User Manual

FBG interrogator AGSWA-V3.0.2

Change Log:

Version	Date	Description
V2.1	2022/11/20	Initial version
V2.2	2022/11/29	1, Chapter 5.2: The field of "channel" change to 4 bytes unsigned int. 2.Add chapter 5.5 and chapter 5.6. 3. Add chapter 4.6
V3.0.1	2023/6/1	Add chapter 4.2.2 HDR; Add chapter 4.3 Parameter criterion
V3.0.2	2023/7/23	Add principle introduction in 1 Descriptions
V3.0.3	2023/11/20	Add Start continuous raw spectral data

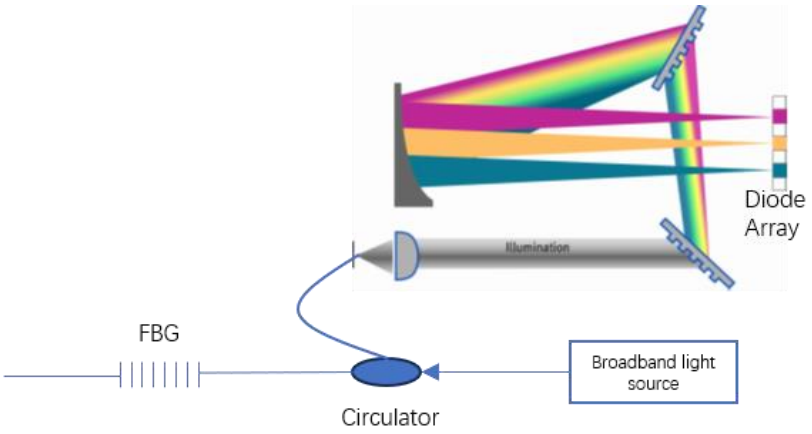
Contents

1 Descriptions

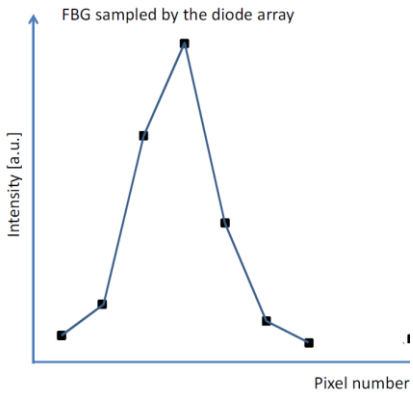
Equipped with broadband light source and based on diffraction grating, the AGSWA is capable of calculating the wavelength in high stable. AGSWA has the very excellent features as:

No moving part
No fan design
High speed response
Broadband measurement
Temperature compensation in real time
No need wavelength calibration
Wavelength reading out simultaneously

There's a high-resolution spectrometer platform inside the interrogator which spatially separates the wavelength spectrum. The spectra reflected from the FBGs are focused onto a diode array. The reflected FBG spectra are sampled by the diode array with either 256 pixels (40nm bandwidth) or 512 pixels (80nm bandwidth). The average pixel spacing in wavelength is about 156 pm. The inside spectrometer is temperature characterized. With the temperature correction, the effects of temperature will be eliminated. The repeatability is typical 3pm(5pm max) when the polarization is rotated 360 deg.



Structure diagram



2 Specifications

Optical Properties		
Number of Optical channels	1, 4 or Customized	
Scan Frequency*	16 KHz 1.6K 800 Hz	Single Channel Two Channels Four Channels
Wavelength Range	1510nm-1590nm	
Wavelength Repeatability	5pm	
Wavelength Resolution	1pm	
Dynamic Range	30 dB	
Standard number of FBG Per Channel	40	
Optical Connector	FC/APC	Customized
Data Processing Capabilities		
Interface	Ethernet	
Software Features	For spectral analysis, peak detection, data logger, peak tracking, user can readout in temperature, pressure, or strain etc. save data to csv document	
Software support	Windows	
Mechanical, Environmental, Electrical Properties		
Dimension	260mm*210mm*62mm	
Operation Humidity	0%-80%RH	
Operation Temperature	-5° to +50° C	
Storage Temperature	-20° to +60° C	
Input Voltage	DC 12V	
Maximum Power	30W	

* The max scan frequency is 16KHz when use AGSWA Application Software with single channel. The max scan frequency is 2KHz when use remote interface with single channel.

PC recommended:

Operating system	Windows 7 or higher
CPU	At least 2.3 GHz
RAM	More than 4G Bit

Network interface	Gigabit Ethernet
GPU	Support openGL

3 System Setup

Connect the client PC to the AGSWA interrogator through Gigabit Ethernet cable.

Connect a 12V power supply to the 12V DC IN connector on the rear of the AGSWA. 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.

We offer two ways to use the interrogator, the first is to use AGSWA GUI software, or you can build your software by remote interface.

4 AGSWA Application Software User Guide

4.1 Connect interrogator and IP setup

The desktop application software about the interrogator AGSWA system can be run on a client PC or Laptop.

Double click the software named AtGrating FBG Interrogator-x.x.exe and the following window will be displayed as Figure 1 shows. The top-left of the window shows the network

information management. The interrogator uses static IP address and does not support DHCP. One end-user is permitted for each time.

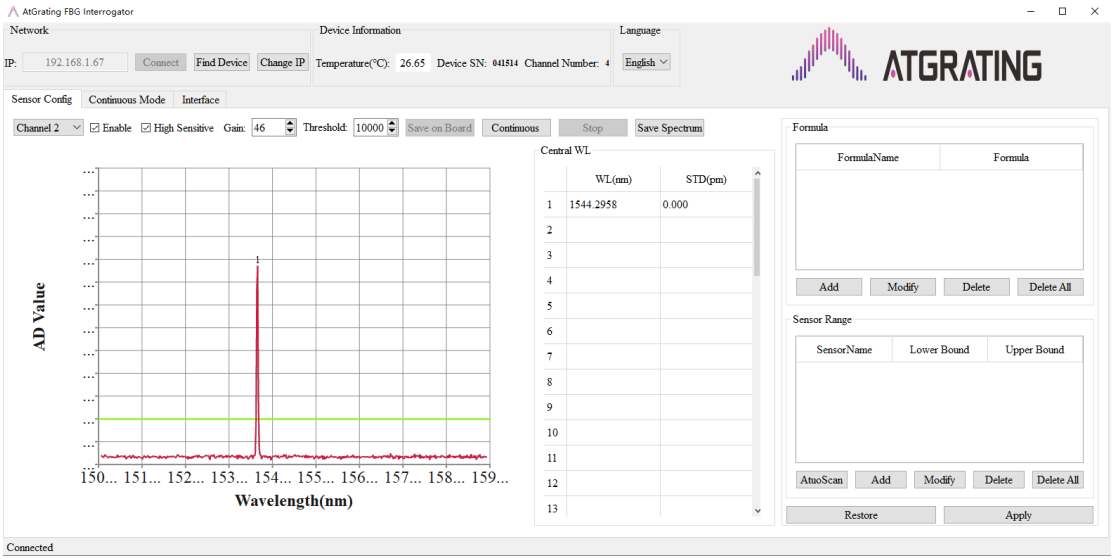


Figure 1 Main Window

If the IP address is forgotten, you can search the interrogator in the network. First, make sure that the interrogator is power-on and in the same network with the PC. Then click the Find Device button.

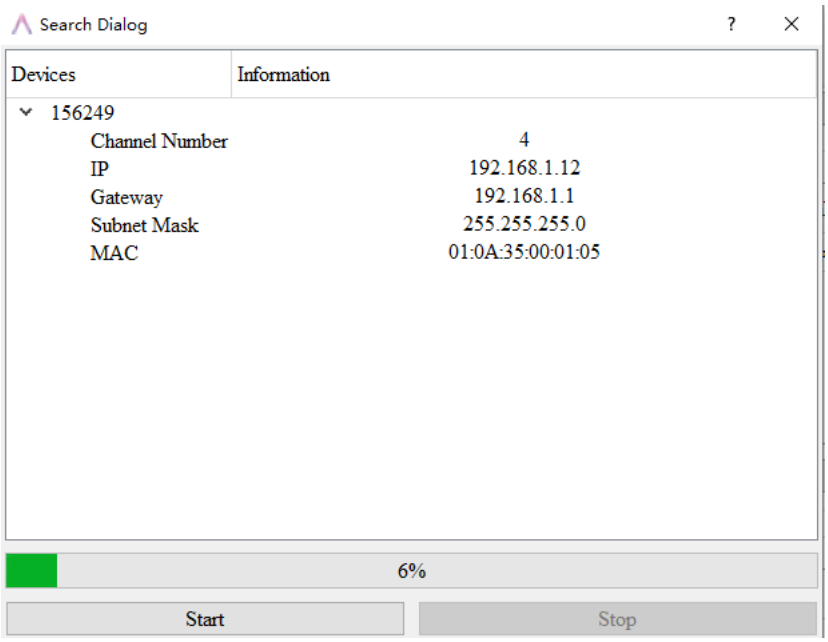


Figure 2 Device Search Dialog

The search result will display like Fig. 2. In the table, the list of device SN and device information is displayed. Then configure the PC IP address to same sub-network with interrogator, click the Connect button to connect to the interrogator. Click the Change IP button to change the static IP of the interrogator, when the connection is established. As the Fig 3 shows, input the network information and click the Apply button, the interrogator will reboot immediately and boot with new IP. Wait a few moments, then use the new static IP to connect the interrogator.

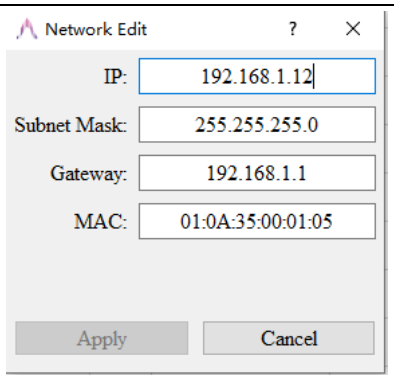


Figure 3 Network Edit Dialog

4.2 Parameters setup for measurement

4.2.1 basic parameter

After successful connection, click the channel combo box to select one channel. One frame spectrum will be displayed automatically for this channel. The spectrum will be updated at the frequency of 5Hz if the Continuous button is clicked. The Stop button can be clicked to stop the continuous sampling.

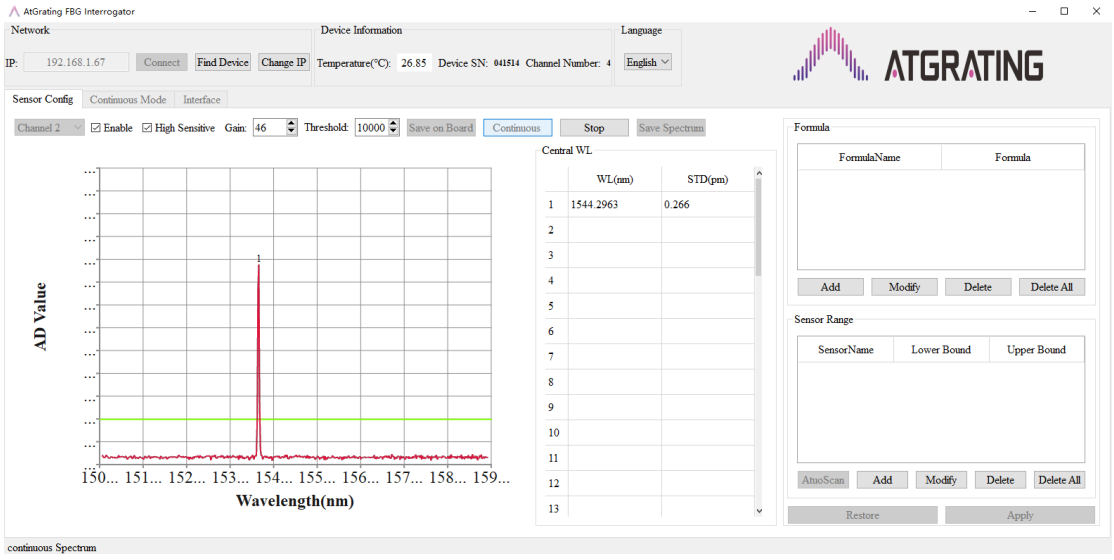


Figure 4 Main Window with Spectrum show

Figure 5, the measurement parameters for current selected channel could be configured, including Enable, Sensitivity, Gain and Threshold.

Figure 5 Measurement Parameters for Channel 1

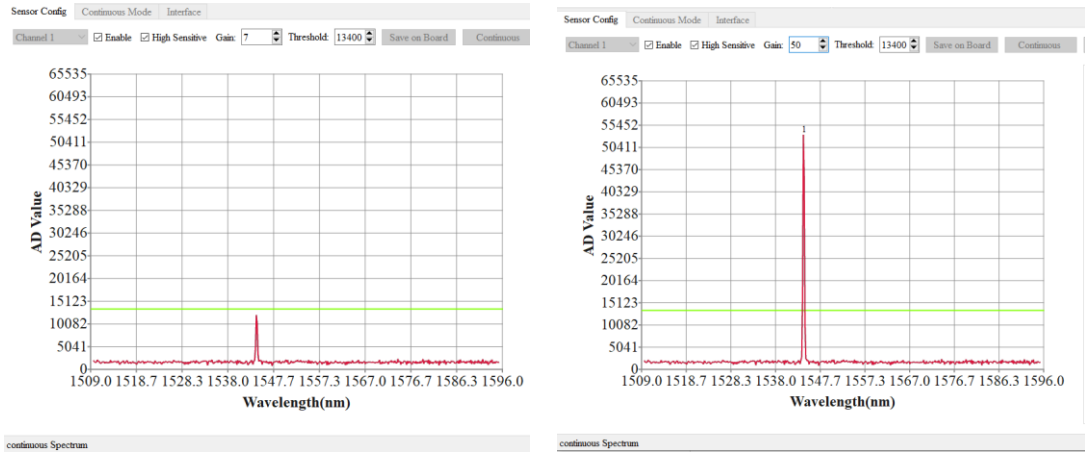


Figure 6 Spectrum with Different Gain

1, Enable: To enable or disable the channel in the formula continuous mode.

2, High sensitive: Choose the sensitivity of the CCD sensor. you can check this checkbox to choose high sensitive when the light by FBG reflected is weak.

3, Gain: The value of gain corresponds to the exposure time of CCD. The longer the exposure time is, the bigger the gain value is. The power of measured spectrum could be adjusted to be appropriate by adjusting the value of gain. If the gain is too big, the measured value will exceed the maximum range of AD (analog-digital converter).

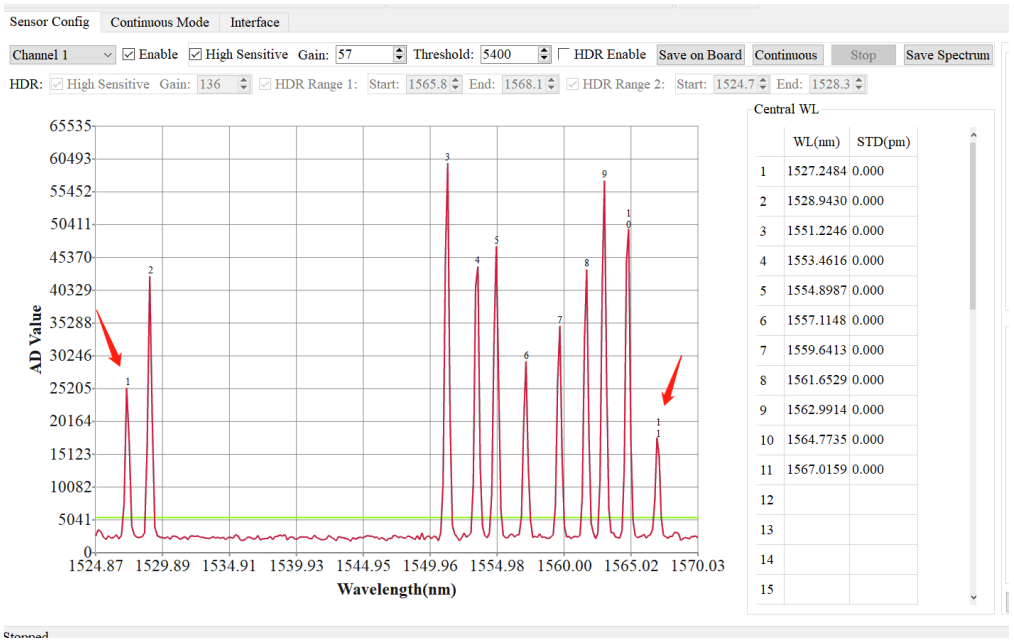
4, Threshold: The measured value below the threshold will be recognized as noise signal. The peak above the threshold will be calculated as FBGs.

The STD(standard deviation) of central wavelength will help you to assess the effects of parameters. A lower STD(standard deviation) is better. Click the Continuous button into spectrum continuous mode, adjust sensitivity and the gain to get a lower std.

4.2.2 HDR (High Dynamic Range) parameter

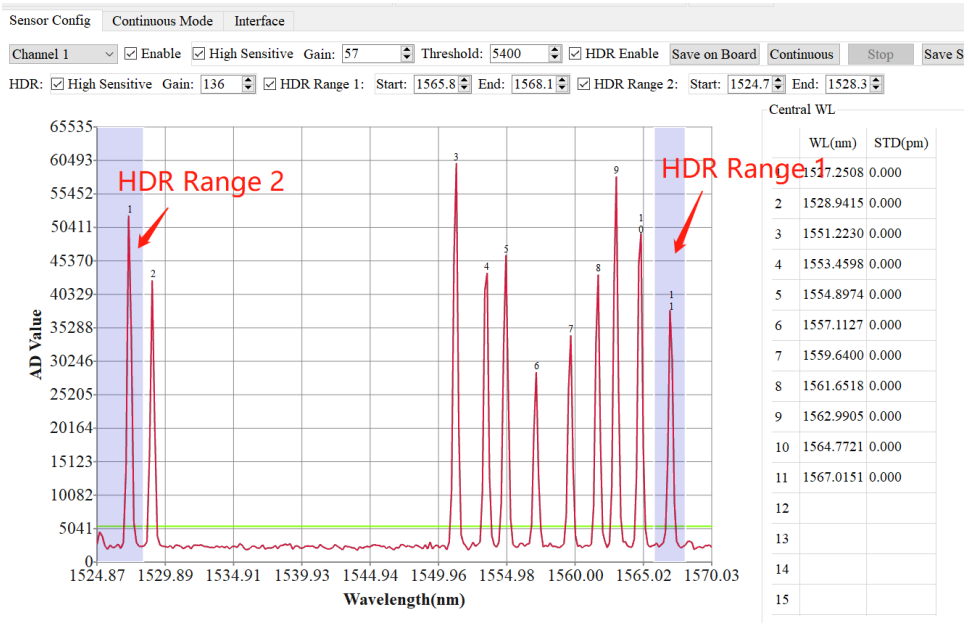
HDR can improve the dynamic range of the interrogator. The interrogator takes two frames of the spectrum at a time and fuses the two frames to improve the dynamic range. HDR will reduces the maximum sampling rate slightly.

As shown in the following figure, the FBG No. 1 and No. 11 reflected a relatively weak spectrum. But If you increase the gain, FBG No. 3 will go out of range. In this case, the HDR mode can be enabled.



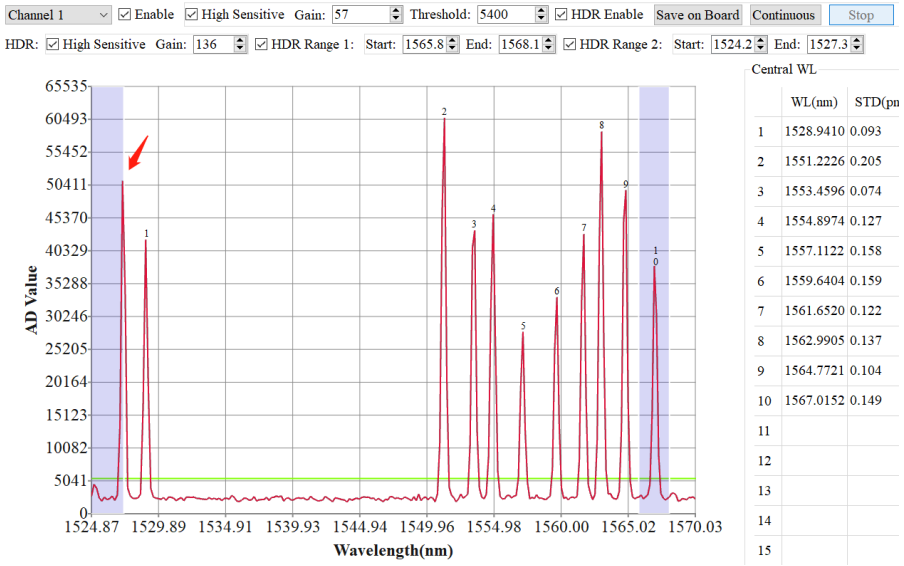
	WL(nm)	STD(pm)
1	1527.2484	0.000
2	1528.9430	0.000
3	1551.2246	0.000
4	1553.4616	0.000
5	1554.8987	0.000
6	1557.1148	0.000
7	1559.6413	0.000
8	1561.6529	0.000
9	1562.9914	0.000
10	1564.7735	0.000
11	1567.0159	0.000
12		
13		
14		
15		

As shown in the following figure, we checked HDR Enable and configured two HDR ranges, let the HDR Range 1 cover the FBG No.1, the HDR Range 2 cover the FBG No.11. Then we increase the HDR Gain to 136, the FBG No.1 and No.11's spectrum will get stronger, the spectrum of the other FBGs remain unchanged.



	WL(nm)	STD(pm)
1	1527.2508	0.000
2	1528.9415	0.000
3	1551.2230	0.000
4	1553.4598	0.000
5	1554.8974	0.000
6	1557.1127	0.000
7	1559.6400	0.000
8	1561.6518	0.000
9	1562.9905	0.000
10	1564.7721	0.000
11	1567.0151	0.000
12		
13		
14		
15		

It's important to note here, if the reflection spectrum of the grating crosses the HDR range, that is, half of the spectrum is in the HDR range and half is not in the HDR range, the interrogator will not be able to get the wavelength of the grating. The situation is shown in the following figure:



Note: Please remember to click the Save on Board button to save the configuration to the device flash memory when you finish config of one channel.t.

4.3 Parameter configuration criterion

The spectral signal intensity measured by CCD is different with different sensitivity level and gain. Generally speaking, the higher the signal strength, the higher the signal-to-noise ratio.

When the sensitivity is low, the corresponding noise signal will also be reduced, but at same time the measured spectral signal will also decline. only when the spectral signal reaches a certain intensity can get relatively high signal-to-noise ratio.

It is recommended that when the sensitivity is low, adjust the gain let the spectral peak value reaches more than 20000 (maximum 65535), that is, the relative light intensity value represented by the vertical coordinate of the spectrum display interface reaches more than 20000, which can ensure a high signal-to-noise ratio. Below this threshold, the signal-to-noise ratio will decrease and the measurement accuracy will be reduced.

At high sensitivity, the noise signal and the spectral signal are amplified simultaneously. For high sensitivity, it is recommended to let the spectral peak more than 30000, which can ensure a high signal-to-noise ratio.

The increase of the spectral peak value will increase the SNR of the sample, but the SNR will not continue to increase after the peak value reaches a certain value. It is recommended that the maximum spectral peak value be maintained at about 50000, which has a high signal-to-noise ratio and can prevent optical path changes from increasing the spectral peak value beyond the range.

The SNR of the spectrum will be different with different measurement parameters, and the difference of measurement parameters can lead to a difference of about 1~2pm in the central wavelength measured by the same spectrum. It is recommended to keep the optical path stable during measurement to avoid measurement errors caused by optical loss.

4.4 Sensor configuration

After acquisition of one frame spectrum, according to the threshold values, the software will display the FBGs and the wavelengths. Then these FBGs could be added as sensors. The maximum number of FBG sensors in one channel could be up to 40.

Add single sensor:

Click the Add button in Sensor Range widget, a dialog will display as below. Then input the sensor name and bound.

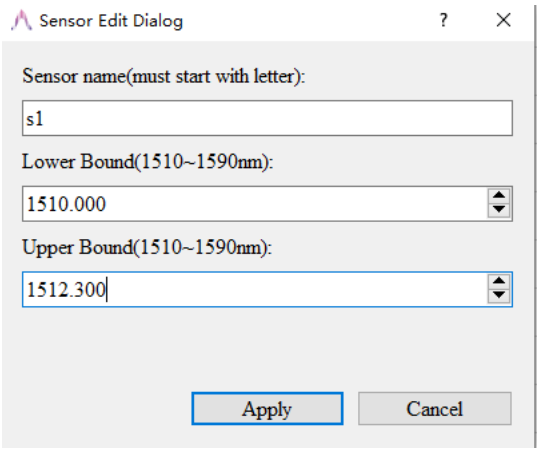


Figure 7 Add single sensor dialog

Automatic scan and identify sensor:

Click the AutoScan button in Sensor Range widget, input the Range Width and sensor name prefix, then the FBGs will be added as sensor automatic. The center of sensor range is the wavelength of FBG and the max width of the sensor range the Range Width. The sensor range will be shown in spectrum figure.

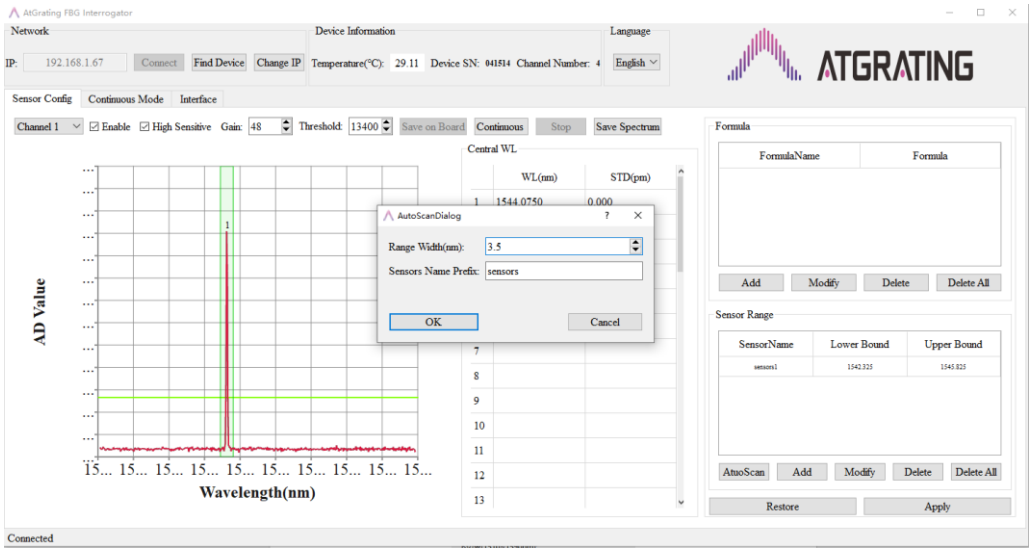


Figure 8 Automatic scan dialog

4.5 Edit Formula

According to formula, the sensor measured value can convert to strain, temperature, pressure etc. Fig 9 show the dialog of formula. First, select the sensor from the sensor list. Then edit the formula mathematical expression by mathematical operator or function. The maximum number of formulas in one channel could be up to 40.

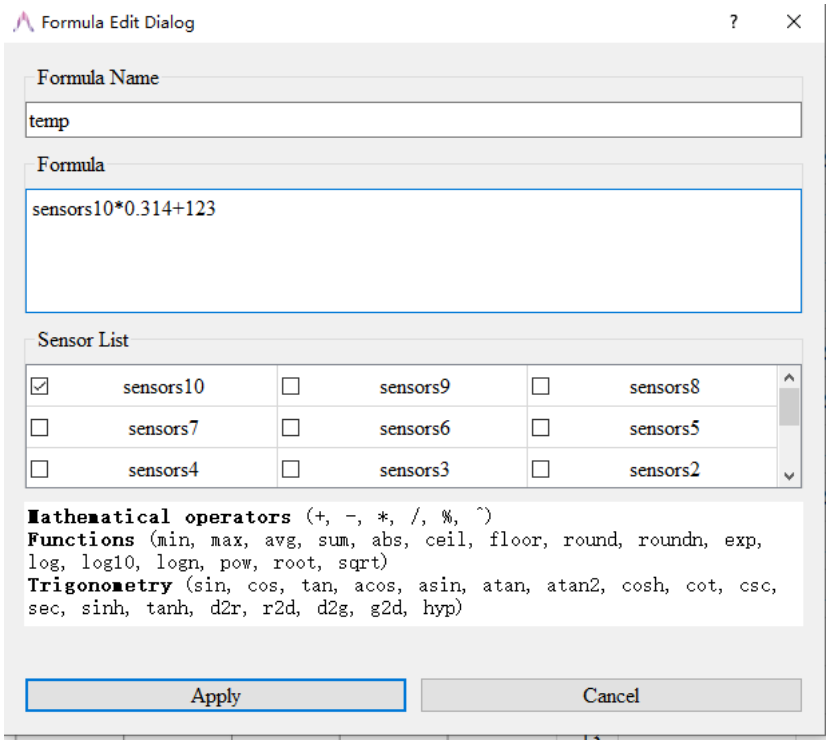


Figure 9 Edit Formula Dialog

Note: Please remember to click the Apply button to save the formula to PC when you finish config of one channel.

4.6 Continuous Mode

Click the Continuous Mode tab Widget switch to formula continuous mode, when you finish edit formula. You can see the formulas which the channel has been enable in sensor configuration. Before continuous measurement, you can input the scan interval by Hz unit and choose whether to save the file locally.

Click the StartContinuous button to start the measurement, it will show the formula's value in the numerical view and chart view. You can choose which formula will be shown in

the chart view, and the maximum number of charts displayed at the same time is 6. The data maximum refresh frequency shown in this view is 10Hz.

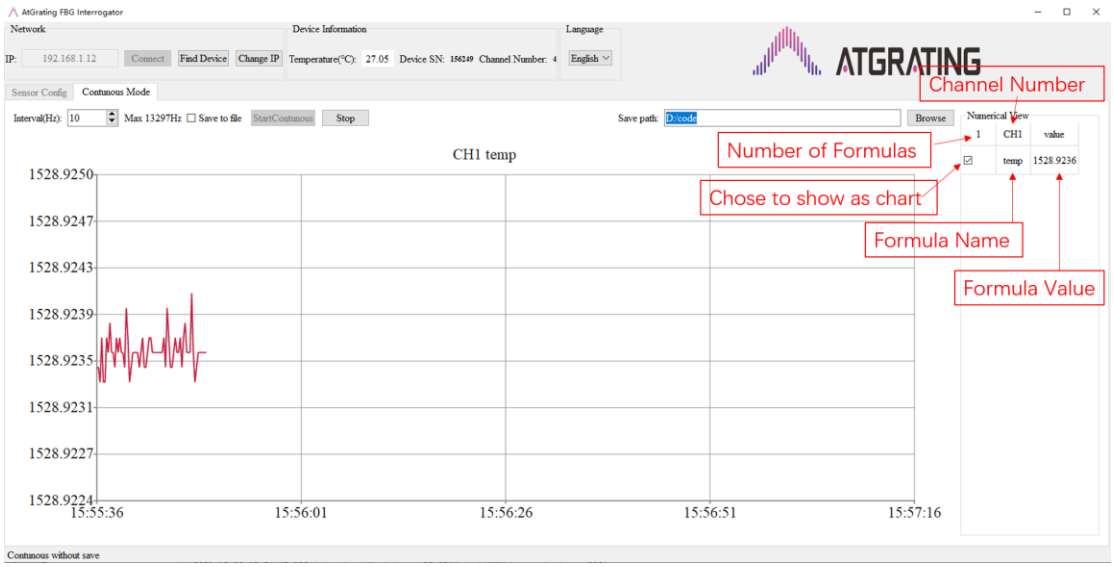


Figure 10 Continuous Mode tab Widget

A new directory named by date will be created in save path and the measured value will be saved in this directory by file. The measured value will be saved by CSV format and the maximum size for single file is 80MB. The format of csv file show in Fig 11.

	A	B	C	D	E	F	G	H	I
1	Start Time								
2	2021/8/12 19:21								
3		CH1	CH2						
4	Time Stamp	temperatu	s1	s10	s11	s12	s13	s14	s15
5	0	82.5012	nan	nan	1568.428	1567.035	1564.78	1563.012	1561.677
6	1	82.5012	nan	nan	1568.429	1567.036	1564.779	1563.011	1561.678
7	2	82.5013	nan	nan	1568.429	1567.034	1564.78	1563.009	1561.678
8	3	82.5013	nan	nan	1568.429	1567.035	1564.781	1563.011	1561.677
9	4	82.5012	nan	nan	1568.429	1567.034	1564.78	1563.009	1561.676

Figure 11 CSV File Format

4.7 Upgrade the embedded software in interrogator

If we have fixed bugs, we can use the new software image file to upgrade the device. We suggest that use network cables to connect the device directly when upgrade, and do not power off during the upgrading process.

Before upgrade, record the image build info like :Nov 29 2022-08:54:22 594.

Nov 29 2022-08:54:22 : build time

594: software version.

When upgrade succeed, reboot the device, it will load the new software. Check the build info again, it will be changed.

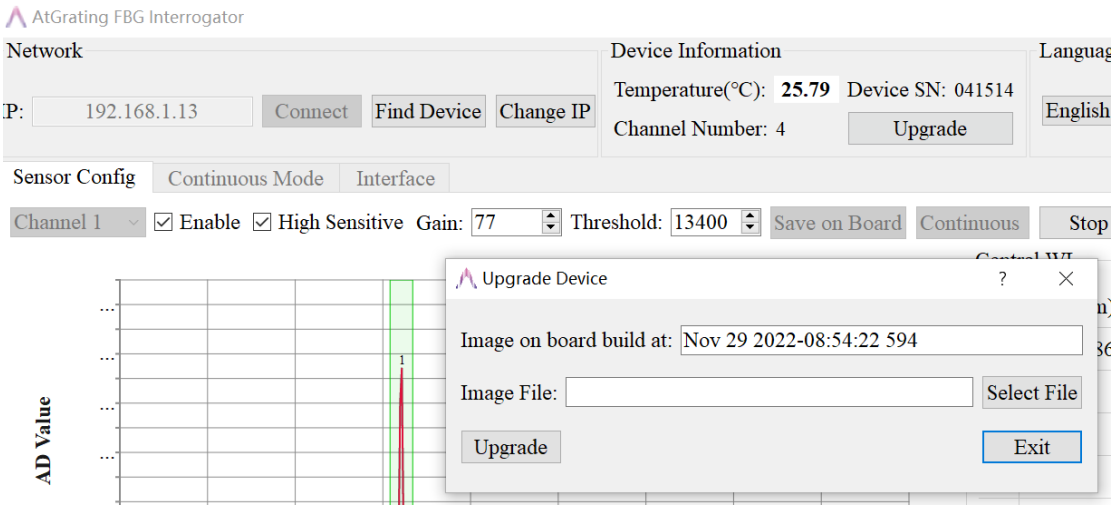


Figure 12 Upgrade

5 Remote Call Interface

The client can request the wavelength data through the remote call interface base TCP/IP protocol. The interrogator listen port 5001 as a server. The structure of the packet is little endian, the same as ARM, X86 CPU. You may need to swap the order in which bytes are read or sent, depending on the architecture of the CPU.

The structure of the packet is shown in the following table:

length	type	data
2 bytes unsigned int	2 bytes	length-4 bytes

The length field represents the length of the entire packet. The type field represents what kind of this request. What the data field will carry depending on the type field.

5.1 Get basic information

Through this interface, we can get the basic information about the device, such as SN, number of channels, temperature of the device.

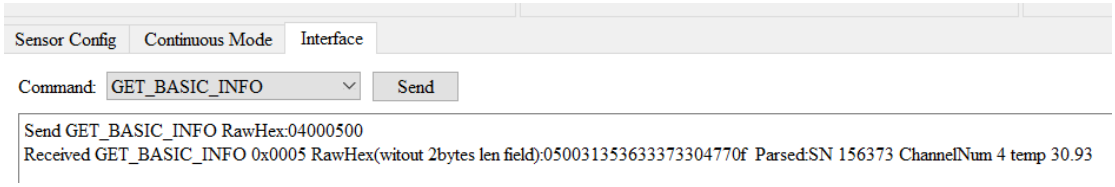
The type field of request packet is 0x0005, and the data field is empty.

The structure of the reply packet by interrogator is shown in the following table:

type (2 bytes)	data		
0x0005	SN (6 bytes char)	Channel Num (1 byte unsigned int)	Temperature (2 bytes signed int)

The SN field represents the SN of the interrogator, the Channel Num field represents the number of channels. The temperature field represents the temperature of CCD sensor in the interrogator, it need divided by 128 to get the temperature in Celsius(℃).

We can try to send this request in the Interface widget and it will show the packet by the raw hex.



5.2 Start continuous wavelength calculate

Before start continuous wavelength calculate, we need to save the configuration parameters to the flash of interrogator, such as channel enable, gain, sensitivity level and threshold of the channel.

The structure of the start command packet is shown in the following table:

type	data
0x000F	frequency (4 bytes unsigned int)

The type field of request packet is 0x000F, and followed by the frequency field in Hz.

The structure of the reply packet is shown in the following table:

type	data
0x000F	error code (1 bytes unsigned int)

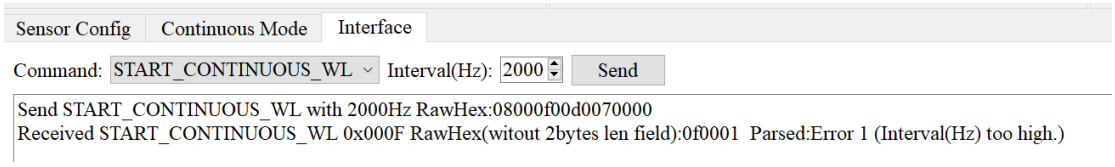
The interrogator start succeed when the error code is 0; Error code 1 indicates that the sampling frequency exceeds the upper limit. Error code 2 indicates that it has been started, can not start again. The maximum sampling frequency supported by the interrogator is shown in the following table:

Number of Channel	1	2	3	4
Max Frequency (Hz)	2000	1000	667	500

The maximum sampling frequency supported by this interface is different from the sampling frequency in section 4.5 continuous sampling mode. The wavelength returned by this interface is calculated by the CPU of the embedded board, but the wavelength in section 4.5 continuous acquisition mode was calculated by computer. Due to the limited computing power of embedded, the maximum sampling rate of this interface is lower than the continuous acquisition mode of 4.5 sections.

The following is an example of an error:

1, Error code 1 :Sampling frequency exceeds the upper limit



2, Error code 2

If it starts successfully, the interrogator sends wavelength data to the client in the following format:

type	0x000E	2 bytes
data	sequence number	2 bytes unsigned int
	channel	4 byte unsigned int
	Temperature	2 bytes signed int
	channel 1 wavelength number（1 byte）	1 byte unsigned int
	wavelength 0	4 bytes unsigned int
	wavelength 1 (4 bytes)	4 bytes unsigned int
	wavelength 2 (4 bytes)	4 bytes unsigned int
	…	
	wavelength m (4 bytes)	4 bytes unsigned int
	channel 3 wavelength number（1 byte）	1 byte unsigned int
	wavelength 0 (4 bytes)	4 bytes unsigned int
	wavelength 1 (4 bytes)	4 bytes unsigned int
	wavelength 2 (4 bytes)	4 bytes unsigned int
	…	
	wavelength m (4 bytes)	4 bytes unsigned int
	channel n wavelength number（1 byte）	1 byte unsigned int
	wavelength 0 (4 bytes)	4 bytes unsigned int
	wavelength 1 (4 bytes)	4 bytes unsigned int
	wavelength 2 (4 bytes)	4 bytes unsigned int
	…	
	wavelength m (4 bytes)	4 bytes unsigned int

The type field of the wavelength data is 0x000E;

Sequence number field indicates the number of the data packet. The sampling interval is determined by the sampling frequency;

Channel field indicates whether a channel is enabled. For example, if the binary data of channel field is 0000 0101, it means channel 1 and channel 3 are enabled. The subsequent wavelength data only contains the enabled channel. You can modify channel enable configuration in Section 4.2.

Channel N wavelength number refers to the total number of wavelengths in the channel N.

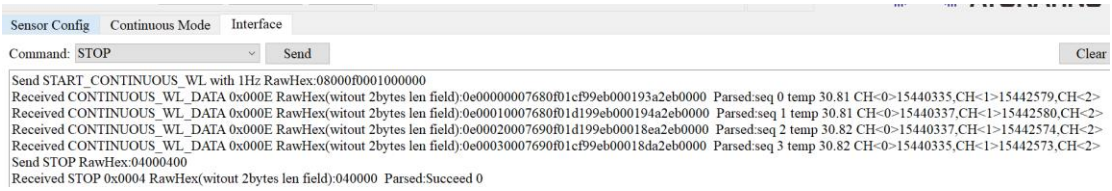
Wavelength m represents the m th wavelength (unit:0.1pm) of channel N;

Sample Qt C++ code for parsing this packet is shown below:

```
QDataStream data_stream(&data, QIODevice::ReadOnly);
data_stream.skipRawData(2);//skip 2bytes type
quint16 sequence;
```

```
data_stream.readRawData((char*) &sequence, 2);
quint32 channels;
qint16 temp16;
data_stream.readRawData((char*) &channels, 4);
data_stream.readRawData((char*) &temp16, 2);
float temp = temp16/128.0f;
for(int i = 0; i < 32; i++){
    if(channels & 0x01){
       quint8 num;
       data_stream.readRawData((char*) &num, 1);
       for(int j =0; j < num;j++){
            quint32 wavelength;
            data_stream.readRawData((char*) & wavelength, 4);
        }
     }
     channels = channels >> 1;
}
```

On the interface widget, you can try this interface to view the content of original packets. As shown below, the channel 1, 2, and 3 are enabled. Channel 1 and 2 has one wavelength respectively, and channel 3 has no one.



One example:

Raw Packet show as hex below

34 00 0E 00 04 00 FF 00 00 00 02 0E 08 03 C3 F0 00 68 5E EF 00 FE 01 EE 00 26 A5 EC 00 D4 44 EB 00 B6 E6 E9 00 20 88 E8 00 18 23 E7 00 00 00 00 00 00 00 00

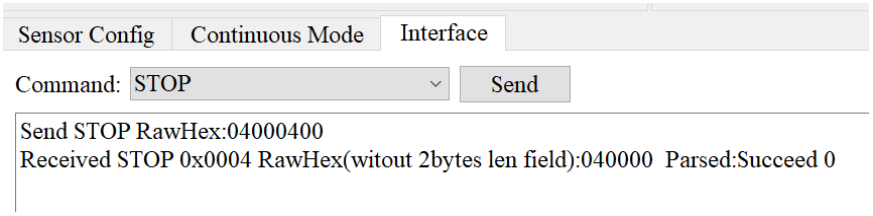
The packet is parsed like this:

34 00	length
0E 00	type
04 00	sequence number
FF 00 00 00	channel
02 0E	Temperature
08	channel 1 wavelength number
03 C3 F0 00	wavelength 1
68 5E EF 00	wavelength 2
FE 01 EE 00	wavelength 3
26 A5 EC 00	wavelength 4
D4 44 EB 00	wavelength 5
B6 E6 E9 00	wavelength 6
20 88 E8 00	wavelength 7

18 23 E7 00	wavelength 8
00	channel 2 wavelength number
00	channel 3 wavelength number
00	channel 4 wavelength number
00	channel 5 wavelength number
00	channel 6 wavelength number
00	channel 7 wavelength number
00	channel 8 wavelength number

5.3 Stop continuous wavelength calculate

The client can send a Stop command to stop continuous wavelength calculating or stop continuous raw spectral data. The type field of Stop command is 0x0009, and the data field is empty. The packet of send and reply is shown below by the raw hex:



5.4 Heartbeat

After the client establish the TCP connection with the interrogator, the client can send the heartbeat to detect the connection failure. The type field of heartbeat is 0x0009, and the data field is empty.

The structure of the reply packet by interrogator is shown in the following table:

type	data
0x0009	Temperature (2 bytes signed int)

The temperature field represents the temperature of CCD sensor in the interrogator, it need divided by 128 to get the temperature in Celsius(℃).

5.5 Get parameter

we can get the configuration parameters from the flash of interrogator, such as channel enable, gain, sensitivity level and threshold of the channel. The type field of request packet is 0x000C, and the data field is empty.

The structure of the reply packet is shown in the following table:

data			
Channel enable bit map (4 bytes unsigned int)	Channel sensitivity level bit map (4 bytes unsigned int)	Channel HDR Enable bit map (4 bytes unsigned int)	Channel HDR sensitivity level bit map (4 bytes unsigned int)
Gain Array (2 bytes unsigned int * channel Num)	HDR Gain Array (2 bytes unsigned int * channel Num)	Threshold array (2 bytes unsigned int * channel Num)	HDR Range Array

The channel enable bit map is 32 bit unsigned int type, each bit represent one channel. Bit 1 means enable. Bit 0 means disable. The same as channel sensitivity level bit map, bit 1 means high sensitivity.

Channel HDR Enable bit map: each bit represent one channel. Bit 1 means HDR enable. Bit 0 means HDR disable. The length of gain array is the number of channel, the same as threshold array.

After HDR is enabled for one channel, two HDR ranges can be configured. HDR Range Array is array of this HDR ranges. One HDR ranges include the HDR Range Enable, upper and lower bound. The array length is twice the number of channels of the interrogator. The HDR range for each channel is configured as follows:

HDR Range 1 Enable (1 byte unsigned int)	Lower Bound Wavelength (2 bytes unsigned int)	Upper Bound Wavelength (2 bytes unsigned int)
HDR Range 2 Enable (1 byte unsigned int)	Lower Bound Wavelength (2 bytes unsigned int)	Upper Bound Wavelength (2 bytes unsigned int)

The following describes how to parse the packet based on the original packet. The hexadecimal representation of the original packet is as follows:

6c 00 0c 00 01 00 00 00 03 00 00 00 01 00 00 00
03 00 00 00 6d 00 55 00 00 00 00 00 00 00 00 00
00 00 00 00 52 01 10 00 00 00 00 00 00 00 00 00
00 00 00 00 18 15 68 10 10 27 10 27 10 27 10 27
10 27 10 27 01 f9 3c 40 3d 00 c9 3b 7d 3c 00 c9
3b 7d 3c 00 c9 3b 7d 3c 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00

The original packets are arranged in byte order of the small end and the interrogator have 4 channel.

6c 00 represents the packet length

0c 00 represents the packet type is Get Parameter

01 00 00 00 represents the channel enable, only channel 1 is enabled;

03 00 00 00 represents channel sensitivity level;

01 00 00 00 represents channel HDR Enable, only channel 1 enable the HDR;

01 f9 3c 40 3d 00 c9 3b 7d 3c represents the 2 HDR Ranges of channel 1, 01 means HDR Range 1 is enable, f9 3c represents Lower Bound 15609, 40 3d represents Upper Bound 15680, so the HDR Range 1 is 1560.9nm~1568.0nm; 00 means HDR Range 2 is disable.

00 c9 3b 7d 3c 00 c9 3b 7d 3c represents the 2 HDR Ranges of channel 2, HDR Range 1 and 2 is both disable.

5.6 Save parameter by channel

Configure the enable, gain, sensitivity level and threshold by channel. The type field of request packet is 0x000D, and the structure of the data field is shown in the following table:

data			
Channel index (1 byte unsigned int)	Channel enable (1 byte unsigned int)	Sensitivity level (1 byte unsigned int)	Gain (2 bytes unsigned int)
Threshold (2 bytes unsigned int)	HDR Enable (1 byte unsigned int)	HDR Sensitivity level (1 byte unsigned int)	HDR Gain (2 bytes unsigned int)
HDR Range 1 Enable (1 byte unsigned int)	Lower Bound Wavelength (2 bytes unsigned int)	Upper Bound Wavelength (2 bytes unsigned int)	
HDR Range 2 Enable (1 byte unsigned int)	Lower Bound Wavelength (2 bytes unsigned int)	Upper Bound Wavelength (2 bytes unsigned int)	

Channel index (1 byte unsigned int): range 0~31, 0 represent channel 1.

Channel enable (1 byte unsigned int): 0 represent disable, other represent enable.

Sensitivity level (1 byte unsigned int): 0 represent low Sensitivity, other represent high.

HDR Enable (1 byte unsigned int): 0 represent disable, other represent enable.

HDR Sensitivity level (1 byte unsigned int): 0 represent low Sensitivity, other represent high.

HDR Range x Enable (1 byte unsigned int): 0 represent disable, other represent enable.

Lower Bound Wavelength (2 byte unsigned int) and Upper Bound Wavelength: The wavelength is reserved to one decimal. For example, if Lower Bound is set to 1551.2, multiply by 10 to set the Lower Bound wavelength to 15512

After interrogator save succeed, it will reply the "Get parameter" packet in 5.5 (The type field is 0x000C).

5.7 Obtain device details and configuration information

This interface can obtain the SN, channel number, network configuration information, channel parameter configuration, and spectral calibration parameters.

The type field of request packet is 0x0001, and the data field is empty.

length (2 bytes)	type (2 bytes)	data (0 byte)
4	0x0001	

The structure of the reply packet by interrogator is shown in the following table:

type	0x0001		unsigned int (2 bytes)
data	SN		6 Char (6 bytes)
	Channel Number		unsigned int(1 byte)
	Wavelength calibration Coefficient Array		Double(8 bytes) array (total 8*10 bytes)
	Temperature		signed int(2 bytes)
	IP address		unsigned int (4 bytes)
	Subnet Mask		unsigned int (4 bytes)
	Gateway		unsigned int (4 bytes)
	MAC Address		6 Char (6 bytes)
	CCD Sensor Pixel number		unsigned int (2 bytes)
	Channel enable bit map		unsigned int(4 bytes)
	Channel sensitivity level bit map		unsigned int(4 bytes)
	Channel HDR Enable bit map		unsigned int(4 bytes)
	Channel HDR sensitivity level bit map		unsigned int(4 bytes)
	Gain Array		unsigned int (2 bytes) array (total 2*channel Num bytes)
	HDR Gain Array		unsigned int (2 bytes) array (total 2*channel Num bytes)
	Threshold array		unsigned int (2 bytes) array (total 2*channel Num bytes)
	Channel 1 HDR Range	HDR Range 1 Enable	unsigned int(1 byte)
		HDR Range 1 Lower Bound Wavelength	unsigned int(2 bytes)
		HDR Range 1 Upper Bound Wavelength	unsigned int(2 bytes)
		HDR Range 2 Enable	unsigned int(1 byte)
		HDR Range 2 Lower Bound Wavelength	unsigned int(2 bytes)

		HDR Range 2 Upper Bound Wavelength	unsigned int(2 bytes)
	Channel 2 HDR Range	HDR Range 1 Enable	unsigned int(1 byte)
		HDR Range 1 Lower Bound Wavelength	unsigned int(2 bytes)
		HDR Range 1 Upper Bound Wavelength	unsigned int(2 bytes)
		HDR Range 2 Enable	unsigned int(1 byte)
		HDR Range 2 Lower Bound Wavelength	unsigned int(2 bytes)
		HDR Range 2 Upper Bound Wavelength	unsigned int(2 bytes)
	Channel n HDR Range	HDR Range 1 Enable	unsigned int(1 byte)
		HDR Range 1 Lower Bound Wavelength	unsigned int(2 bytes)
		HDR Range 1 Upper Bound Wavelength	unsigned int(2 bytes)
		HDR Range 2 Enable	unsigned int(1 byte)
		HDR Range 2 Lower Bound Wavelength	unsigned int(2 bytes)
		HDR Range 2 Upper Bound Wavelength	unsigned int(2 bytes)

5.8 Start continuous raw spectral data

The type field of request packet is 0x0010, and the data field carry the frequency.

length (2 bytes)	type (2 bytes)	data
8	0x0010	frequency (4 bytes unsigned int)

If it starts successfully, the interrogator will send spectral data at the set frequency to the client in the following format. The client can send a Stop command to stop continuous raw spectral data, Refer 5.3.

The structure of spectral data packet is shown in the following table:

type	0x0010	unsigned int (2 bytes)
data	sequence	unsigned int (2 bytes)
	Number of spectrum frame	unsigned int(1 byte)
	Channel Enable bit map	unsigned int (4 bytes)
	Temperature	signed int(2 bytes)
	Channel HDR Enable bit map	unsigned int (4 bytes)

	Channel 1 Spectrum data	Pixel array data	unsigned int(2 byte) Array(total Pixel number * bytes)
		[HDR Pixel array data]	unsigned int(2 byte) Array(total Pixel number * bytes)
	Channel n Spectrum data	Pixel array data	unsigned int(2 byte) Array(total Pixel number * bytes)
		[HDR Pixel array data]	unsigned int(2 byte) Array(total Pixel number * bytes)

Sequence number field indicates the number of the data packet. The sequence increases from 0 to 65535, it will back to 0 when reach the 65535.

Channel Enable bit map indicates whether a channel is enabled. For example, if the binary data of bit map is 0000 0101, it means channel 1 and channel 3 are enabled. The subsequent spectrum data only contains the enabled channel. You can modify channel enable configuration in Section 4.2.

The temperature field represents the temperature of CCD sensor in the interrogator, it need divided by 128 to get the temperature in Celsius(℃).

Channel HDR Enable bit map indicates whether the channel HDR is enabled, just like Channel Enable bit map.

If HDR is enabled for the channel, this channel will have two frames of spectrum: Pixel array data and HDR Pixel array data. Otherwise only one frame: Pixel array data.

The length of Pixel array data and HDR Pixel array depend on the CCD Sensor Pixel number. Pixel number is 256 when the bandwidth of interrogator is 40nm, 512 when bandwidth is 80nm. The number of pixels can be obtained from the interface in Section 5.7.

This equation describes the relation between the pixel array index(pix) on the image sensor and the optical wavelength (λ).

$$\lambda[nm] = A + B_1 pix + B_2 pix^2 + B_3 pix^3 + B_4 pix^4 + B_5 pix^5, pix = 0 \sim 255 \; or \; 511$$

The interrogator is temperature characterized, and wavelength drift can be reduced by using the following correction equation:

$$\lambda_{corrected}[nm] = \frac{\lambda[nm] - \beta T[degC] - \beta_0}{1 + \alpha T[degC] + \alpha_0}$$

The length of Wavelength calibration Coefficient Array is 10, the Coefficient Array can be obtained from the interface in Section 5.7.

$$\text{Wavelength calibration Coefficient Array} = [A, B_1, B_2, B_3, B_4, B_5, \alpha, \alpha_0, \beta, \beta_0]$$

The value from the pixel array at the pix is relative optical power.

5.9 Interface summary

Interface Description	type (2 bytes)	data		
Get Basic Info	0x0005	SN (6 bytes char)	Channel Num (1 byte unsigned int)	Temperature (2 bytes signed int)
Start Continuous	0x000F	frequency (4 bytes unsigned int)		
Stop Continuous	0x0004			
Heartbeat	0x0009	Temperature (2 bytes signed int)		
Wavelength Data	0x000E	Refer 5.2		
Get_parameter	0x000C	Refer 5.5		
Save parameter by channel	0x000D	Refer 5.6		
Obtain device details and configuration information	0x0001	Refer 5.7		
Start continuous raw spectral data	0x0010	Refer 5.8		