (24 hours format)
b. mm = minutes
c. ss = seconds

This number is a unique sample number. It increments with 1 for each new sample. In this way, it can be checked if some samples are missing.

The number of optical channels that is read out (enabled) during the measurement of 1 sample. For each optical channel, the following information will be provided:

a. The optical channel. This value sweeps over all the active channels.
b. Number of FBG-sensors detected in the current optical channel.
c. 4 space separated integers specifying different types of detected errors.
d. Array of the peak wavelengths. One wavelength per detected sensor.
e. Array of the peak powers. One power value per detected sensor.

The table below gives the data type that the string data represents for the different items.

1	Length of string in bytes	4 byte integer
2	Date	DD/MM/YYYY
3	Time	hh:mm:ss
3	Line Number	Integer
4	Qty of Optical Lines Measured	Integer
5	Optical Line Number	Integer
6	Qty of FBG's	Integer
7	Error status (A, B, C, D)	4 space separated integers
8	Peak Wavelengths	array of singles (xxxx.xxx or NaN example: 1531.241)
9	Peak Powers	array of integers (range integers 0-100 or NaN)
10	Optical Line Number	Integer
11	Qty of FBG's	Integer
12	Error status (A, B, C, D)	4 space separated integers
13	Peak Wavelenghts	array of singles (xxxx.xxx or NaN example: 1531.241)
14	Peak Powers	array of integers (range integers 0-100 or NaN)
…	…	…
…	Qty of Engineered values	Integer

…	Engineered values	array of doubles

Below, an example of such a data string is shown:

232	Length of the string in bytes
31/08/2010	Date
16:11:46	Time
746	Line Number
4	Qty of Optical Lines Measured
1	Optical Line Number
6	Qty of FBG's
0	System status A
0	System status B
0	System status C
0	System status D
1510.26	Peak Wavelenghts
1524.211	
1536.696	
1550.656	
1563.708	
1577.245	
45	Peak Powers
58	
41	
53	
47	
52	
2	OpticalLineNumber
10	Qty of FBG's
0	System status A
0	System status B
0	System status C
0	System status D
1510.183	Peak Wavelenghts
1518.992	
1526.103	
1534.053	
1542.337	
1550.394	
1558.08	
1566.224	
1574.09	
1582.431	
44	Peak Powers
60	
42	
41	
47	
48	
42	
44	
42	

49	
3	OpticalLineNumber
9	Qty of FBG's
0	System status A
0	System status B
0	System status C
0	System status D
1510.95	Peak Wavelenghts
1518.936	
1528.055	
1536.916	
1545.605	
1555.107	
1563.437	
1572.349	
1582.091	
59	Peak Powers
41	
46	
45	
41	
53	
42	
43	
60	
4	OpticalLineNumber
15	Qty of FBG's
0	System status A
0	System status B
0	System status C
0	System status D
1510.72	Peak Wavelenghts
1516	
1520.677	
1526.604	
1531.569	
1537.594	
1542.333	
1547.744	
1553.187	
1558.118	
1564.245	
1569.357	
1574.308	
1579.758	
1585.661	
54	
53	
40	
52	
45	
59	

47	
48	Peak Powers
50	
42	
58	
54	
46	
48	
60	

The senor calibration file is a txt file that contains the calibration parameters, which are tab separated. The last line of the file contains the parameters for the last sensor (FBG) i.e. there is no empty line at the end of the file. The format is defined as follows:

- The 1st line specifies the type of sensor ('Temp' or 'Strain')
- The 2nd line specifies the serial number of the sensor.
- The 3rd line lists the calibration parameter(s) of the first sensor (FBG).
- The 4th line lists the calibration parameter(s) of the second sensor (FBG).
- …
- The last line lists the calibration parameter(s) of the last sensor (FBG).

Example1:

```
Temp
PR2020_05/06_09
6.46E-06	7.70E-09	1513.9836
6.46E-06	7.72E-09	1517.7557
6.46E-06	7.70E-09	1521.7519
```

Last line of file

Example2:

```
Strain
PR2020_05/06_08
7.71E-07
7.72E-07
7.73E-07
7.74E-07
```

Last line of file

General:

Type of sensor
Serial Number senor
S1 S2 WavRef
or
k